Exceptional Event Documentation Package for the 8-Hour Ozone NAAQS Exceedance in Clark County Caused by the Wildland Fire Event on June 29-30, 2005

November 13, 2009

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ACRONYMS AND ABBREVIATIONS

Acronyms

AQI	Air Quality Index
CAA	Clean Air Act
CFR	Code of Federal Regulations
DAQEM	Clark County Department of Air Quality and Environmental Management
DRA	Desert Rock Airport
DRI	Desert Research Institute
EER	Exceptional Events Rule
EPA	U.S. Environmental Protection Agency
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory Model
NAAQS	National Ambient Air Quality Standards
PST	Pacific Standard Time
VOC	volatile organic compound

Abbreviations

°C	degrees Celsius
CO	carbon monoxide
ft	feet
km	kilometer
m	meter
mb	millibars
msl	mean sea level
ng/m^3	nanograms per meter cubed
NO_x	oxides of nitrogen
O_3	ozone
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
ppb	parts per billion
R^2	correlation coefficient

1.0 INTRODUCTION

1.1 STATEMENT OF PURPOSE

Clark County has determined that ozone concentrations exceeding the National Ambient Air Quality Standards (NAAQS) on June 29-30, 2005, qualify as an exceptional event under Title 40, Part 50 of the Code of Federal Regulations (40 CFR 50), the final Exceptional Events Rule (EER). The purpose of this document is to petition the Regional Administrator for Region 9 of the U.S. Environmental Protection Agency (EPA) to exclude air quality monitoring data for ozone from the normal planning and regulatory requirements under the Clean Air Act (CAA) in accordance with the EER. Section 3.5 provides documentation that this exceptional event demonstration underwent public review and comment before submittal to EPA.

On June 29-30, 2005, Clark County recorded violations of the ozone NAAQS across its air quality monitoring network because of smoke plumes from wildfires in Nevada, Arizona, California, and Utah. This document demonstrates, in accordance with the EER, that these NAAQS violations would not have occurred without the wildfire impacts. In August 2007, the Clark County Department of Air Quality and Environmental Management (DAQEM) submitted a demonstration package supporting the flagging of elevated ozone concentrations for June 29-30, 2005, because of wildfire impacts. In October 2007, after evaluating the demonstration package, EPA Region 9 notified DAQEM that there was insufficient evidence to concur.

Since October 2007, in continued coordination with Region 9, DAQEM has completed additional technical studies characterizing wildfire smoke plume impacts on ozone concentrations. This document is a revised demonstration with additional supporting technical data, including air quality modeling, to support the petition for EPA concurrence that ozone concentrations exceeding the ozone NAAQS on June 29-30, 2005, were the result of an exceptional event.

Additional narrative and supporting technical data in this revised demonstration address deficiencies cited in the Region 9 nonconcurrence letter regarding the original August 2007 submittal. The focus of this revised demonstration is to show, through additional technical analyses and regression modeling, that ozone exceedances would not have occurred in Clark County on June 29-30, 2005, in the absence of smoke plumes from surrounding wildfires.

1.2 SCOPE OF DEMONSTRATION

The EER governs the review and handling of air quality monitoring data influenced by exceptional events (e.g., wildfires). Exceptional events are "events for which the normal planning and regulatory process established by the CAA is not appropriate" (*Federal Register*, Volume 72, p. 13560). In its final rule, EPA intended to:

> Implement section 319(b)(3)(B) and 107(d)(3) authority to exclude air quality monitoring data from regulatory determinations related to exceedances or violations of the National Ambient Air Quality Standards (NAAQS) and avoid designating an area as nonattainment, redesignating an area as nonattainment, or reclassifying an existing nonattainment area to a higher classification if a State

adequately demonstrates that an exceptional event has caused an exceedance or violation of a NAAQS.

The EER contains procedures and criteria whereby states can petition EPA to exclude data from regulatory considerations because of an exceptional event that caused an area to exceed the NAAQS for a particular pollutant. The term “exceedance” refers to a measured or modeled concentration greater than the level of one or more NAAQS at a specific air quality monitoring location.

EPA requires states to take reasonable measures to mitigate the impacts of an exceptional event. In accordance with Section 319 of the CAA, EPA defines the term "exceptional event" to mean an event that:

(i) Affects air quality;
(ii) Is not reasonably controllable or preventable;
(iii) Is an event caused by human activity that is unlikely to recur at a particular location or a natural event; and
(iv) Is determined by EPA through the process established in the regulations to be an exceptional event. (*Federal Register*, Vol 72, p. 13562, Section IV.D)

Clark County flagged ozone concentrations on June 29-30, 2005, to indicate that NAAQS exceedances were likely caused by ozone precursor emissions produced by smoke plumes from wildfires, an exceptional event. EPA notes that natural events, which are one form of exceptional events according to its definition, may recur, sometimes frequently (e.g., western wildfires).

In this revised exceptional event demonstration, Section 2 addresses a conceptual model for ozone air pollution and wildfire impacts in Clark County based on technical studies completed to date. It describes topography, land use, and meteorology in the context of conditions leading to elevated ozone concentrations, then summarizes the role of local emissions and transport into southern Nevada.

Section 3 describes the event in detail, including associated meteorology, air quality, and wildfire locations. In accordance with the EER, technical analyses and related documentation in this report provide a “weight of evidence” demonstration of the following:

- The event met the exceptional event criteria as set forth by EPA.
- There was a clear causal relationship between the concentration and the event.
- The event was above normal historical fluctuations, including background.
- The concentration at the monitoring sites would not have exceeded the standards but for the event.
- DAQEM took reasonable and appropriate actions to inform the public of smoke impacts and protect the public health.

1.3 PREVIOUS RESEARCH ON OZONE FORMATION AND SMOKE IMPACTS

The impact of wildfires on ozone concentrations at both the local and regional level has been studied extensively in recent years. Nikolov (2008) provides an excellent summary of past studies, as well as a conceptual discussion of the physical and chemical mechanisms contributing to the observed impacts. Nicolov concludes that on a regional scale, biomass burning can significantly increase background surface ozone concentrations, resulting in NAAQS exceedances. Moreover, these impacts can be observed in areas that may be hundreds of miles away from wildfire locations.

Individual studies to evaluate the impacts of wildfires on ozone concentrations include both direct observations, such as aircraft flights or ozonesondes, and photochemical or smoke plume modeling. Aircraft flights through smoke plumes have demonstrated increased ozone concentrations of 15 to 30 parts per billion (ppb) in California (DAQEM 2008), while ozonesonde measurements in Texas found increased ozone levels aloft of 25 to 100 ppb attributable to long-range transport of smoke plumes from Canada and Alaska (Morris et al. 2006).

Increased levels of ozone from large fires have also been estimated using air quality modeling. McKeen et al. (2002) found that Canadian fires in 1995 increased ozone levels by 10 to 30 ppb throughout a large region of the central and eastern United States. Lamb (2007) found similar results in simulating the impacts of fires in the Pacific Northwest in 2006, with increases of over 30 ppb.

Junquera et al. (2005) further found that within 10 km of a fire, ozone concentrations could increase by up to 60 ppb. In one of the most recent studies, Pfister et al. (2008) simulated the large fires of 2007 in northern and southern California. The authors found ozone increases of approximately 15 ppb in many locations. Although the 2007 California fires occurred mostly in northern California, they added at least 5 ppb to ozone concentrations in southern Nevada. The authors concluded, “Our findings demonstrate a clear impact of wildfires on surface ozone nearby and potentially far downwind from the fire location, and show that intense wildfire periods frequently can cause ozone levels to exceed current health standards.”

Finally, in a presentation at an emission inventory conference, Pace et al. (2007) modeled the June 2005 fires, showing that the wildfire impacts added as much as 15 ppb to ozone concentrations in southern Nevada (Figure 1-1). DAQEM has also carried out technical studies addressing smoke plume impacts on ozone concentrations in southern Nevada, which Section 3 discusses in detail.

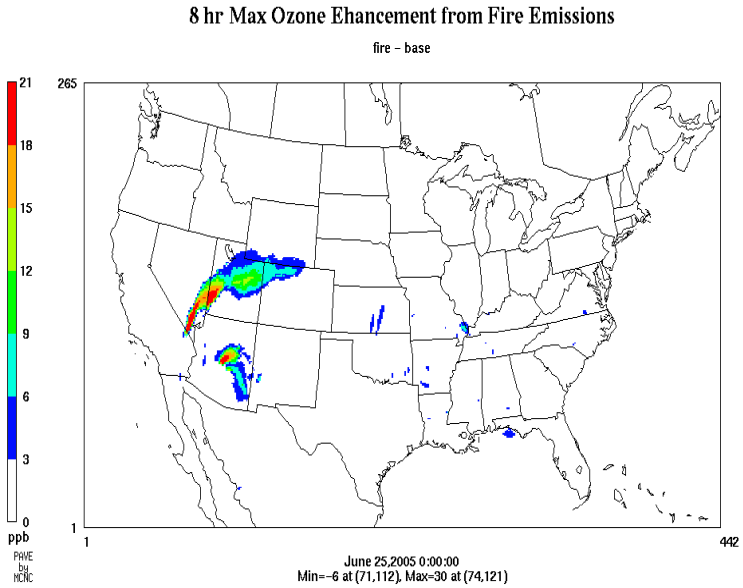


Figure 1-1. Difference in Maximum 8-Hour Ozone for June 25, 2005 (Levels with Fires Minus Levels with No Fires).

2.0 CONCEPTUAL MODEL OF OZONE AIR POLLUTION IN CLARK COUNTY

2.1 TOPOGRAPHY AND METEOROLOGY

Located in southern Nevada, Clark County consists of 8,091 square miles characterized by basin and range topography. It is one of the nation's largest counties, with an area bigger than the states of Connecticut and Delaware combined. The Las Vegas Valley sits in a broad desert basin surrounded by mountains rising from 2,000 feet to over 10,000 feet above the valley floor. The relief map in Figure 2-1 illustrates the basins and mountain ranges surrounding the valley. Terrain within the Las Vegas Valley rises significantly, from approximately 1,200 feet at Lake Mead to 2,000 feet in downtown Las Vegas to over 2,800 feet in the suburbs on the west side of the valley, near the Spring Mountain Range.

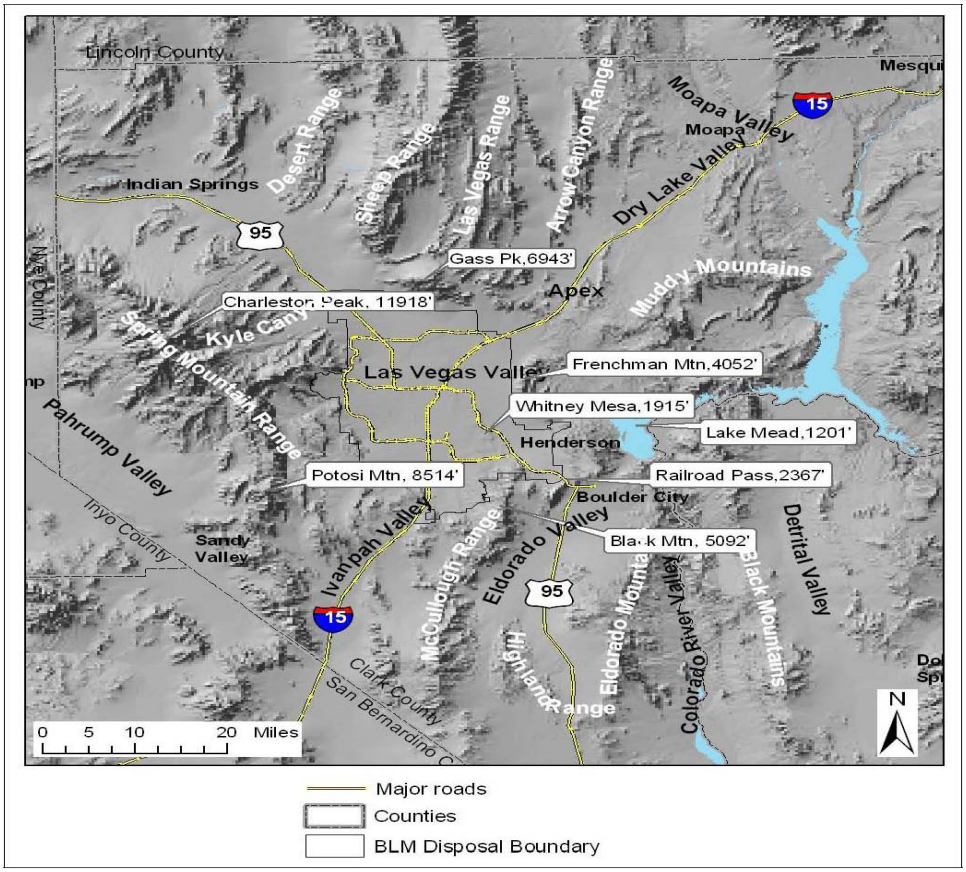


Figure 2-1. Mountain Ranges and Basins Surrounding the Las Vegas Valley.

Although located in the Mojave Desert, Clark County has four well-defined seasons. Summers display the classic characteristics of the desert Southwest: daily high temperatures in the lower elevations often exceed 100ºF, with lows in the 70s. The summer heat is usually tempered by low relative humidity, which may increase for several weeks during July and August in association with moist monsoonal wind flows from the south. Average annual rainfall in the valley, measured at McCarran International Airport, is approximately 4.5 inches. Table 2-1 lists temperature and rainfall averages in Clark County over a 30-year period.

Table 2-1. Monthly Averages for Temperature and Rainfall (1971-2000)

Month	Maximum (°F)	Minimum (°F)	Average (°F)	Rainfall (inches)
January	57.1	36.8	47.0	0.59
February	63.0	41.4	52.2	0.69
March	69.5	47.0	58.3	0.59
April	78.1	53.9	66.0	0.15
May	87.8	62.9	75.4	0.24
June	98.9	72.3	85.6	0.08
July	104.1	78.2	91.2	0.44
August	101.8	76.7	89.3	0.45
September	93.8	68.8	81.3	0.31
October	80.8	56.5	68.7	0.24
November	66.0	44.0	55.0	0.31
December	57.3	36.6	47.0	0.41
Annual Average	**79.9**	**56.3**	**68.1**	**4.49**

Source: National Weather Service Forecast Office.

2.2 POPULATION AND LAND USE

The population of Clark County exceeds two million people. More than 95 percent reside in the Las Vegas Valley, which encompasses the cities of Las Vegas, North Las Vegas, and Henderson, along with portions of Boulder City near Hoover Dam. Figure 2-2 depicts land use and vegetation in Clark County along with the two major transportation routes, Interstate 15 and U.S. Highway 95.

2.3 OZONE AIR POLLUTION IN CLARK COUNTY

Local emissions of pollutants which lead to the formation of ozone are largely limited to the Las Vegas Valley. Air quality modeling indicates that local emissions from outside the valley are insignificant in forming ozone in Clark County. The *Ozone Characterization Study* (DAQEM 2006a) identified the meteorological features that affect the timing and location of elevated ozone levels in Clark County. Synoptic weather patterns during the ozone season (May through August), as depicted by 500 constant pressure patterns, were classified into five types:

1. Pacific trough
2. Interior trough
3. Pacific ridge
4. Interior ridge
5. Flat ridge.

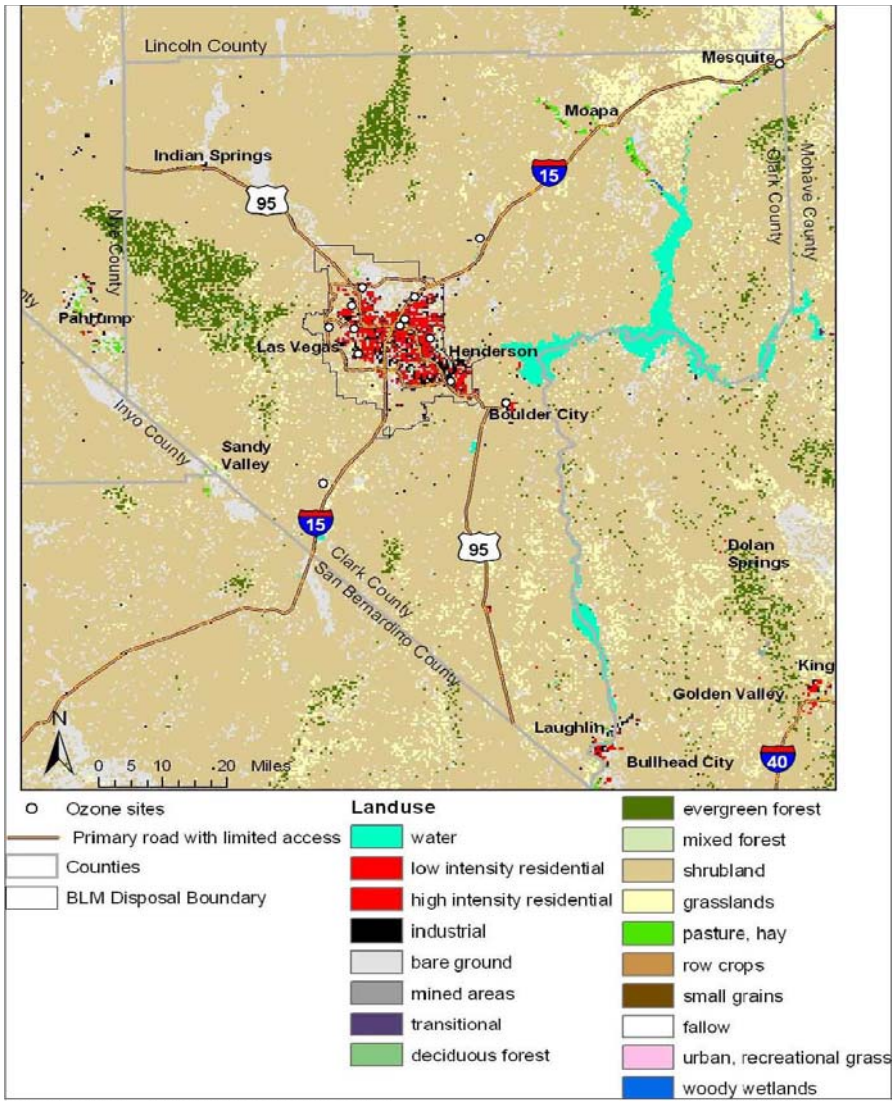


Figure 2-2. Land Use and Vegetation in Clark County.

Ozone air quality monitoring for the period from 2001–2003 was analyzed to determine the frequency of elevated ozone concentrations under these five synoptic weather patterns. (Table 2-2). High ozone events in Clark County occurred most frequently under the three weather types—Pacific ridge, interior ridge, and flat ridge—that are generally characterized by high pressure that results in a stable atmosphere with light winds aloft.

Table 2-2. Frequency of Weather Types versus Daily Maximum 8-Hour Ozone Concentration, 2001-2003

Maximum 8-hr Avg.	PT	IT	PR	IR	FR	Total
80 – 85 ppb	7	2	8	24	19	60
>85 ppb	1	1	10	16	10	38
Total	*8*	*3*	*18*	*40*	*29*	*98*
% of High Ozone Cases	8%	3%	18%	41%	29.6%	
% of Type Cases	7%	2%	26%	17%	17.2%	

Surface winds in Clark County are controlled by local terrain influences superimposed on the larger-scale synoptic and regional wind fields. Local influences include channeling of winds through passes and/or gaps in the terrain, and slope and valley wind systems. Slope and valley wind systems are local, thermally-driven flow circulations that form in complex terrain areas. These processes directly affect the transport and dispersion of pollutants.

The diurnal behavior of the prevailing Las Vegas Valley wind field follows a particular pattern. At night, when the atmosphere is most stable, local drainage flows dominate in the lower elevations. The flow appears to follow the terrain along the longitudinal axis of the valley toward Lake Mead. The surface flow pattern during this stable nocturnal period is clearly decoupled from the stronger winds aloft, as seen in measurements taken at higher elevations around the valley. By mid-morning, drainage flows cease and, as the sun heats the terrain, shift to an upslope flow that runs most frequently west-northwest. By mid-afternoon and continuing into evening, a fairly uniform, moderately strong southwest wind field prevails as flows at all levels become strongly coupled. There appears to be a steady influx into the valley from the southwest.

The temporal and spatial behavior of ozone and associated weather patterns during ten high ozone episodes from 2001 through 2003 were analyzed in detail. Table 2-3 shows the episode dates, the number of monitoring stations that showed an exceedance of the 1997 ozone NAAQS, and an assessment of the relative contributions from local sources and interbasin transport. During most episodes, the northwest quadrant of the Las Vegas Valley typically experienced the highest ozone levels. When interbasin transport was significant, sites throughout western Clark County had high ozone levels.

Table 2-3. Summary of Ozone Episodes, 2001-2003

Date	# Sites > 85 ppb	Transport/Local Scenario
8/10/01	6	Significant local contribution
8/11/01	3	Significant local contribution
6/16/02	5	Interbasin transport significant contribution
6/27/02	5	Interbasin transport significant contribution
6/28/02	3	Interbasin transport significant contribution
8/11/02	3	Significant contribution from both interbasin transport and local sources
8/18/02	5	Interbasin transport significant contribution
5/26/03	3	Interbasin transport may be significant contribution
5/27/03	1	Significant local contribution
6/1/03	1	Interbasin transport significant contribution

Date	# Sites > 85 ppb	Transport/Local Scenario
6/3/03	1	Interbasin transport may be significant contribution
6/4/03	1	Significant local contribution
6/29/03	8	Overwhelming interbasin transport
7/9/03	2	Significant local contribution
7/21/03	7	Significant local contribution

Ozone and its precursor pollutants may be transported hundreds of miles downwind from their original sources, which include human activities and wildfire smoke plumes. In Clark County, transport is sometimes entirely responsible for ozone concentrations exceeding the ozone NAAQS; in fact, interbasin transport played an important role in 9 of the 15 exceedance days analyzed in these case studies. Transport of ozone—and the precursor pollutants that lead to its formation—can be the dominant variable causing NAAQS violations in Clark County.

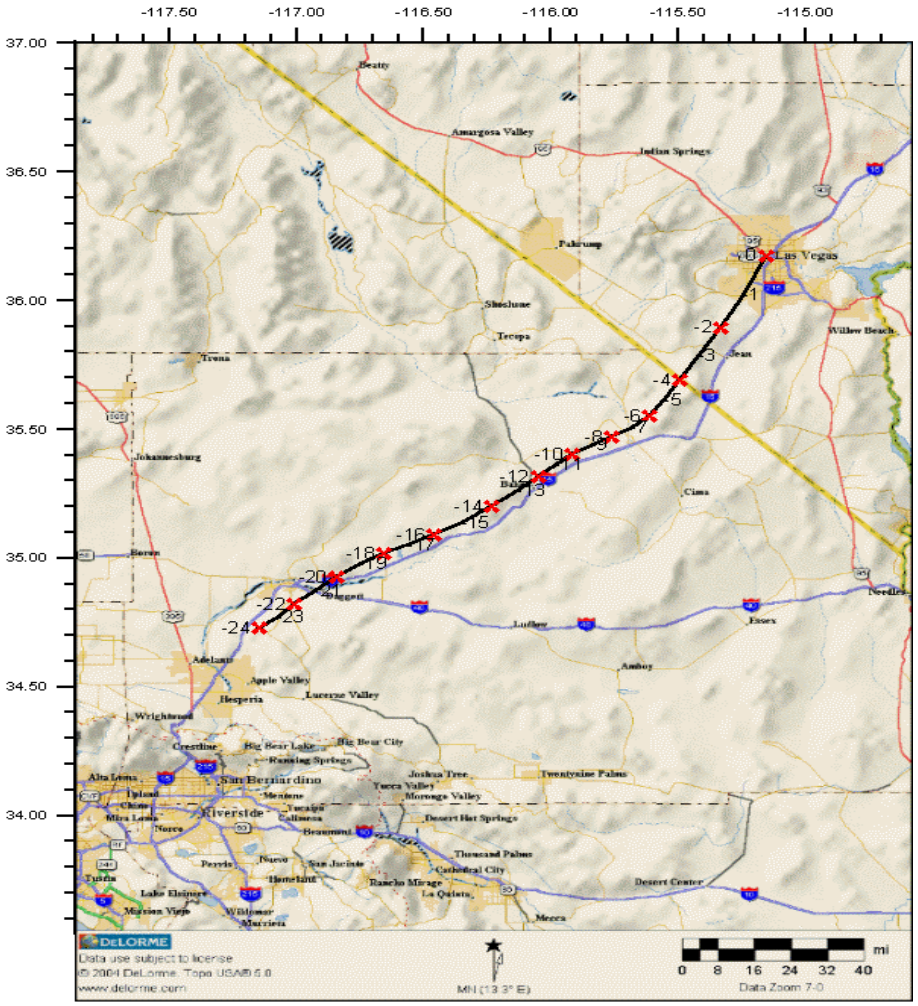
On June 29, 2003, interbasin transport overwhelmed any local contribution to elevated ozone levels. This one-day episode was characterized by the greatest number of sites exceeding the NAAQS, and recorded one of the highest ozone concentrations of all the case studies examined. Table 2-4 lists maximum ozone levels by monitoring site for June 29, as well as the days before and after. The last row shows the number of sites exceeding the NAAQS on each day.

Table 2-4. Maximum 8-Hour Ozone Concentrations (ppb)

Site Name	Site ID	6/28/2003	6/29/2003	6/30/2003
Apex	AP	78	92	75
Boulder City	BC	78	80	63
E Craig Rd	BS	79	85	64
City Center	CC	82	81	52
JD Smith	JD	80	86	64
Jean	JN	84	89	72
Joe Neal	JO	85	94	76
Lone Mt	LO	83	88	71
Mesquite	MQ	70	80	64
SE Valley	PL	--	--	33
Paul Myer	PM	83	85	69
Palo Verde	PV	82	87	71
Shadow Lane	SL	--	--	--
Searchlight	ST	74	82	59
Walter Johnson	WJ	81	87	70
Winterwood	WW	77	88	70
Network Max	--	85	94	76
# Sites Exceeding NAAQS	**--**	**0**	**8**	**0**

The ozone exceedances on June 29 took place during a period that had transitioned from a flat ridge to an interior ridge. During the relative stagnation caused by the flat pressure-height gradients and stable air mass persisting over southern California, ozone levels became quite high in the South Coast air basin. Time-series graphs of hourly ozone levels at California desert sites (and Jean) show that by late afternoon on June 28, ozone levels from Barstow to Joshua Tree

were 100 ppb or greater. Figure 2-3 shows a back-trajectory analysis from the center of the Las Vegas urban area, ending at 1200 Pacific Standard Time (PST) on June 29, when the highest peak ozone concentrations were recorded. The estimated air-parcel trajectory shown originates 24 hours earlier, near Antelope Valley in the South Coast air basin. Local Clark County wind patterns support strong transport winds on June 29. The wind direction and speed contours at 1600 PST exhibit a uniform southwesterly flow at moderate speeds throughout Clark County.



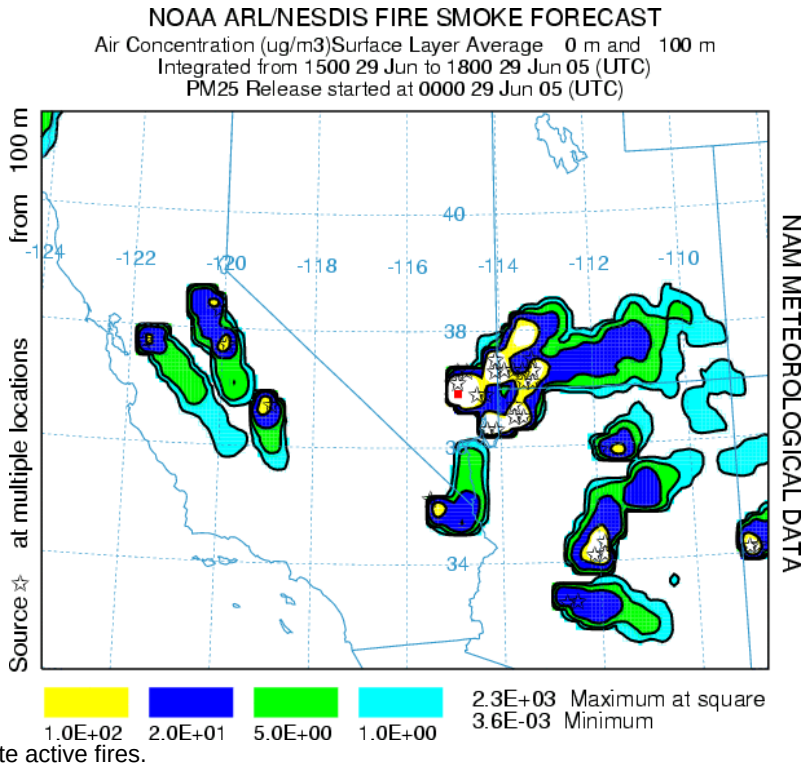
Backward Trajectory Ending at 12 PST June 29, 2003
Hours prior to end point shown

Figure 2-3. Backward Trajectory Ending at 1200 PST on June 29, 2003.

This episode is one example of ozone NAAQS violations resulting from an overwhelming transport of pollutants into southern Nevada. Similarly, on June 29-30, 2005, ozone NAAQS violations resulted from the transport of ozone and its precursors within wildfire smoke plumes that surrounded the Las Vegas Valley for several days preceding the exceptional event. Meteorology before the event was conducive to the pooling of smoke from wildfires throughout the southern Nevada region: between June 26 and 28, a West Coast low-pressure front progressed from west to east as a short-wave trough. Considerable thunderstorm activity ensued as the system moved across the Great Basin, with lightning strikes causing additional wildfires in Nevada, Arizona, and Utah. By June 29, a flat high-pressure ridge had built up in the southern Great Basin as the

short-wave trough exited to the east. This ridge brought an end to the thunderstorms, promoting a stable air mass and stagnant conditions that prevailed through June 30. Smoke plumes from the numerous wildfires were visible throughout southern Nevada. Surface smoke impacts were documented through laboratory analysis of samples of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) to determine concentrations of wildfire markers (e.g., levoglucosan).

Clark County was conducting an intensive sampling program for the Clark County Regional Ozone and Precursor Study (CCROPS) (DAQEM 2006b) during the 2005 summer season, and researchers anticipated elevated ozone concentrations from wildfires in the second half of June. Figure 2-4 illustrates the smoke forecast for June 29, 2005, and the locations of active fires. Many of the fires were active before June 29.



Note: Stars designate active fires.

Figure 2-4. NOAA Smoke Forecast for Afternoon of June 29, 2005.

These wildfires, particularly the Goodsprings fire (20 km south of Las Vegas) and wildfires in southern California and Utah, inundated the Las Vegas Valley with smoke. The smoke plumes were associated with widespread violations of the ozone NAAQS throughout Clark County on June 29-30, 2005, with 8-hour concentrations reaching 108 ppb—among the highest ever recorded in this region. The CCROPS data shows an apparent relationship between ozone levels and wildfire plumes that seems to depend on the age of the constituents comprising the plume.

As in an urban plume, reactants in a wildfire plume titrate ambient ozone. Thus ozone levels near a wildfire may be lower than regional background levels; conversely, as a fire plume in which ozone production has been active begins aging, ozone levels increase to above background. The Goodsprings fire on June 23, 2005, produced a plume that was in its infancy, in terms of converting precursors to ozone, during the time it was in the greater Las Vegas area. A glider equipped

with an ozone monitor conducted soundings during this period; it operated out of the Jean airport, only a few kilometers from the Goodsprings fire. Figure 2-5 shows a plot of the glider ozone profile taken during the fire.

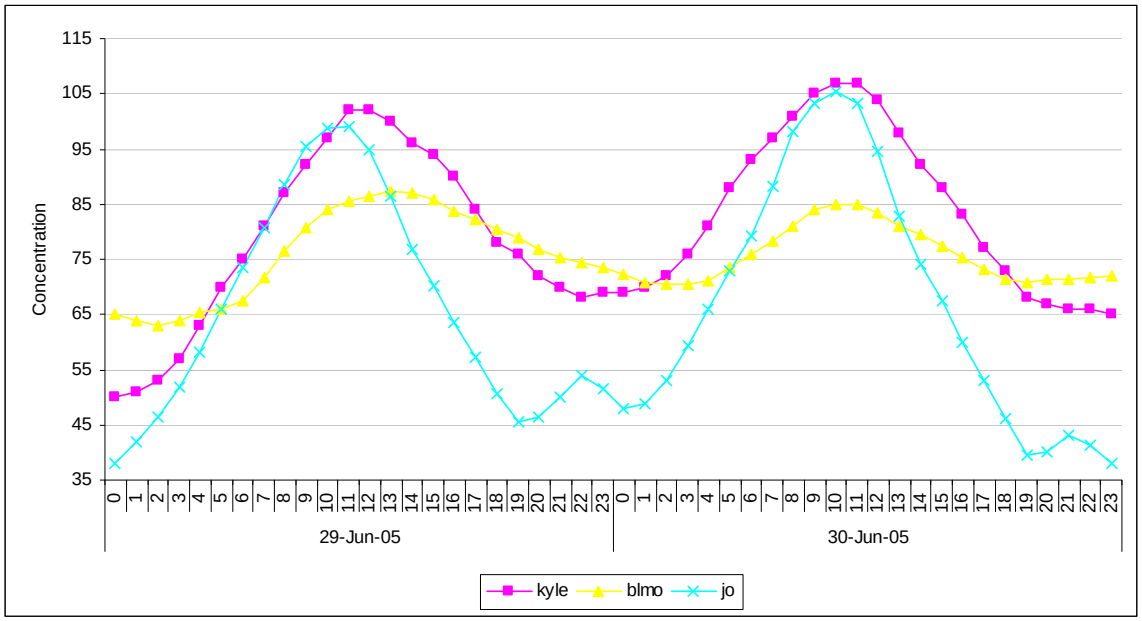


Figure 2-5. Upper-Level Reservoir Between 68 ppb and 107 ppb.

The pilot observed that entrance to the Goodsprings wildfire plume was accompanied by a significant decrease in ozone levels, most likely caused by titration. By contrast, when the glider was above the Goodsprings plume—i.e., flying in air that back-trajectory analysis indicated came from fires near Joshua Tree in southern California—upper-air ozone concentrations were clearly higher than those near the surface (Figure 2-6).

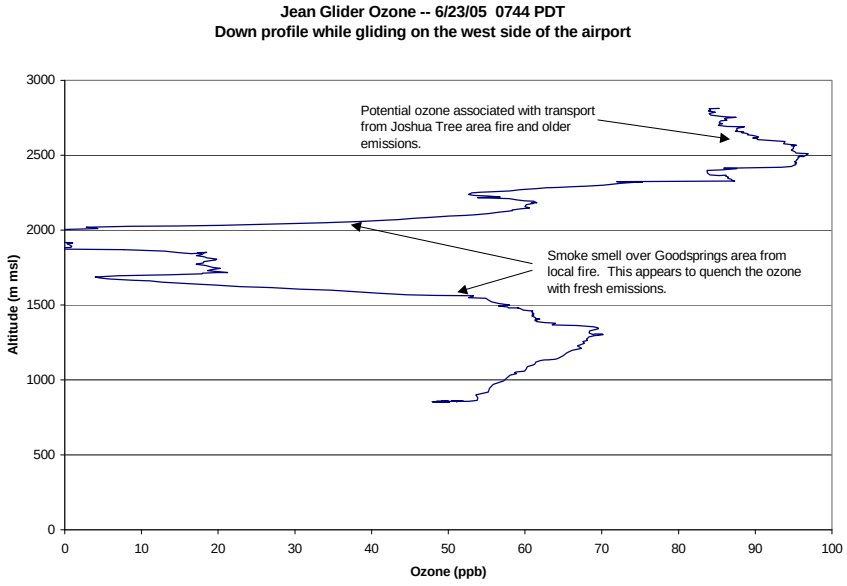


Figure 2-6. Ozone Profile for Morning of 6/23/05 near the Goodsprings Fire.

This association of higher ozone concentrations with wildfire smoke plumes was further demonstrated during another air sounding on July 1, 2005, as the smoke was beginning to clear after the June 29-30 exceptional event. For this sounding, the tow aircraft was equipped with a portable light-scattering PM_{10} analyzer as well as an ozone monitor. In Figure 2-7, the sounding clearly shows an increase in measured ozone concentrations as the aircraft encounters the remnants of the smoke plume, indicated by a corresponding increase in PM_{10} concentrations. Smoke impacts at the surface, which included higher concentrations of ozone and ozone precursors, were further exacerbated by pollutants entrained from the upper air to the surface during daytime convective mixing.

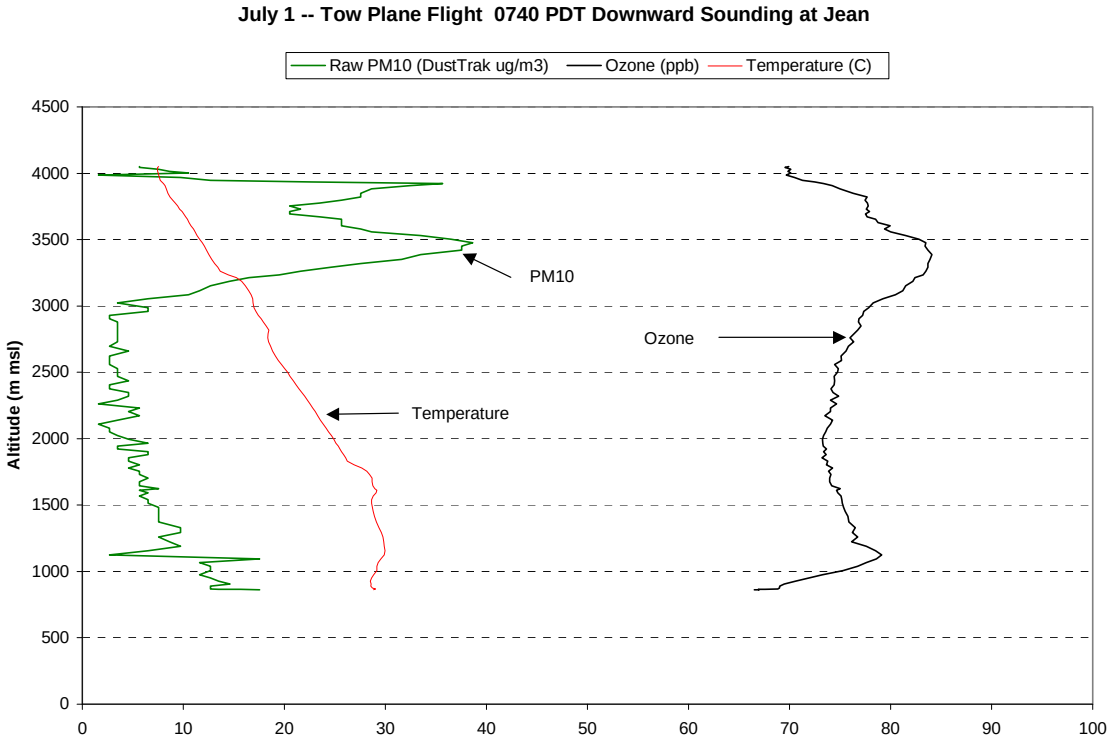


Figure 2-7. Ozone and PM_{10} Profile for Morning of 7/1/05.

As an example, Black Mountain and Kyle Canyon are located above the typical top of the inversion layer—at 1,221 m and 1,129 m above mean sea level (msl), respectively—in a rural area upwind of Las Vegas. Ozone at both sites exhibited less diurnal variation than at the Joe Neal site, located at 709 meters above msl in the northwest part of Clark County (Figure 2-8). Joe Neal typically records higher ozone concentrations relative to other monitoring sites in the Las Vegas Valley. Readings from the Black Mountain and Kyle Canyon sites are reasonable surrogates for regional background concentrations, because they are for the most part unaffected by nocturnal inversions. Figures 2-4 and 2-5 show the diurnal cycles at the Black Mountain and Kyle Canyon sites relative to the Joe Neal site. Ozone concentrations at the two background sites are significantly higher than at Joe Neal. The readings at these higher elevations represent potential ozone that can be entrained to the surface during daytime convective mixing.

As the ground surface cools in the early evening, a surface-based inversion develops. This nocturnal boundary layer is typically decoupled from the air aloft, which can cause complex ozone layering in the vertical and associated wind shears. The boundary layer deepens during the day, as the ground surface warms due to insolation, and surface-emitted pollutants readily mix vertically. Thus mixing during the night and early morning hours is limited by a nocturnal inversion; daytime mixing intensifies throughout the late morning, peaking in the afternoon, usually at more than 4,000 m above the ground.

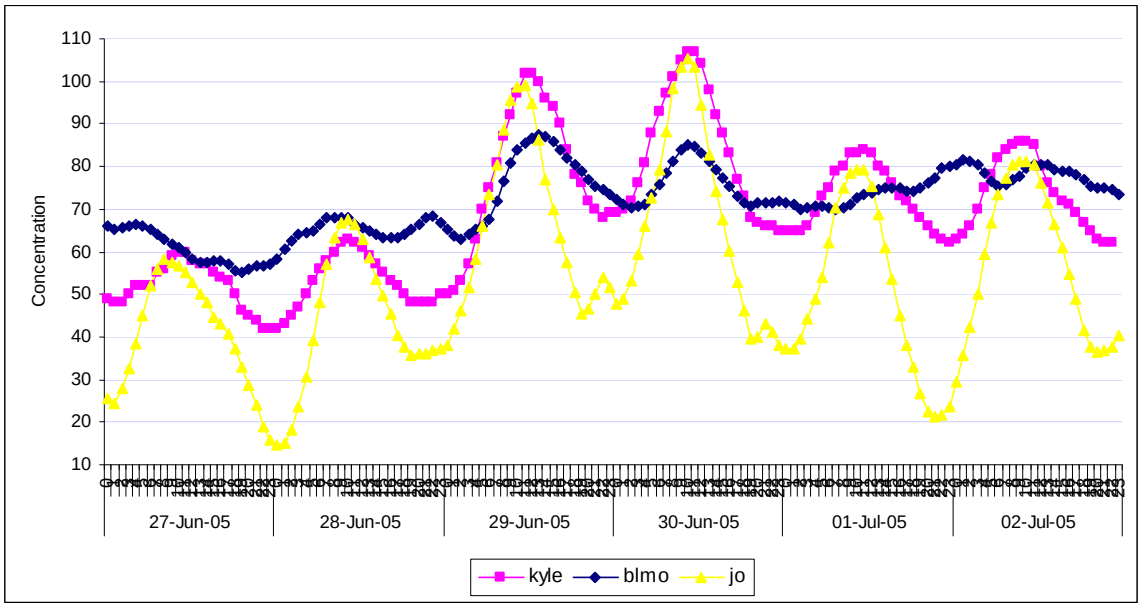


Figure 2-8. Diurnal Cycles during 6-Day Period.

The stagnant air quality conditions that prevailed before the June 29-30, 2005, exceptional event would have resulted in elevated ozone conditions, but not in excess of the ozone NAAQS. Section 3 presents a detailed analysis showing that the June 29-30 ozone violations were caused by pollutants in smoke plumes from wildfires. The technical analyses in this revised demonstration address deficiencies EPA cited for the first submittal, and include regression modeling showing that ozone NAAQS violations would not have occurred “but for” smoke plumes from wildfires.

3.0 WILDFIRE EXCEPTIONAL EVENT DEMONSTRATION FOR JUNE 29-30, 2005

The EER requires a demonstration of the following criteria to exclude air quality data from the normal planning and regulatory process established by the CAA:

1. The event satisfies the criteria set forth in 40 CFR 50.1(j), which defines an exceptional event.

2. There is a clear causal relationship between the measurements under consideration and the event that is claimed to have affected the air quality in the area.

3. The event is associated with measured concentrations in excess of normal historical fluctuations, including background.

4. There would have been no exceedance or violation but for the event.

5. Documentation is provided with the submission of the demonstration that the public comment process was followed.

The EER further requires that Clark County prove it took reasonable and appropriate actions to inform the public of deteriorating air quality caused by wildfire smoke plumes and a possible exceedance of the ozone NAAQS. The following sections address each of these requirements.

3.1 COMPLIANCE WITH CRITERIA FOR EXCEPTIONAL EVENTS

An exceptional event, as defined in 40 CFR 50.1(j), is

> an event that affects air quality, is not reasonably controllable or preventable, is an event caused by human activity that is unlikely to recur at a particular location or a natural event, and is determined by the Administrator in accordance with 40 CFR 50.14 to be an exceptional event. It does not include stagnation of air masses or meteorological inversions, a meteorological event involving high temperatures or lack of precipitation, or air pollution relating to source noncompliance.

The summer of 2005 was an exceptionally active wildfire season relative to previous years. Table 3-1 lists the number of fires larger than 40,000 acres in Nevada, California, Arizona, and Utah, along with the approximate start date and duration of the burn. The table does not list smaller fires of less than 40,000 acres, of which there were many in 2005. Figure 3-1, a satellite image for June 23, 2005, shows the locations of fires and corresponding smoke plumes. Wildfires in California, Nevada, Utah, and Arizona encircled the Las Vegas Valley. The prevailing wind direction was from the south on this and the following day, as Figure 3-2 shows. Smoke plumes from southern California and the wildfire in Goodsprings, 20 km southwest of Las Vegas, can clearly be seen impacting the Las Vegas Valley. These wildfires continued burning or smoldering, and new wildfires developed, through early July. Figure 3-3 is a satellite image from June 29, 2005, and Figure 3-4 is a satellite image for June 30. Both images clearly show a dense veil of smoke over the Las Vegas Valley and the rest of southern Nevada.

Table 3-1. Fires Over 40,000 Acres in 2005

Name	State	Start Date	Contain/Control Date	Final Size	Cause[2]
Southern Nevada Complex	NV	6/22/05	7/18/05	508,751	L
Cave Creek Complex	AZ	6/21/05	7/11/05	248,310	L
Delamar[1]	NV	6/28/05	8/9/05	170,089	L
Meadow Valley[1]	NV	6/22/05	8/10/05	146,035	L
Hackberry Complex	CA	6/22/05	7/6/05	70,736	L
Westside Complex	UT	6/23/05	6/30/05	68,264	L
Goldwater	AZ	6/17/05	6/25/05	58,536	H
Fork	NV	6/28/05	7/4/05	43,149	L

[1] These fires also became part of the Southern Nevada Complex.
[2] L = lightning; H = human.

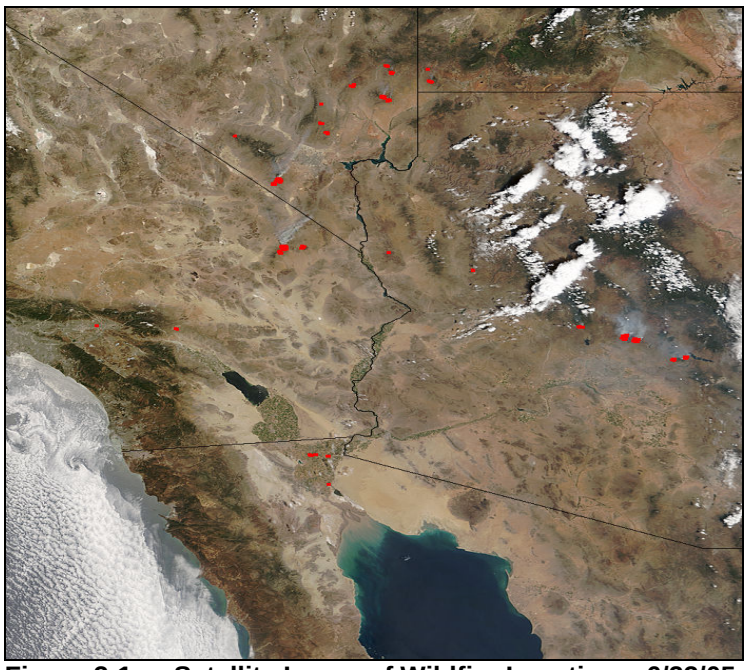


Figure 3-1. Satellite Image of Wildfire Locations, 6/23/05.

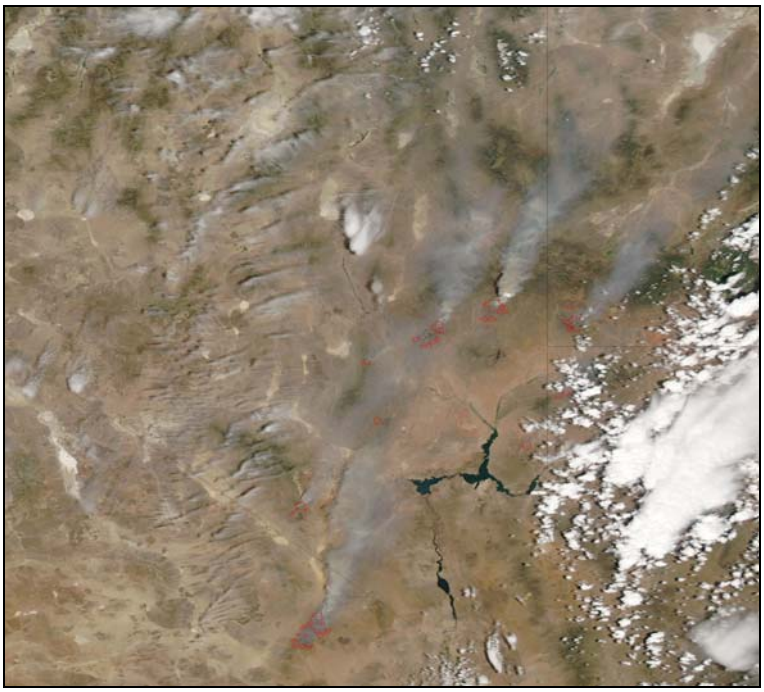


Figure 3-2. Satellite Image of Wildfire Smoke Plumes, 6/24/05.

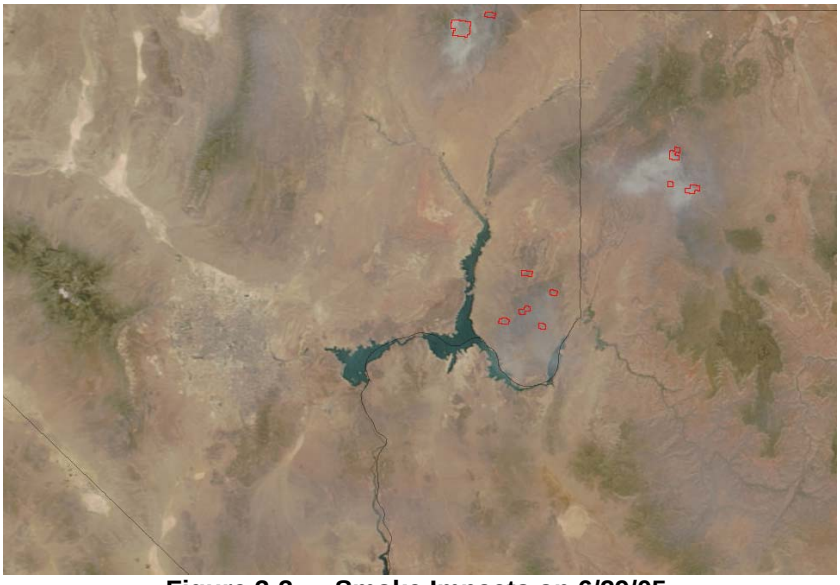


Figure 3-3. Smoke Impacts on 6/29/05.

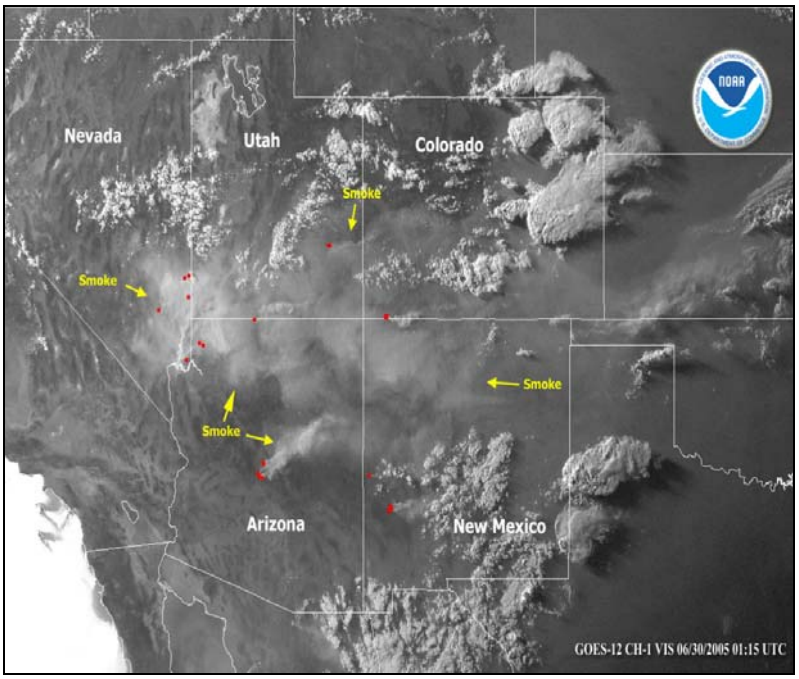


Figure 3-4. Wildfires and Smoke Plumes, 6/30/05.

3.2 CAUSAL RELATIONSHIP BETWEEN OZONE CONCENTRATIONS AND WILDFIRES

Smoke plumes from wildfires contain a variety of pollutants, including volatile organic compounds (VOCs) and oxides of nitrogen (NO_x)—precursor pollutants in the formation of ozone—and particulate organic and inorganic compounds. Wildfire smoke plumes affect air quality not only through the emissions of primary pollutants, such as CO, PM, VOCs, and NO_x, but also through the production of secondary pollutants (i.e., ozone and secondary organic aerosols) when VOCs and NO_x undergo photochemical processing during atmospheric transport. Table 3-2 demonstrates that significant amounts of VOCs are released during wildfires. It lists a range of pollutants emitted, expressed as emission factors, which are defined as the mass of compounds released per mass of dry fuel consumed. Total VOC emissions exceed those of $PM_{2.5}$, and account for 1 to 2 percent of the carbon fuel burned.

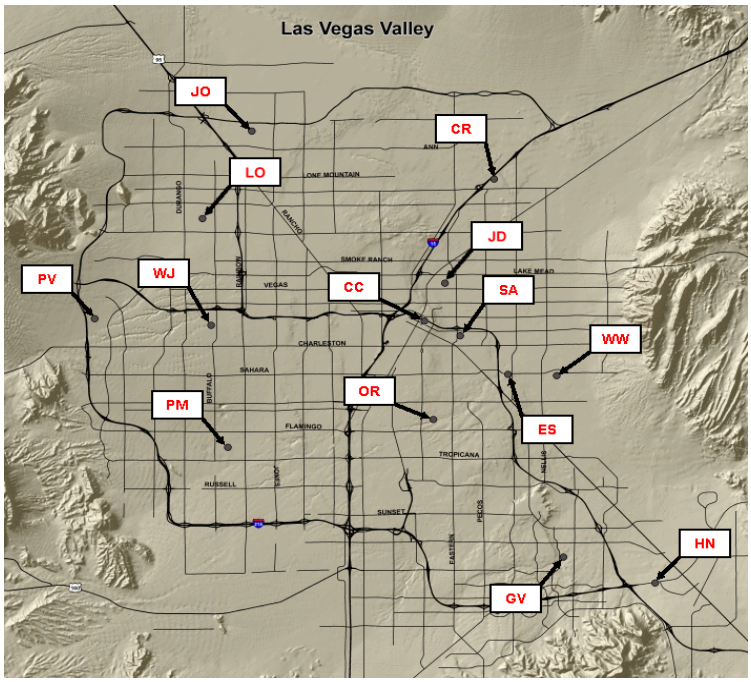
Table 3-2. Chemical Compositions and Emission Factors for Wildfires

Compound or Compound Class	Emission Factors (g/kg)	
	Temperate forest	Temperate rangeland
$PM_{2.5}$	11.7	9.7
Organic carbon (wt. percent of $PM_{2.5}$)	45 - 55	40 - 70
Elemental carbon (wt. percent of $PM_{2.5}$)	4 - 8	4 - 10
Elemental Species (wt. percent of $PM_{2.5}$):	~ 3	~ 6
• Potassium (K, wt. percent of PM2.5)	~ 1	~ 3
• Chloride (Cl, wt. percent of PM2.5)	0.3	2
CO	89.6 ± 13.2	69 ± 17
CO_2	1619 ± 112	1684± 45
Alkanes (C2-C10)	0.8	0.4
Alkenes (C2-C9)	2.2	1.8
Aromatics (BTEX)	0.64	0.42
Oxygenated VOCs:	10.9 – 12.9	N/A
• Methanol	0.31 – 2.03	0.14
• Formic acid	1.17	N/A
• Acetic acid	3.11	N/A
• Formaldehyde	2.25	N/A
• Acetaldehyde	0.24	0.25
• Acetone	0.347	0.25
• Acrolein (propenal)	0.123	0.08
• Furan	0.445	0.1
• 2-methyl-furan	0.521	N/A
• 3-methyl-furan	0.052	N/A
• 2,5-dimethyl-furan	0.053	N/A
• Benzofuran	0.038	N/A

N/A = not available; BTEX = benzene, toluene, ethylbenzene, and xylenes.

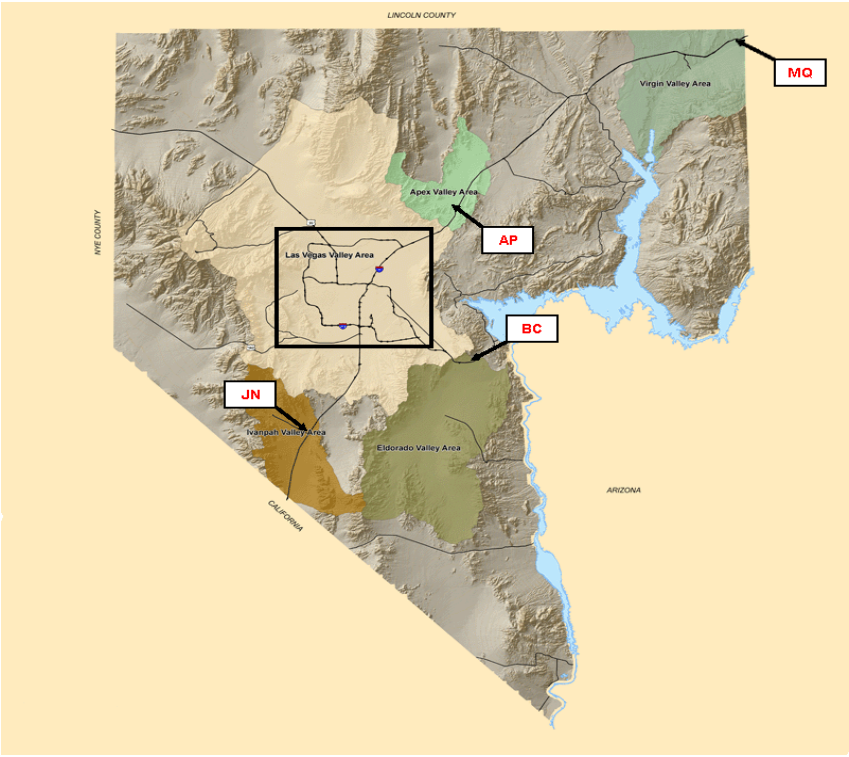
3.2.1 Laboratory Analysis of $PM_{2.5}$ Samples

Smoke plume impacts at the surface during the study period were determined by wildfire markers detected through laboratory analysis of $PM_{2.5}$ samples obtained from the Clark County monitoring network. Figure 3-5 shows air quality monitoring sites within the Las Vegas Valley; Figure 3-6 shows air quality monitoring sites outside the Las Vegas Valley.



Note: JO=Joe Neal, LO=Lone Mountain, CR=E. Craig Road, PV=Palo Verde, WJ=Walter Johnson, CC=City Center, JD=JD Smith, SA=Sunrise Acres, PM=Paul Mayer, OR=Orr, WW=Winterwood, ES=East Sahara, GV=Green Valley, HN=Henderson.

Figure 3-5. Las Vegas Area Monitoring Sites.



Note: JN=Jean, AP=Apex, BC=Boulder City, MQ=Mesquite.

Figure 3-6. Monitoring Sites Outside the Las Vegas Valley.

Levels of $PM_{2.5}$ track closely with those of levoglucosan, a unique tracer for burning biomass because of its relationship to cellulose. When heated to more than 300°C, cellulose undergoes various pyrolytic processes that yield tarry anhydro-sugars and volatile products; these give rise to source-specific molecular tracers, primarily the 1,6-anhydride of glucose known as levoglucosan.

Although levoglucosan is widely reported to be abundant in biomass smoke compared to other organic compounds (Fine et al. 2001; Nolte et al. 2001; Schauer et al. 2001; Fine et al. 2002; Hays et al. 2002; Sheesley et al. 2003; Mazzolini et al. 2007), concentrations are highly variable. In Mazzoleni et al. (2007), the overall range of levoglucosan varied from 3 percent to 36 percent of $PM_{2.5}$ mass. The highest percentage was observed for grasses, white pine needles, straws, and mixed woods. Since wildfires typically consume a high percentage of these materials, the concentration of levoglucosan in wildfire emissions is significant in determining where a wildfire originated.

In addition to levoglucosan, methoxylated phenols (methoxyphenols) are often found in biomass combustion emissions and can be significant in determining where a smoke plume originated. Cellulose fibers in plants are bound together in lignin, a complex polymer. The pyrolysis of wood lignins gives rise to methoxyphenols, most often guaiacols and syringols. In the lignin of hardwoods, structural units of guaiacol and syringol are present in even proportions. In the lignin of softwoods, guaiacols are the predominant structural unit.

Mazzoleni et al. (2007) reported that sagebrush and grasses, like hardwoords, emit guaiacols and syringols in similar quantities. However, he noted that pine needles have a high PM fraction of guaiacols with very few syringols, similar to softwoods. The prescribed burn samples he collected in mixed coniferous forests—Yosemite National Park, CA, and the Toiyabe National Forest near Lake Tahoe, NV—had a high percentage of PM represented by guaiacols and a very low percentage represented by syringols, as hardwoods do. The prescribed burn samples of desert brushes from central rural Nevada had even percentages of guaiacols and syringols, similar to sagebrush. Mazzoleni et al. (2007) also identified methoxy acids originating from pyrolysis of wood lignin (e.g., vanillic, homovanillic, and syringic acids) in biomass combustion source samples and in-field prescribed burn samples. In general, methoxy acids were found in low abundance in wildland fuels.

3.2.1.1 Sample Collection and Analysis

During the 2005 wildfire event, Clark County staff collected ambient $PM_{2.5}$ samples at five monitoring sites: Jean, Apex, Sunrise Acres, J.D. Smith, and Green Valley. The samples were collected over a 24-hour period using 37-mm Teflon filters at a sampling rate of 1 m^3/hr. After gravimetric mass measurements, all filters were archived and kept in airtight containers in a freezer. Filter samples collected from June 21 to July 3 were sent to the Desert Research Institute (DRI) Organic Analytical Laboratory to determine the presence of wildfire markers.

Table 3-3 lists the 24 samples submitted to DRI for analysis, including 5 field blanks, collected at five different sites. All samples were collected between June 21 and July 3, 2005, but only selected samples from each site were submitted for analysis. Table 3-3 also lists the $PM_{2.5}$ concentrations recorded for these dates. The highest $PM_{2.5}$ concentrations at each site were observed on

June 30, 2005, if a sample was collected on that date. A very high concentration was also recorded at Sunrise Acres on June 29, and relatively high concentrations were observed at this site June 21-23 and July 1.

Table 3-3. List of Filter Samples Analyzed for Biomass Smoke Tracers

Site	Date	Filter No	$PM_{2.5}$ (µg/m^3)
AP	6/27/2005	T4184909	3.71
	7/3/2005	T4184936	8.29
CL	6/27/2005	T4184899	4.58
GV	6/30/2005	T4184920	17.00
JD	6/27/2005	T4184908	5.00
	6/30/2005	T4184918	32.08
	7/3/2005	T4184932	10.33
JN	6/21/2005	T4184884	6.87
	6/27/2005	T4184911	3.04
	6/30/2005	T4184919	11.38
SA	6/21/2005	T4184891	12.97
	6/22/2005	T4184892	11.91
	6/23/2005	T4184895	14.68
	6/27/2005	T4184914	4.42
	6/28/2005	T4184915	6.74
	6/29/2005	T4184916	31.65
	6/30/2005	T4184917	33.61
	7/1/2005	T4184921	13.09
	7/2/2005	T4184922	8.30
CL	7/3/2005	T4184927_FB	Field Blank
JD	7/3/2005	T4184933_FB	Field Blank
JN	6/21/2005	T4184885_FB	Field Blank
SA	6/22/2005	T4184893 FB1	Field Blank
	7/2/2005	T4184923_FB2	Field Blank

AP=Apex, CL=collocated, GV=Green Valley, JD=J.D. Smith, JN=Jean, SA=Sunrise Acres.

Figure 3-7 illustrates the concentrations (in ng/m^3) of the main biomass smoke tracers for all samples listed in Table 3-3. It shows the highest concentrations of levoglucosan, the main biomass burning marker, on June 30 at all sites. High concentrations of this marker were also observed on June 23 and 30, and at Sunrise Acres. The sample collected from that site on June 23 also contains a high concentration of dehydroabietic acid, which is one of the resin acids typically found in emissions from coniferous woods, pine needles, and other foliar fuel (Hays et al. 2002). Figure 3-8 shows the concentrations of resin acids in the samples. The sample collected on June 23 at Sunrise Acres is clearly different from the other samples, with high levoglucosan and resin acids concentrations, which indicate a different type of biomass burning.

Methoxyphenol concentrations were also examined for insight into the type of burning biomass that affected the Las Vegas area on June 23. Figure 3-9 shows the concentrations of syringol (2,5dimetoxy-phenol) and guaiacol (2-metoxyphenol) derivatives. The concentrations are rather low; the most abundant are vanillic acid, a guaiacol derivative, and syringic acid and syringaldehyde, both syringol derivatives.

Samples collected on June 29 and 30 contained vanillic acid, syringic acid, and syringaldehyde, whereas the sample collected on June 23 contains 4-formyl-guaiacol and homovanillic acid, in addition to vanillic and syringic acids. These data indicate that the biomass burning during the fire that impacted Clark County on June 29 and 30, 2005, was primarily a mixture of sagebrush, grasses, and/or foliar fuel, whereas the biomass that burned on or before June 23 had a higher component of coniferous wood and pine needles. Thus, these wildfires most likely originated in different areas.

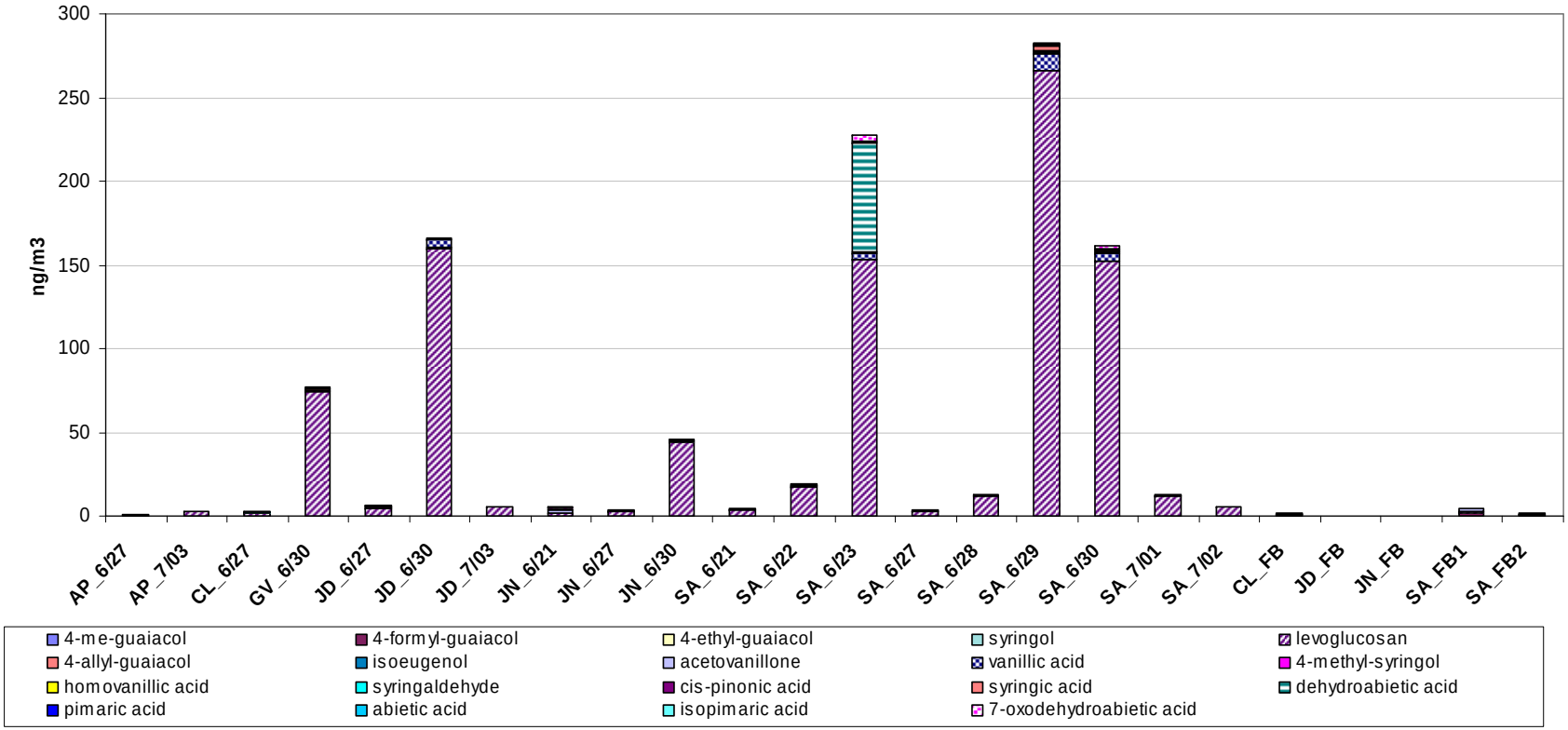


Figure 3-7. Biomass Burning Tracers for All Analyzed Clark County Samples.

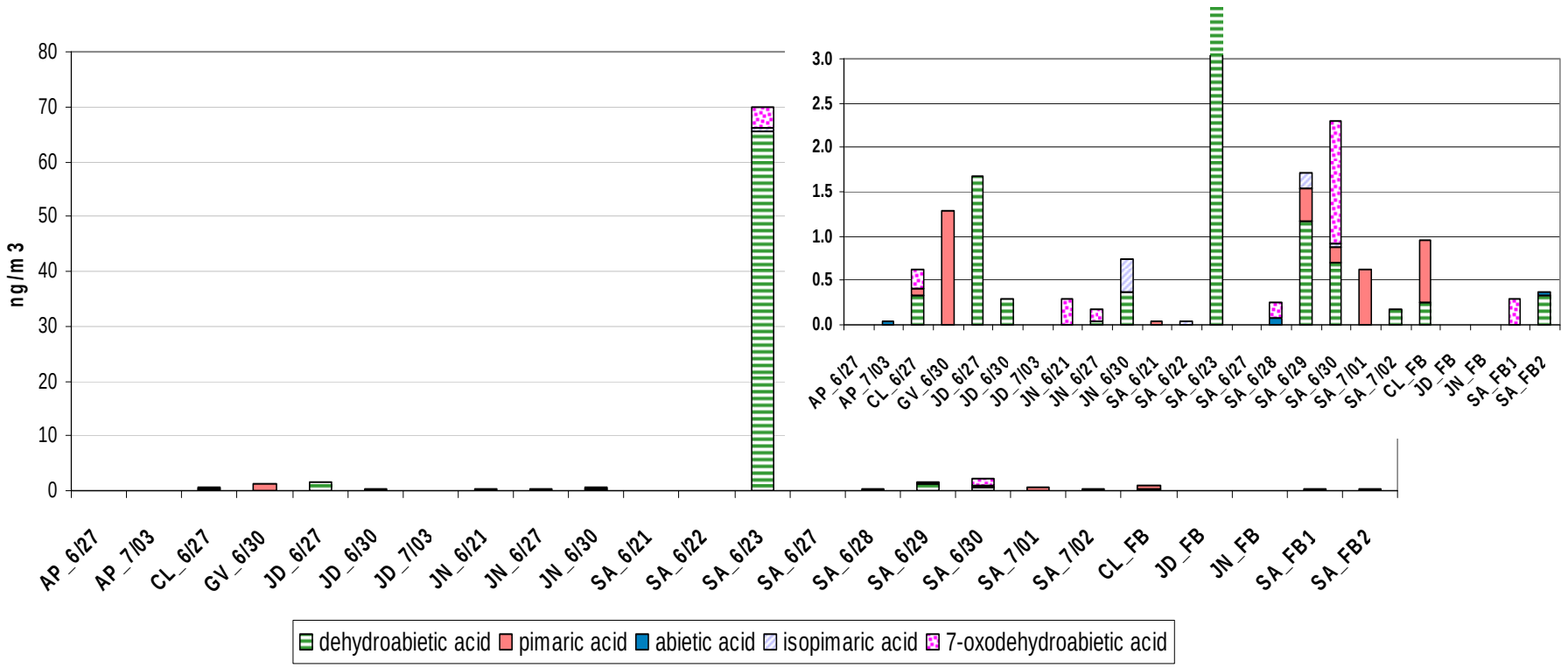


Figure 3-8. Resin Acid Concentrations in the Clark County Samples Analyzed for Biomass Burning Tracers.

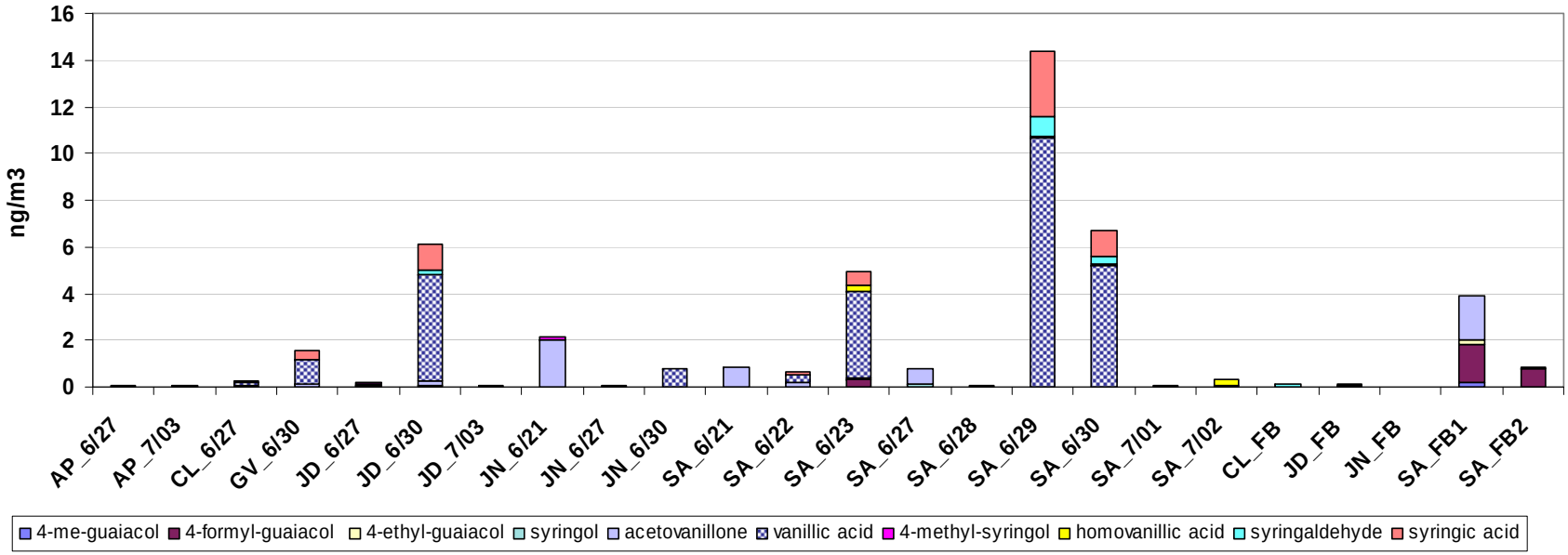


Figure 3-9. Methoxyphenol Concentrations in Clark County Samples.

Since levoglucosan is the most abundant, stable, and universal biomass burning emission marker, the correlations between ozone and levoglucosan concentrations were examined for the 2005 samples. To obtain a true reading, background ozone levels were subtracted from the average and maximum daily ozone concentrations; the "background" ozone level was the reading for days when ozone levels were not influenced by wildfire emissions because no wildfires were impacting the area.

For samples collected during the June 21-23 event, the ozone concentration of the day before the event was subtracted from the overall ozone reading. For samples collected during the June 27-July 2 event, ozone concentrations on the days before and after the event were averaged and subtracted from the ozone concentrations of the days during the event. Only levoglucosan data from the Sunrise Acres monitoring site were used for these correlations, since it was the only site that had a sufficient number of samples analyzed. Table 3-4 shows the uncorrected and corrected ozone concentrations, along with the background ozone concentrations subtracted.

Table 3-4. Uncorrected and Corrected O3 Concentrations (ppb) and Levoglucosan Concentrations (ng/m^3) for Sunrise Acres

Dates	O_3 Avg. (ppb)	O_3 Max. (ppb)	O_3 Avg. Corrected (ppb)	O_3 Max. Corrected (ppb)	Levoglucosan (ng/m^3)
6/21	24	63	2	4	3.9
6/22	27	62	5	3	17.7
6/23	32	75	10	16	153.0
6/27	29	68	-7	0	3.0
6/28	37	74	1	6	12.2
6/29	45	101	9	33	265.6
6/30	40	113	4	45	152.0
7/1	36	81	0	13	12.0
7/2	47	79	11	11	5.0
For O_3 Corrections:					
6/20[a]	22	59			
6/25	36	65			
7/4	37	71			
Average, 6/25 & 7/4[b]	36	68			

[a] Used for 6/21 to 6/23.
[b] Used for 6/27 to 7/2.

Figures 3-10 and 3-11 show the correlation of levoglucosan with average and maximum ozone concentrations, respectively. Figure 3-8 showed that 24-hour levoglucosan and corrected average ozone concentrations track each other well, except on the last day of collected data (July 2). Since the levoglucosan concentration for July 2 is low, the increase in ozone was most likely due to sources other than wildfires. If this one point is excluded from the correlation between the concentrations of the two species, the correlation coefficient (R^2) improves from 0.27 to 0.68. The correlation is slightly worse for 1-hour maximum ozone concentrations (R^2 =0.64). This can be expected from a comparison of 1-hour ozone concentrations with levoglucosan concentrations averaged over a 24-hour period because of the difference in sampling time.

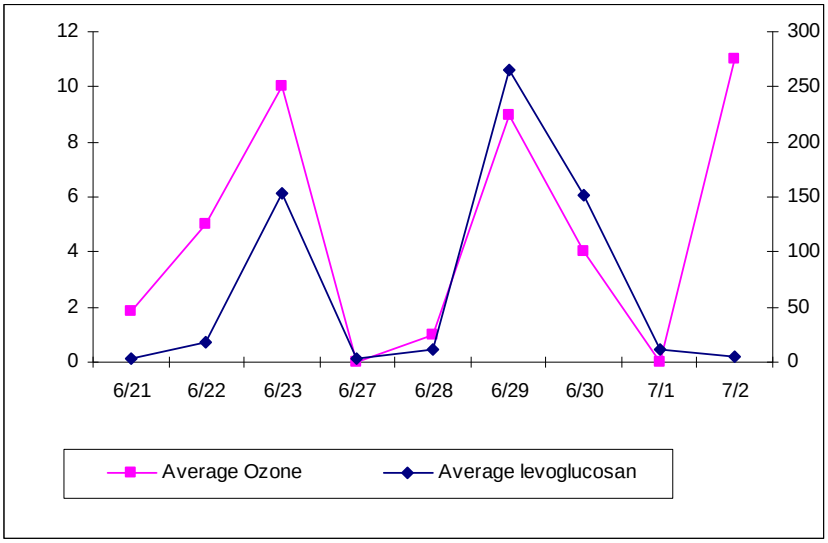


Figure 3-10. Correlation of Average Ozone and Levoglucosan Concentrations.

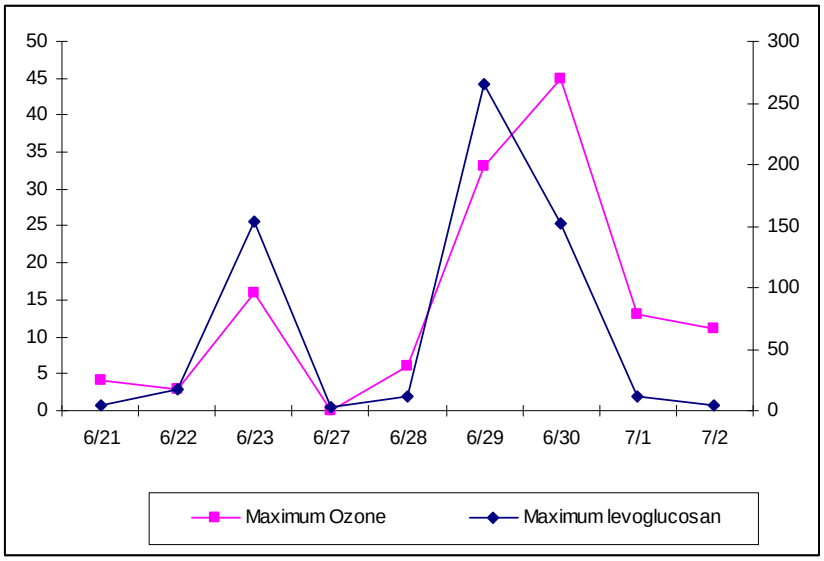


Figure 3-11. Correlation of Maximum Ozone and Levoglucosan Concentrations.

Relatively low ozone concentrations sampled on June 23, compared to June 29-30, are probably due to the age of the smoke plume impacting Clark County and the Las Vegas Valley on these dates.

During the 2005 ozone season, Clark County carried out extensive air quality sampling and data analysis for CCROPS. Data analyses illustrate the relationship between ozone concentrations and smoke plumes from wildfires. The relationship appears to be dependent on the age of the constituents comprising the smoke plume. For example, as in some urban plumes, reactants in the smoke plume titrate ambient ozone resulting in ozone concentrations that are less than regional

background levels. Conversely, as the wildfire smoke plume ages, ozone production is active, increasing concentrations above regional background levels. The Southern Nevada Complex Fires (Table 3-1) produced a smoke plume affecting the Las Vegas Valley that was still in its infancy with respect to precursor conversion to ozone.

3.2.2 Meteorology and Transport of Smoke Plume Pollutants into Southern Nevada

Section 2 provided a general discussion of meteorology associated with elevated ozone concentrations. As part of CCROPS, daily 500-mb charts were examined to determine the synoptic weather patterns for the period of interest (June 22 through July 3, 2005). The synoptic weather patterns during this period were identified as a Pacific trough, beginning around June 23, followed by an interior ridge. These weather patterns are described below, followed by a more detailed description of the meteorology during the periods related to the exceptional event.

Pacific Trough. The axis of the long-wave 500-mb trough, or series of short-wave troughs, is typically located off or along the Pacific Coast, producing falling 500-mb heights and increases from a westerly to a southwesterly flow. Convention dictates that the lowest 500-mb heights during this weather type are west of the Sierra Nevada Mountains. This type of trough influences atmospheric dispersion conditions in the interior southwestern U.S. by slowly eroding the strength and longevity of stable anticyclonic air masses, which results in the breaking down of the broad-scale subsidence needed to sustain poor dispersion conditions. Also by convention, this weather type includes zonal flow situations characterized by light to moderate, straight west-to-east flow across the western U.S. The southerly component of the onshore flow characteristic of this weather type may also open the door for increased moisture aloft over the interior regions. In general, the 700-mb temperature at the Desert Rock Airport (DRA) upper-air station, approximately 60 miles north of Las Vegas, is less than 10^{o}C during Pacific trough occurrences.

Interior Ridge. The primary characteristic of this weather type is the existence of a discernible high-pressure ridge at the 500-mb level over the interior southwestern U.S. The convention for this weather type is that the highest 500-mb heights are located east of the Sierra Nevada Mountains. Typically, an interior ridge occupies the Great Basin and Intermountain Regions, and it is often centered near the Four Corners area east of Las Vegas. The height of the 500-mb surface over the DRA upper-air site is usually greater than 5,900 m, and can be as high as 5,990 m. The 700-mb temperature usually exceeds 12^{o}C, and can be as high as 16^{o}C. The warm temperatures aloft are indicative of strong air mass subsidence in the interior region, where valley capping and limited thermodynamic mixing are prevalent. Because of the lack of cool air advection, the hottest local surface temperatures of the year are usually recorded during interior ridge events; however, mixing-layer depths may sometimes be deeper due to intense surface heating. Flow aloft at DRA for this weather pattern is usually light and variable when the ridge axis is over southern Nevada, and easterly to southeasterly when the ridge axis is father east.

June 22–25: By June 22, a strong West Coast low had weakened and broadened into a trough off the coast. At the same time, a large high-pressure ridge centered in the western Great Plains expanded west. The interface zone between the trough and the ridge was generally situated over the Great Basin during this period. As a result, regional flow remained southwesterly while the air mass stabilized somewhat due to the ridging influence to the east. The interface zone also con-

tained a stronger pressure gradient, which manifested with breezy afternoon local winds and some local cumulus development over higher terrain. Flow was mostly interbasin.

June 26–28: The West Coast low finally progressed from west to east as a short-wave trough. This system kicked off considerable thunderstorm activity as it moved across the Great Basin, particularly in Utah and northern Arizona. Many spots around the study area experienced dry lightning strikes, resulting in an outbreak of wildfires in southern Nevada, Arizona, and Utah.

June 29–July 3: A flat high-pressure ridge built into the southern Great Basin by June 29 as the short-wave trough exited to the east. The ridge brought an end to the thunderstorm activity, with increased air mass stability and little moisture; the stable air mass brought capping subsidence layers to the study area and very light flow below the cap. Boundary layer flow (below about 12,000 ft) in the study area came from the east on June 29, then became light intrabasin by June 30. The flat ridging scenario continued through July 1, with stagnant conditions prevailing in the southern Great Basin. A weak west-to-east zonal flow pattern had developed in the boundary layer by July 2, reflective of conditions higher aloft. A series of weak short-wave troughs migrated across the northern Great Basin within the zonal flow pattern. During July 2-3, boundary layer flow became light southwesterly as a result of the synoptic pattern. The zonal flow pattern was not strong enough to destabilize the air mass, so the capping subsidence layer persisted over the boundary layer.

3.2.3 Smoke Plume Trajectory Model

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model computes simple air parcel trajectories. Its calculation method is a hybrid between the Lagrangian approach, which uses a moving frame of reference as the air parcels move from their initial location, and the Eulerian approach, which uses a fixed three-dimensional grid as a frame of reference. HYSPLIT back-trajectories show the path an air parcel took to reach an area. Applications include tracking and forecasting the release of radioactive material, volcanic ash, and wildfire smoke.

Section 3.1 presented satellite images and data on wildfires in Clark County and surrounding areas, including their duration during the period of interest (June 22-30). The HYSPLIT plots in Figures 3-12 through 3-20 contain 36-hour back-trajectories for the Las Vegas Valley, Apex, and Jean on June 29 and 30. These plots show the air mass traveling at 10 m, 300 m, and 900 m for 36 hours beginning at 1200 PST, illustrating that smoke plumes from wildfires within and around Clark County were impacting the Las Vegas Valley. The back-trajectories demonstrate that the air mass and smoke plumes were swirling at ground level and higher-elevation trajectories for days, exacerbating ozone concentrations in Clark County.

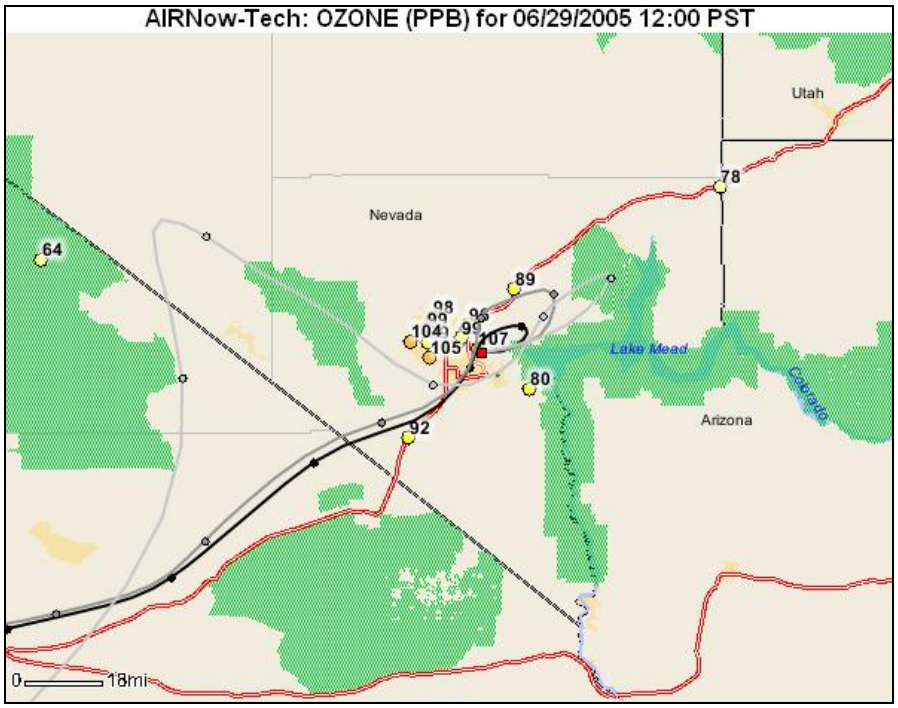


Figure 3-12. Trajectories for Las Vegas Valley at 1200 PST on 6/29/05.

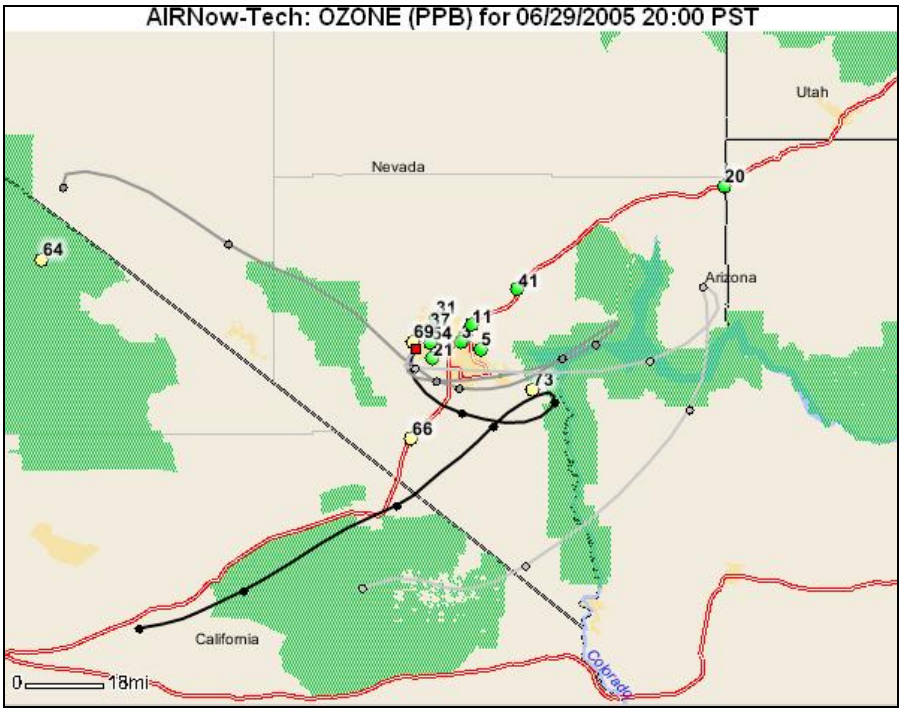


Figure 3-13. Trajectories for Las Vegas Valley at 2000 PST on 6/29/05.

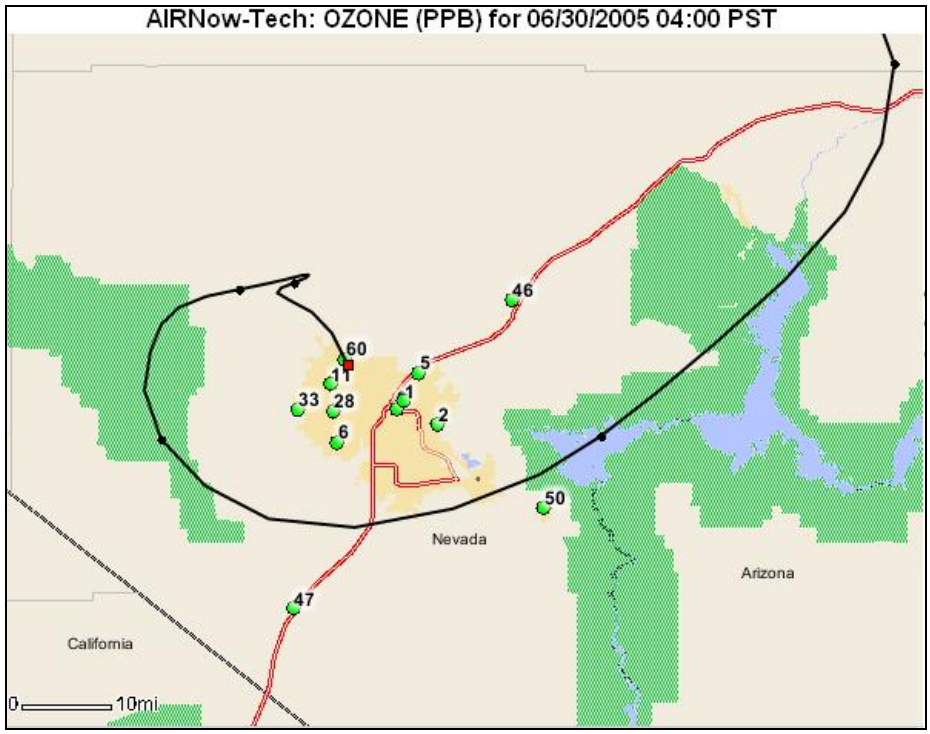


Figure 3-14. Trajectories for Las Vegas Valley at 0400 PST on 6/30/05.

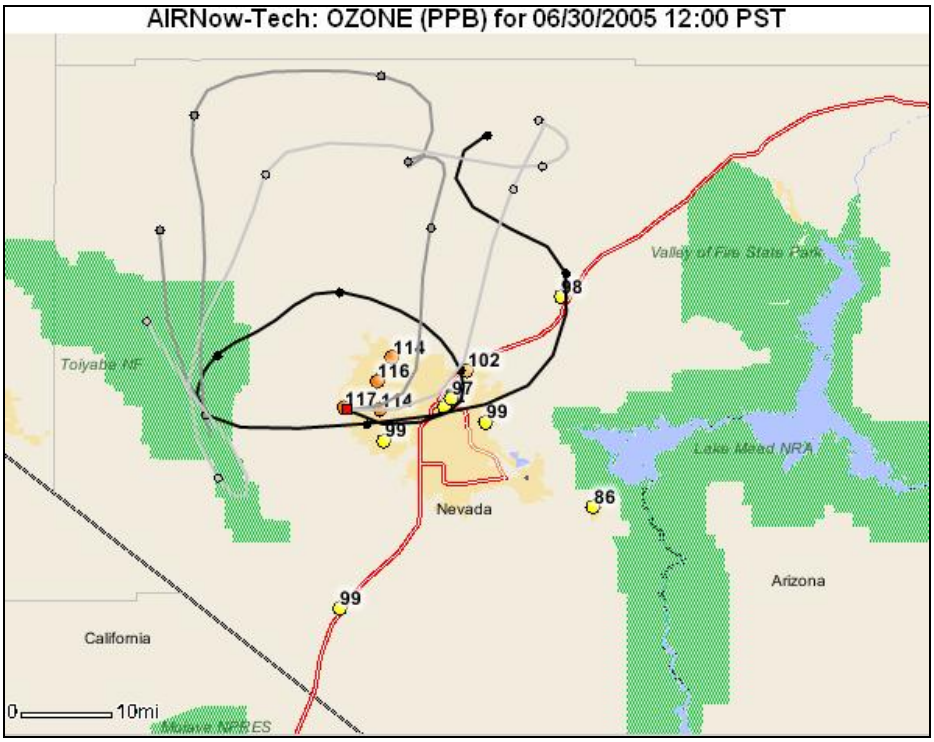


Figure 3-15. Trajectories for Las Vegas Valley at 1200 PST on 6/30/05.

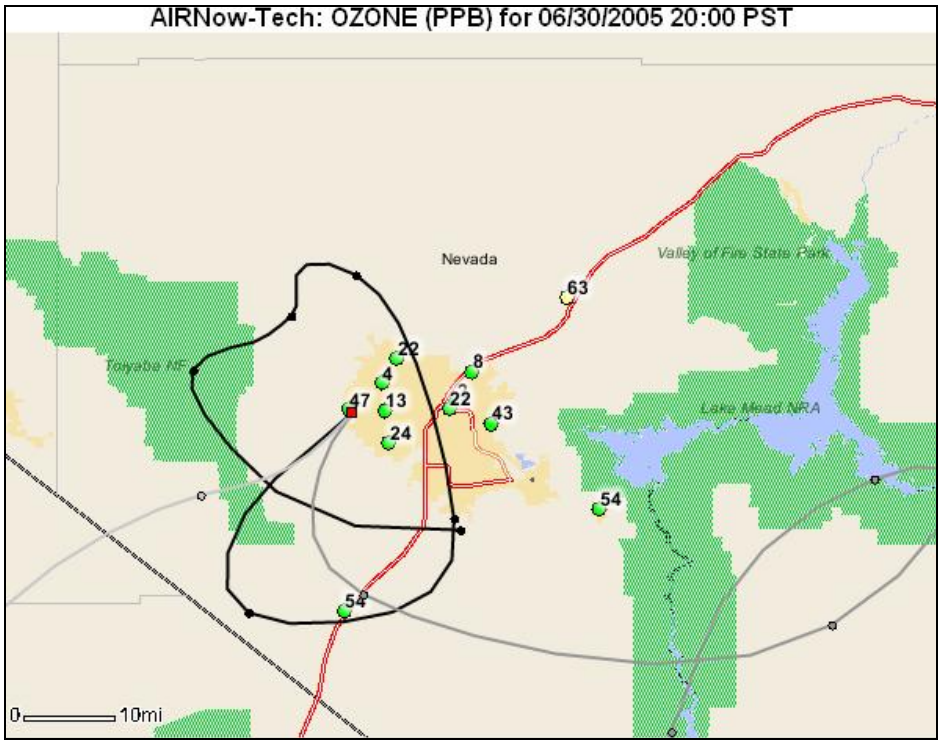


Figure 3-16. Trajectories for Las Vegas Valley at 20000 PST on 6/30/05.

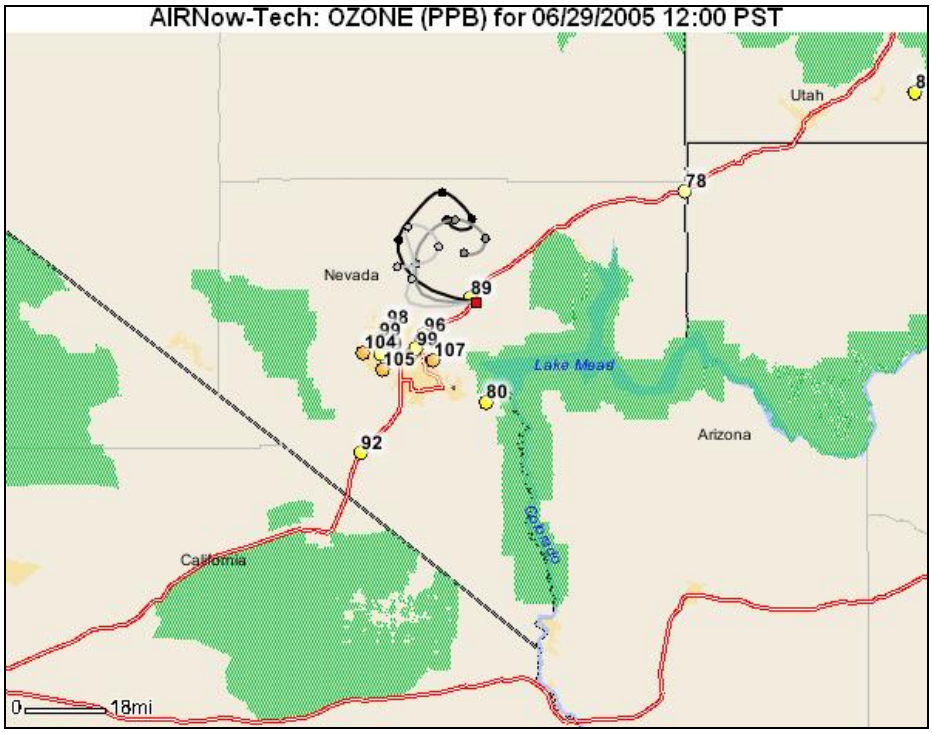


Figure 3-17. Trajectories for Apex at 1200 PST on 6/29/05.

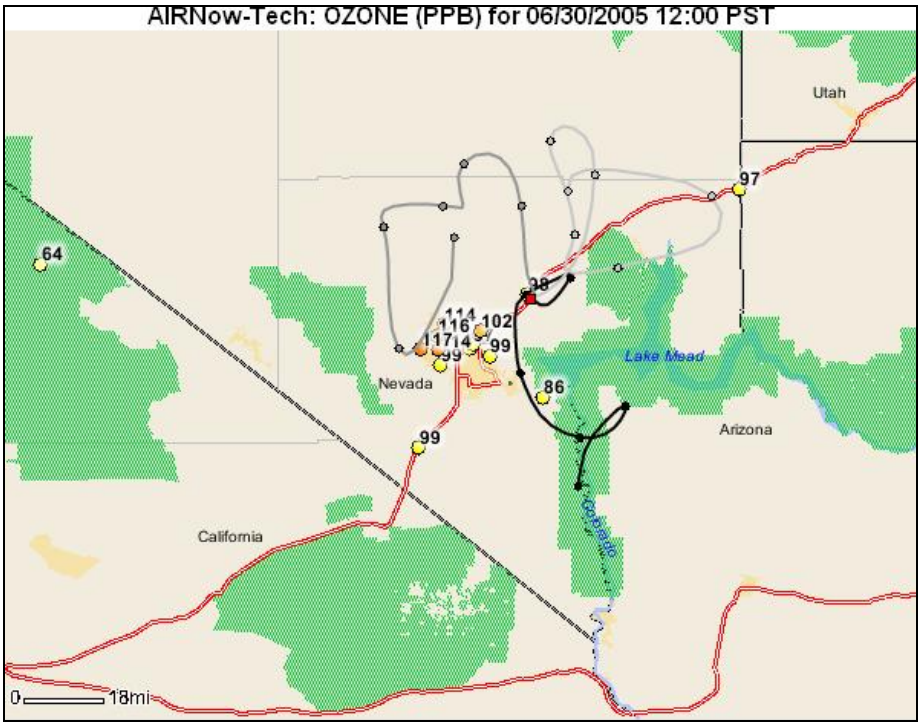


Figure 3-18. Trajectories for Apex at 1200 PST on 6/30/05.

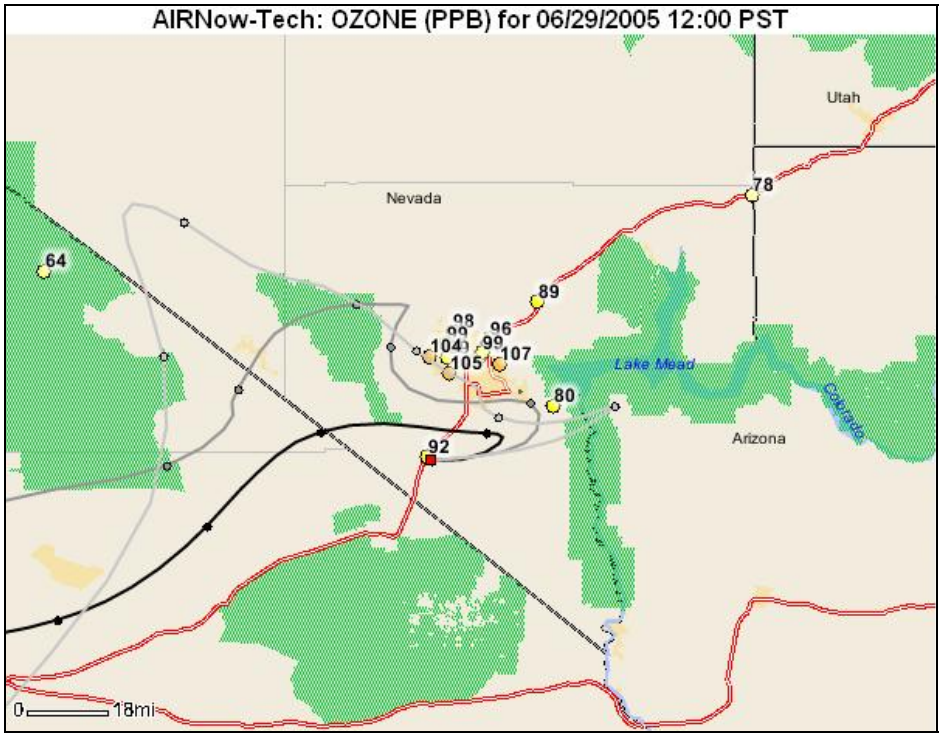


Figure 3-19. Trajectories for Jean at 1200 PST on 6/29/05.

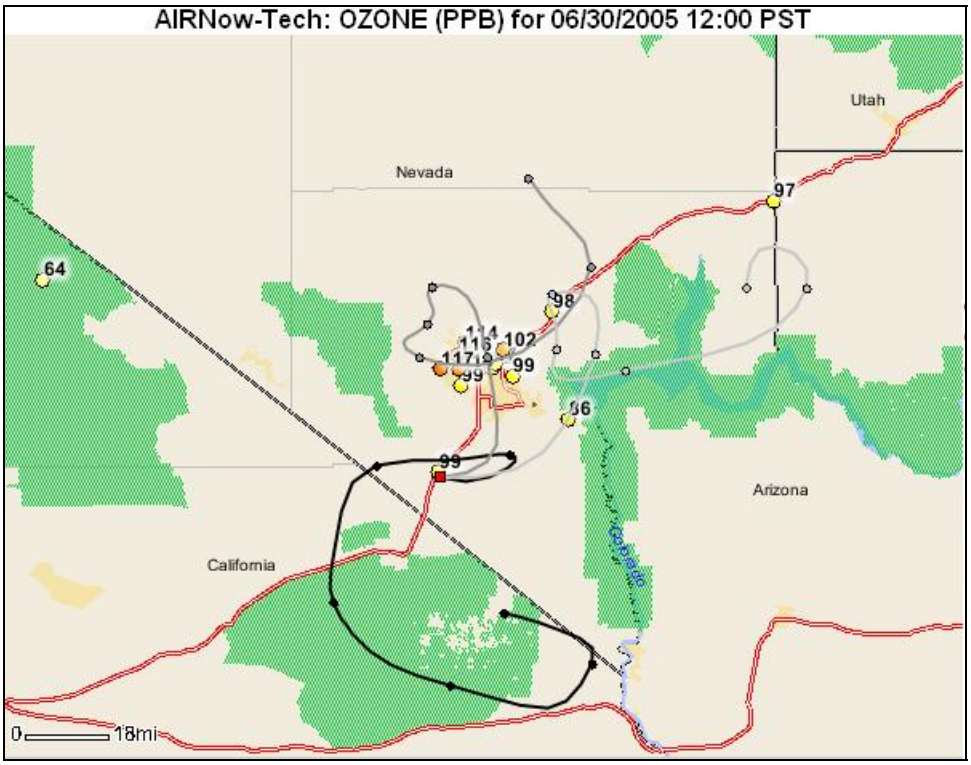


Figure 3-20. Trajectories for Jean at 1200 PST on 6/30/05.

3.2.4 Pollutant Concentrations and Wildfire Impacts

To further illustrate that ozone concentrations on June 29-30 were due to an exceptional event, concentrations of $PM_{2.5}$, CO, ozone, and associated meteorology were analyzed before, during, and after the event (6/27/05–7/2/05). Figure 3-21 depicts the relationship between ozone, $PM_{2.5}$, CO, and meteorological parameters—wind speed, humidity, and temperature—for June 27 through July 2. The graph demonstrates that high concentrations of pollutant levels sampled on June 29 and 30 were not due to meteorological variables or local emissions, since these remained relatively constant, but were related to smoke plumes from wildfires, i.e., the exceptional event.

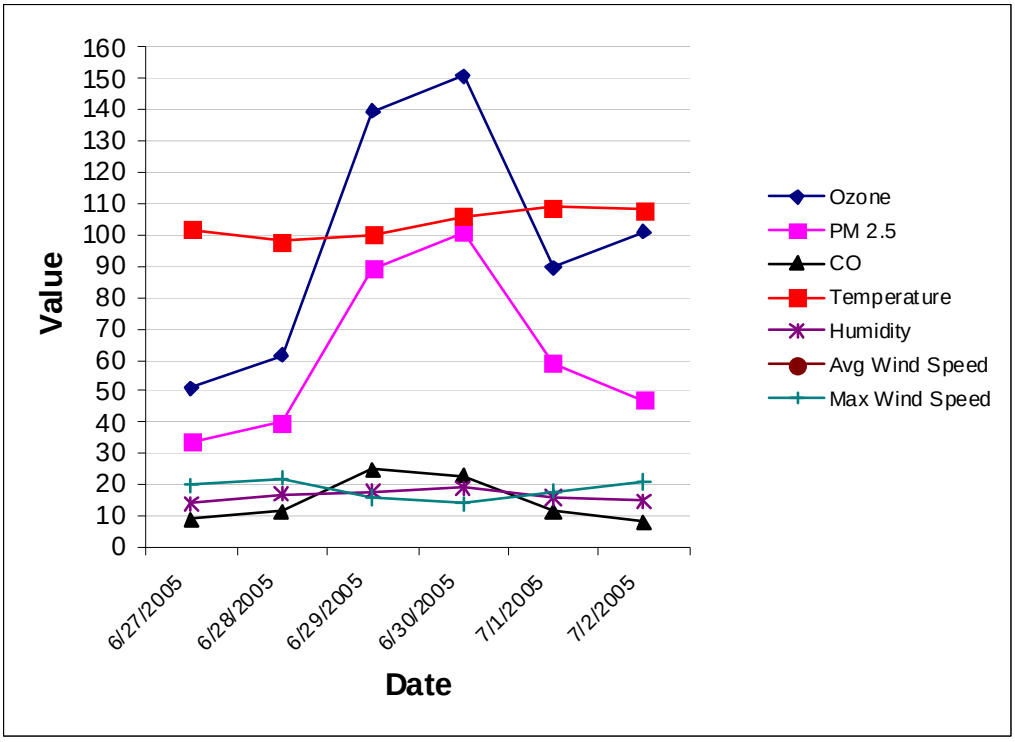


Figure 3-21. Weather Data and Corresponding Concentrations of O3, PM2.5, and CO for 6/27/05 through 7/2/05.

Figure 3-22 illustrates that high Air Quality Index (AQI) values for ozone, $PM_{2.5}$, and CO tracked well before, during, and after the exceptional event. All three pollutants were elevated on the wildfire days (June 29 and 30), providing strong evidence for contribution from wildfires, since these pollutants are the products of combustion. Through a weight-of-evidence approach, this report shows that ozone concentrations on these two dates would not have exceeded the NAAQS "but for" the wildfires.

Figure 3-23 depicts the typical diurnal pattern for ozone formation at the J.D. Smith, Palo Verde, and Winterwood monitoring sites. Ozone values climb in the morning, peak around noon, plateau through the afternoon, and recede in the early evening. The highest ozone concentration occurs during the most intense hours of sunlight, often referred to as the prime ozone cooking period. The highest hourly values occur on the wildfire intrusion days of June 29 and 30. Figures 3-24 through 3-26 depict the hourly data for each individual station during the same period.

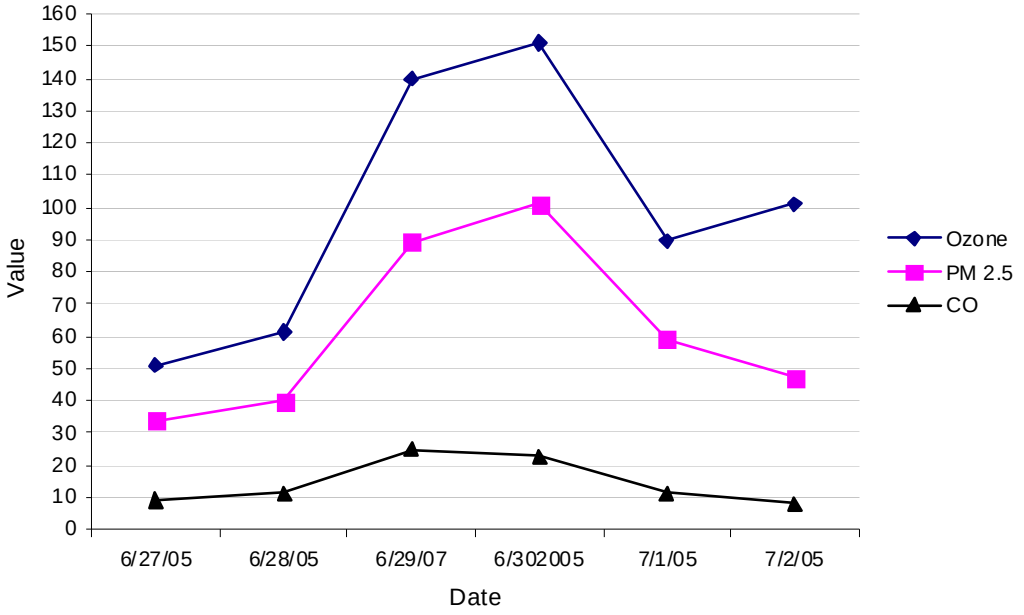


Figure 3-22. O_3, $PM_{2.5}$, and CO Data for 6/27/05 through 7/2/05.

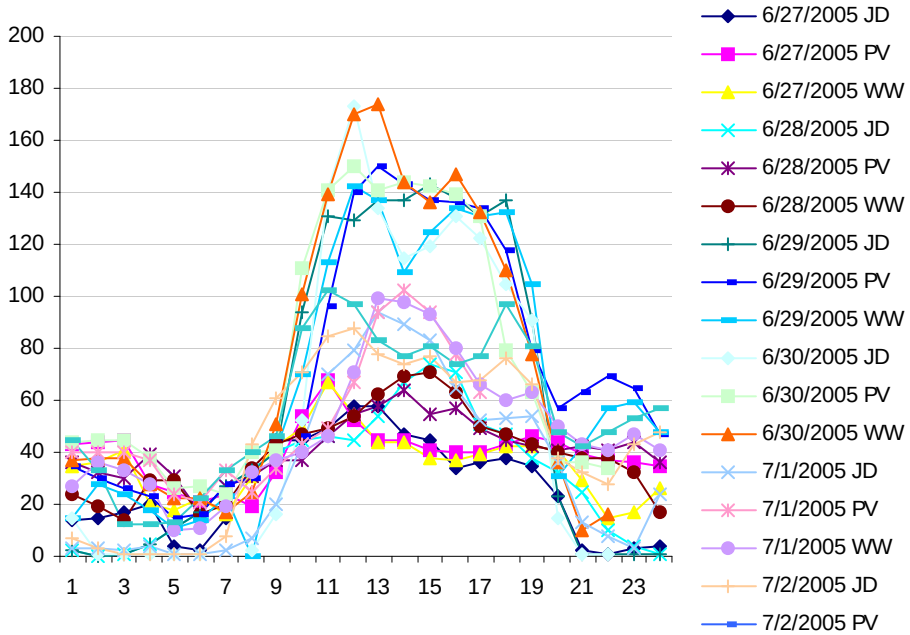


Figure 3-23. J.D. Smith, Palo Verde, and Winterwood Hourly Ozone AQI Values for 6/27/05 through 7/2/05.

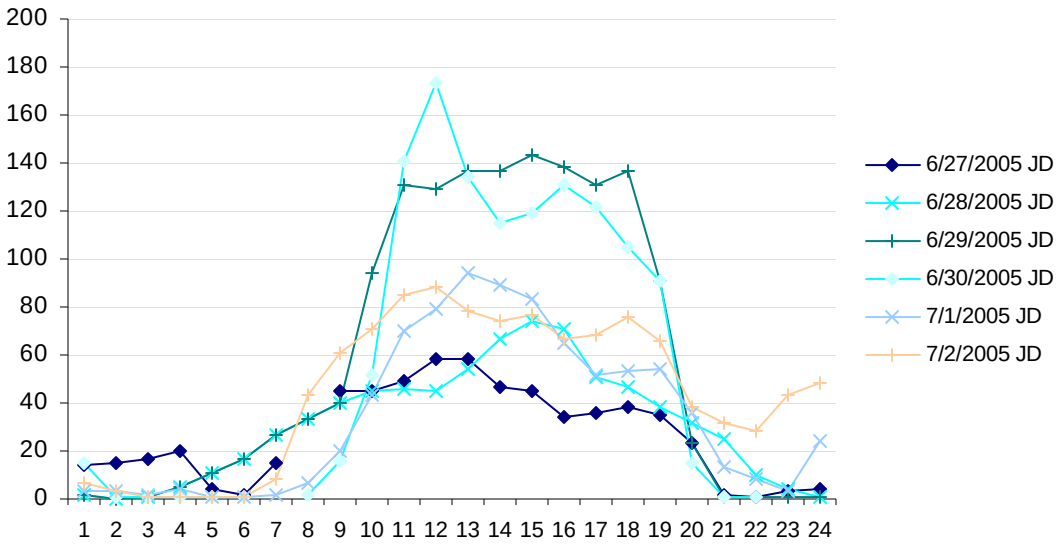


Figure 3-24. J.D. Smith Hourly Ozone AQI Values for 6/27/05 through 7/2/05.

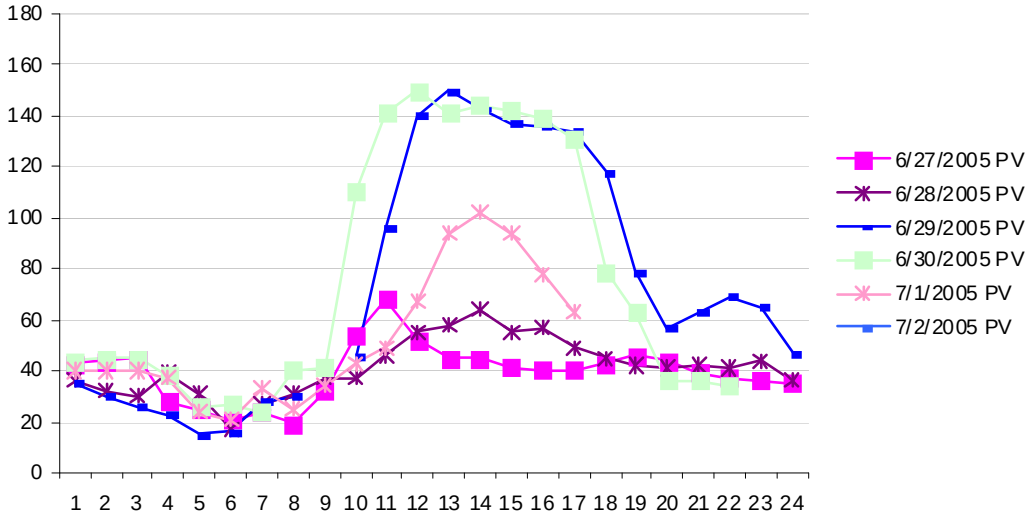


Figure 3-25. Palo Verde Hourly Ozone AQI Values for 6/27/05 through 7/2/05.

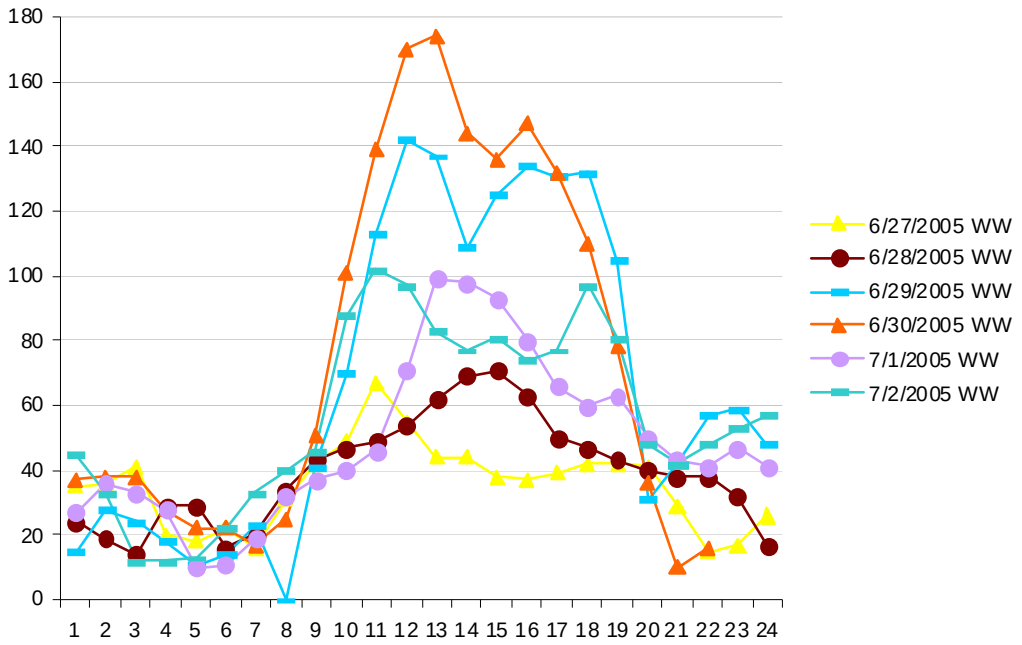


Figure 3-26. Winterwood Hourly Ozone AQI Values 6/27/05 through 7/2/05.

June 29 and 30 have substantially higher AQI values at each measured hour during the exceptional event than before and after. Only five hourly values at the three stations reached the AQI exceedance value of 100 on nonimpacted days; however, all hourly AQI values at all three stations were well above 100 during the prime ozone-cooking period on wildfire-impacted days.

Figures 3-27 through 3-33 illustrate the diurnal cycle for seven ozone monitoring sites from June 22 through July 7. Ozone concentrations begin to increase around June 23, when the Goodsprings fire started southwest of Las Vegas. Smoke plumes from wildfires in neighboring states were also beginning to impact southern Nevada. Ozone concentrations increased significantly on June 29 and 30, but returned to average (below NAAQS) concentrations beginning July 1.

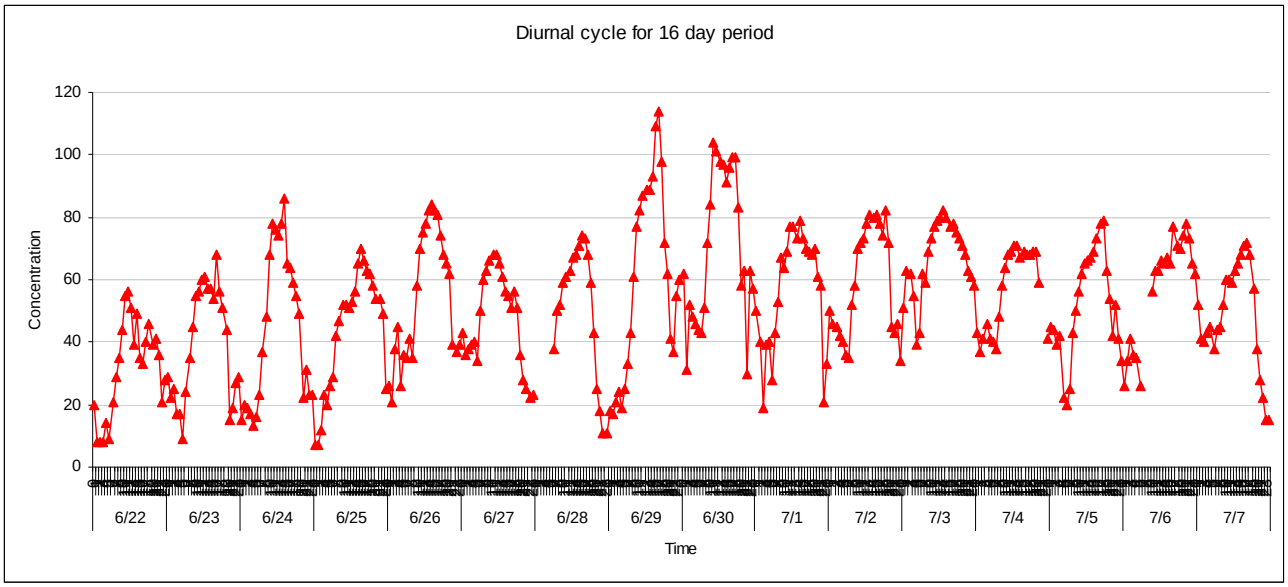


Figure 3-27. Diurnal Cycle for Apex.

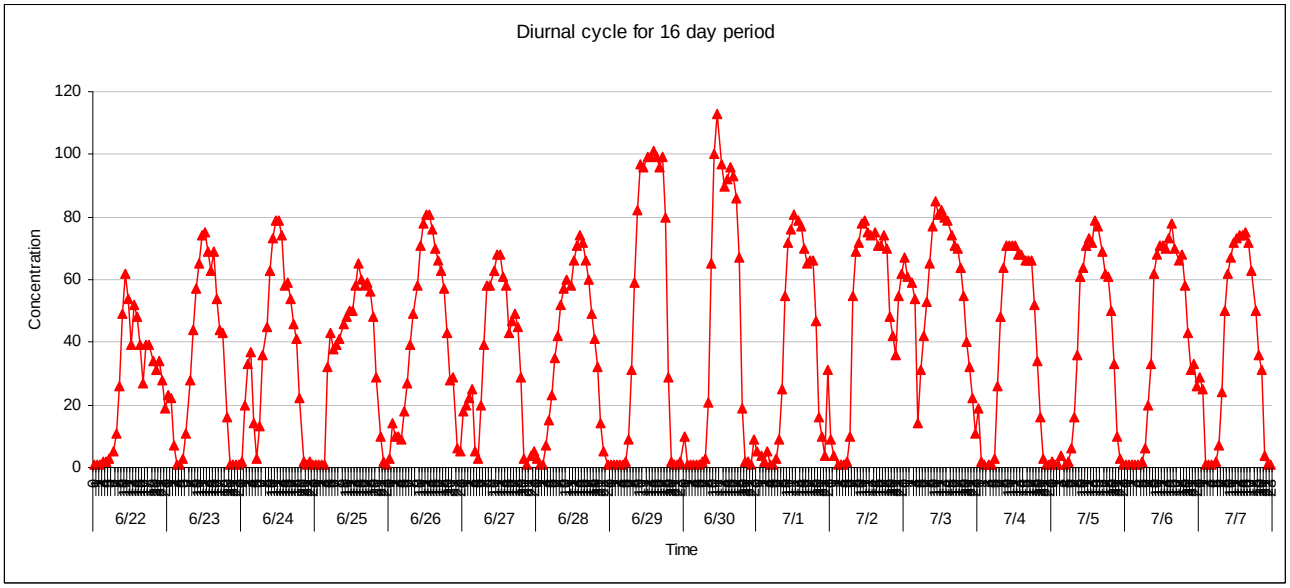


Figure 3-28. Diurnal Cycle for J.D. Smith.

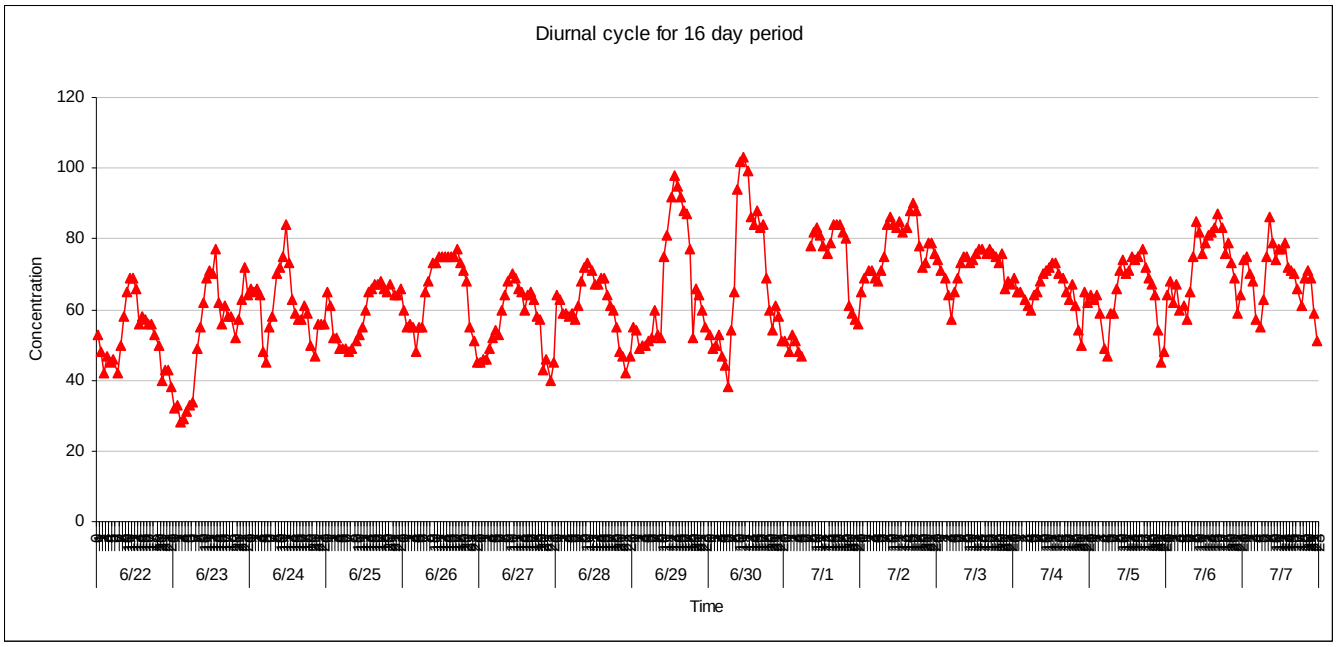


Figure 3-29. Diurnal Cycle for Jean.

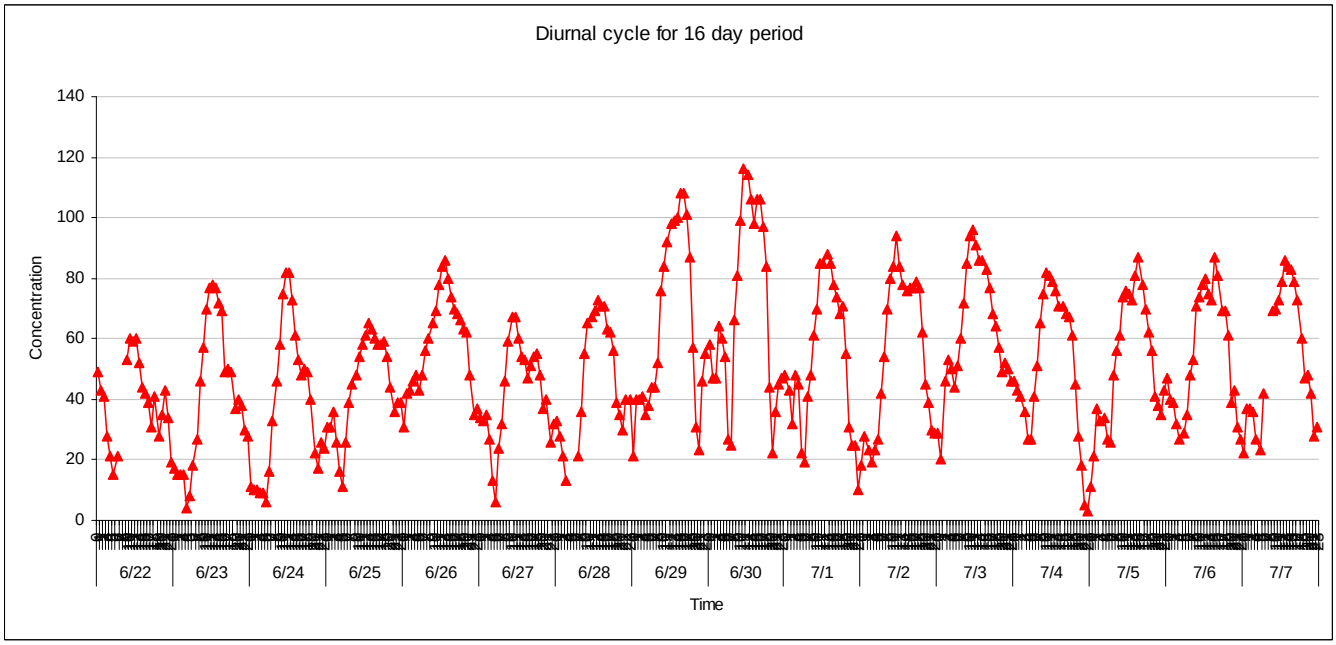


Figure 3-30. Diurnal Cycle for Joe Neal.

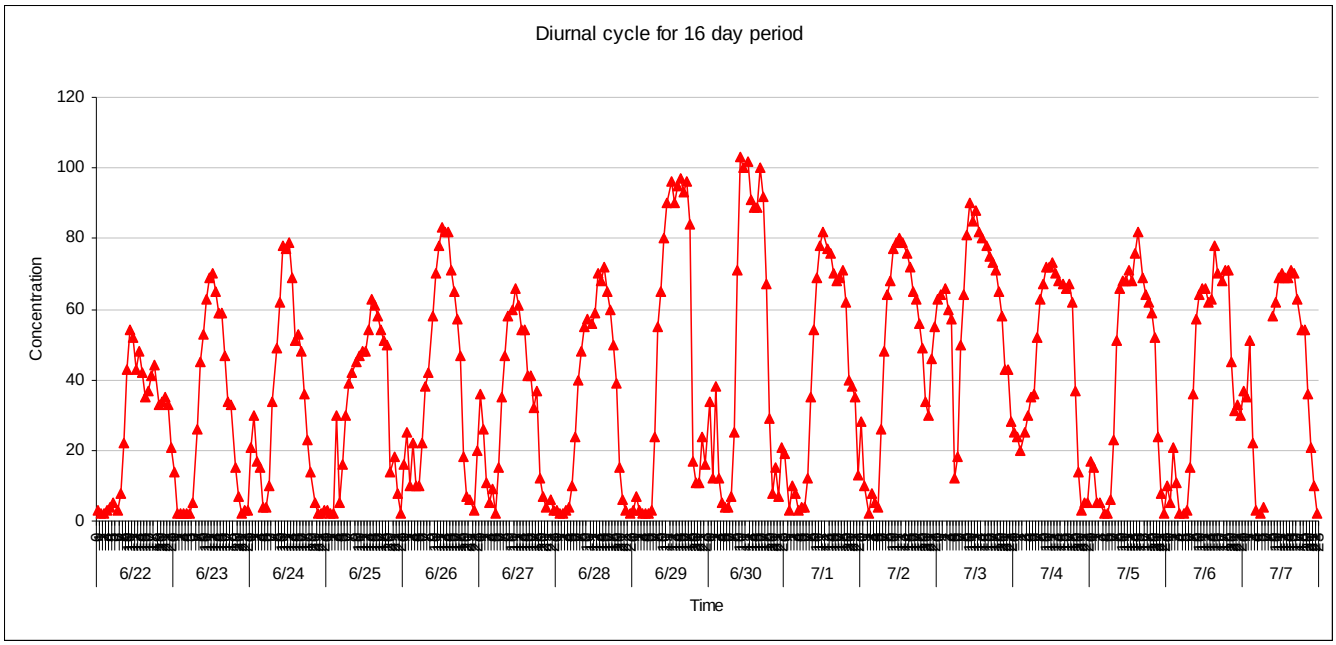


Figure 3-31. Diurnal Cycle for E. Craig Road.

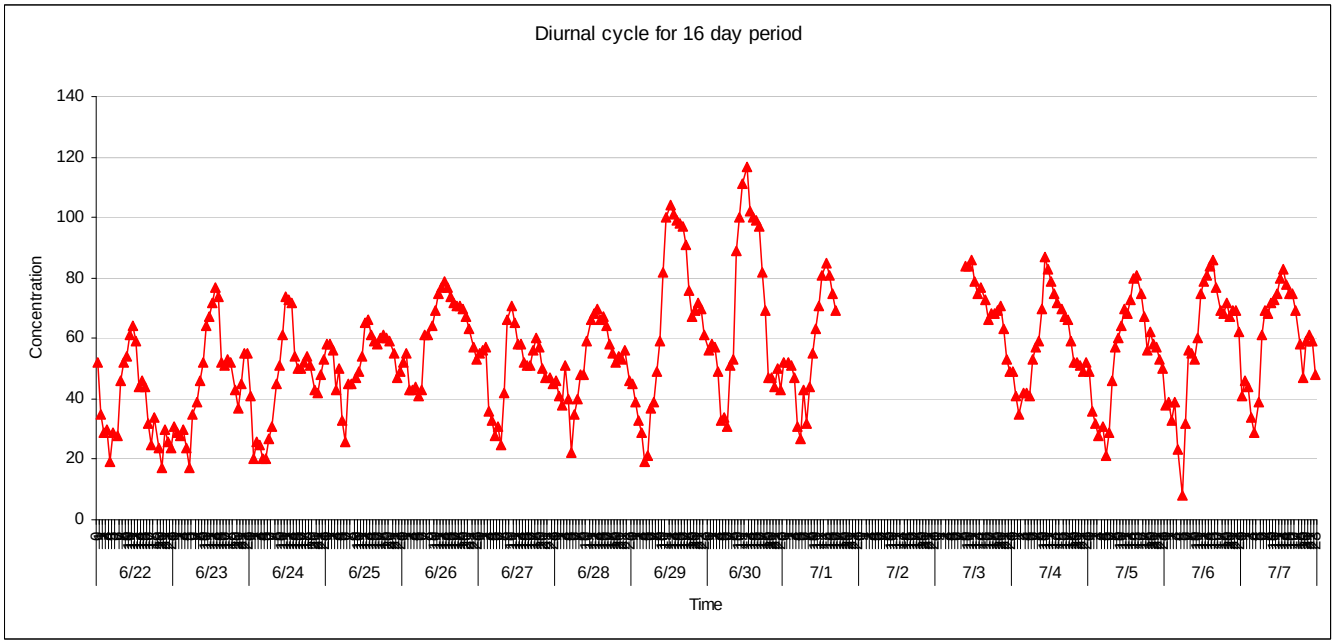


Figure 3-32. Diurnal Cycle for Palo Verde.

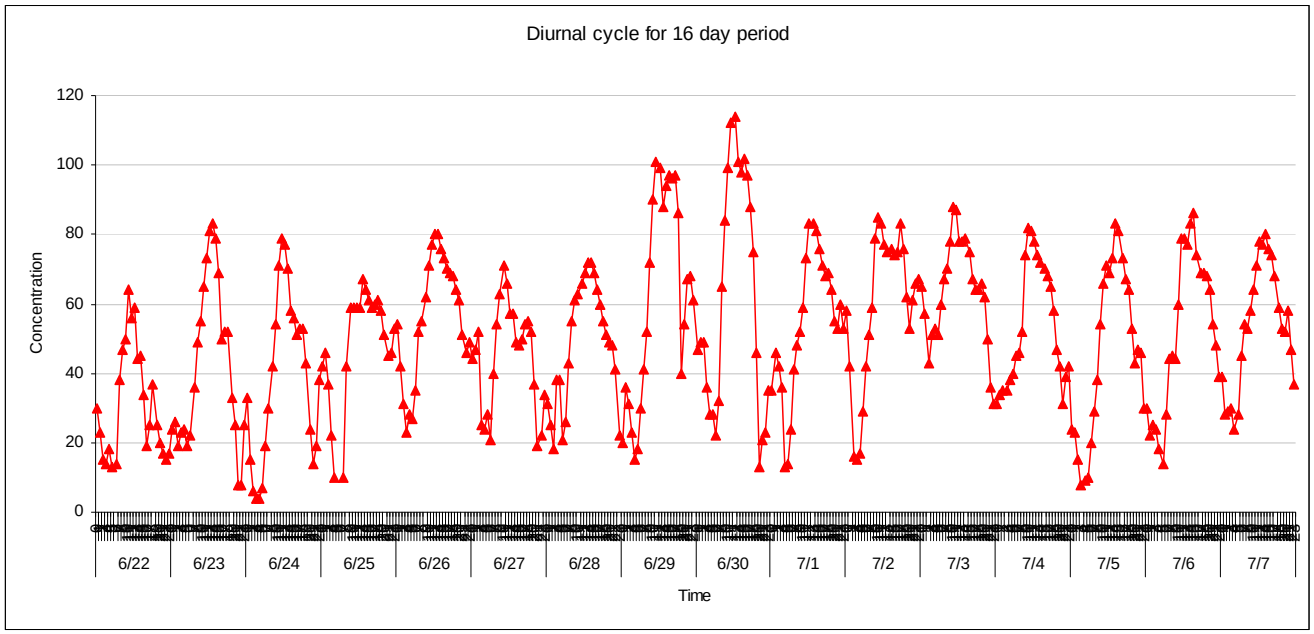


Figure 3-33. Diurnal Cycle for Walter Johnson.

Figure 3-34 shows the time series for $PM_{2.5}$ levels at the J.D. Smith and Palo Verde stations from June 27 to July 2. $PM_{2.5}$ values began to climb early on June 29, and remained high through the evening of June 30; the value receded at both stations on July 1.

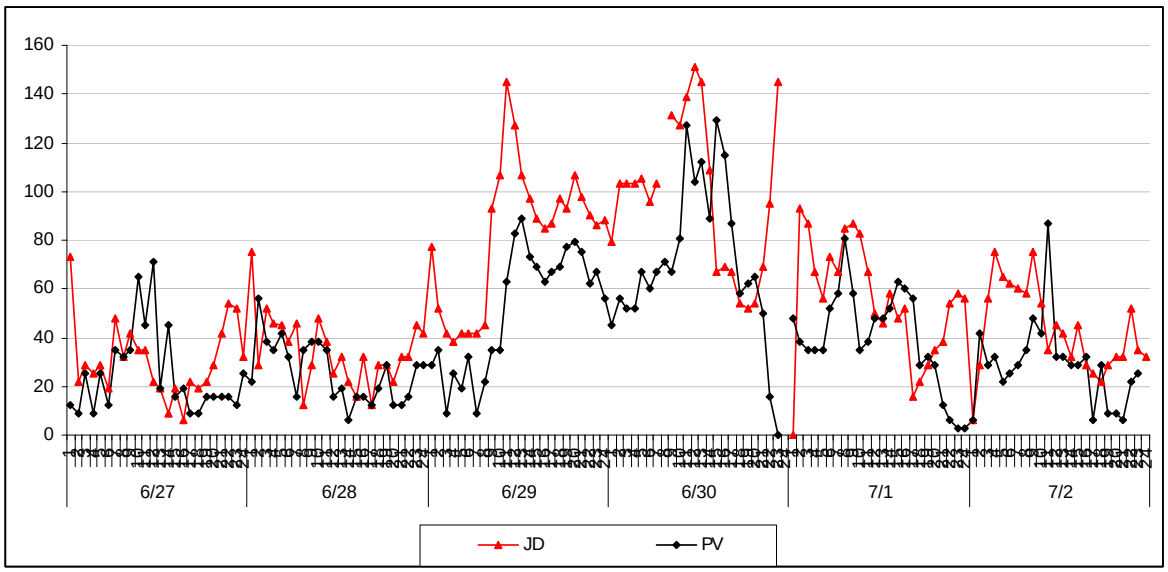


Figure 3-34. J.D. Smith and Palo Verde Hourly $PM_{2.5}$ AQI Values, 6/27/05 through 7/2/05.

Figure 3-35 includes the combined hourly CO data for the J.D Smith and Winterwood stations from June 27 to July 2. It depicts four distinctive peaks from June 29 through July 2: the typical diurnal patterns for CO caused by cooler temperatures and traffic commute patterns in the morning and evening are enhanced by early morning and late evening impacts from the wildfires. The highest hourly AQI values for both stations occur on the wildfire intrusion days of June 29 and 30. High levels were also recorded in the early morning of July 1, though the levels stayed lower

for the rest of the day. This probably marks the clearing out of wildfire emissions from the Las Vegas Valley, and is consistent with lower ozone and $PM_{2.5}$ levels on July 1 and 2.

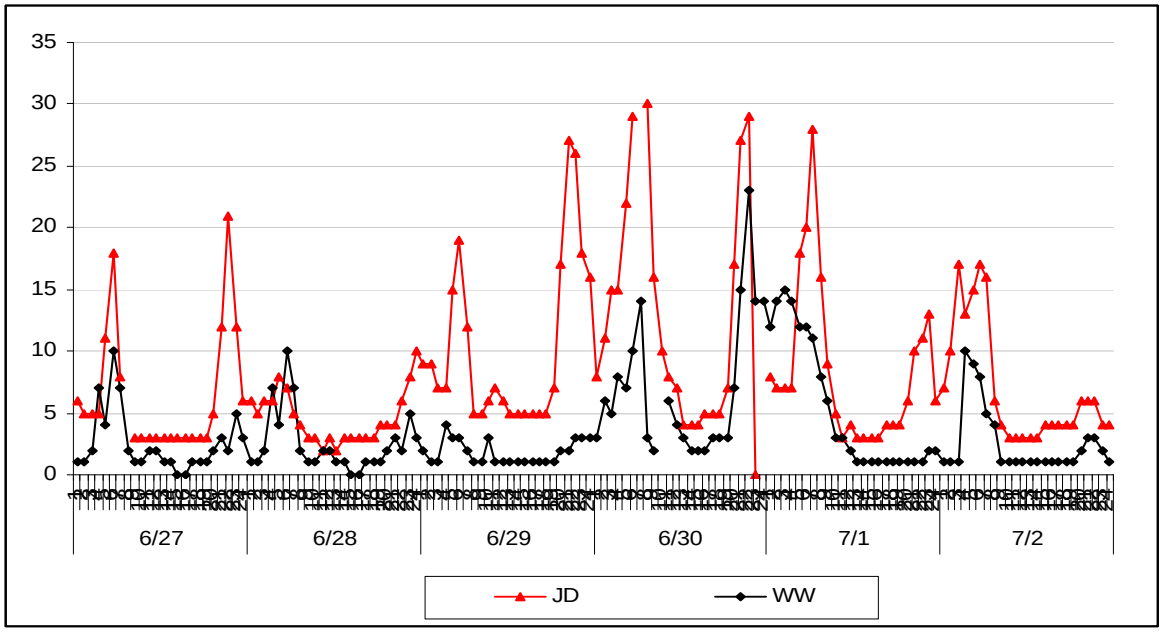


Figure 3-35. J.D. Smith and Winterwood Hourly CO AQI Values, 6/27/05 through 7/2/05.

Figure 3-36 shows the diurnal cycle and correlations for O_3, $PM_{2.5}$, and CO. Ozone and $PM_{2.5}$ correlate very well; CO levels show the impacts from morning and afternoon traffic in Las Vegas, but the concentrations are elevated during the late evening and early morning.

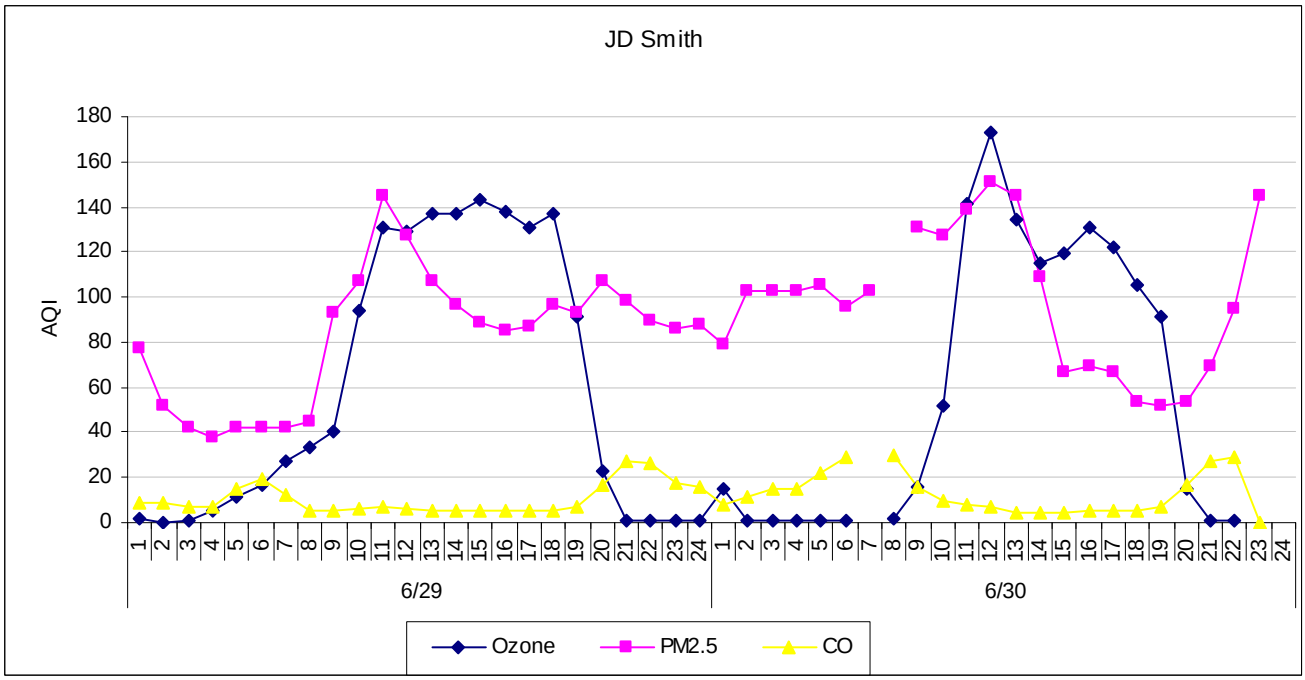


Figure 3-36. Diurnal Cycle for O_3, $PM_{2.5}$, and CO at J.D. Smith.

Figures 3-37 through 3-39 depict the relationships between hourly values of $PM_{2.5}$ and O_3 over a four-day period: the day before the event, the two days of the event, and the day after the event. The data show elevated O_3 and $PM_{2.5}$ concentrations during the wildfire days, and lower concentrations on the days before and after the fires.

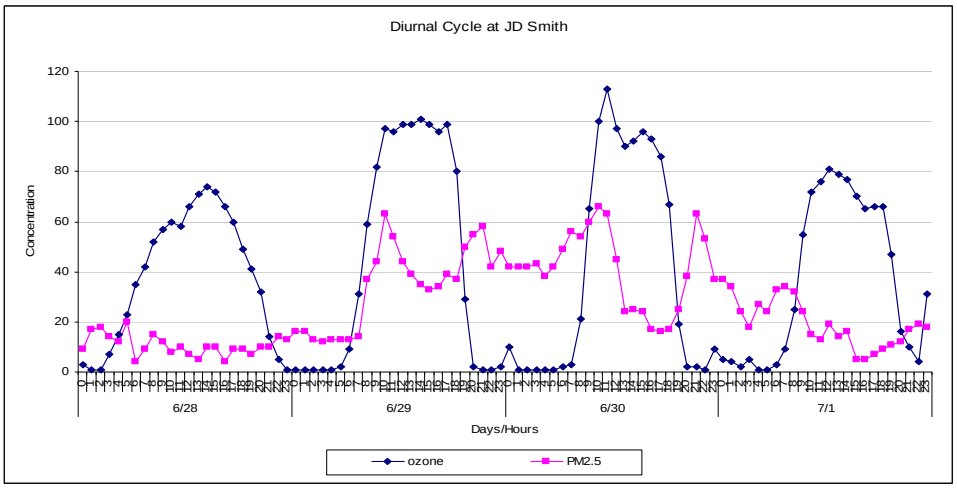


Figure 3-37. Diurnal Cycle at J.D. Smith.

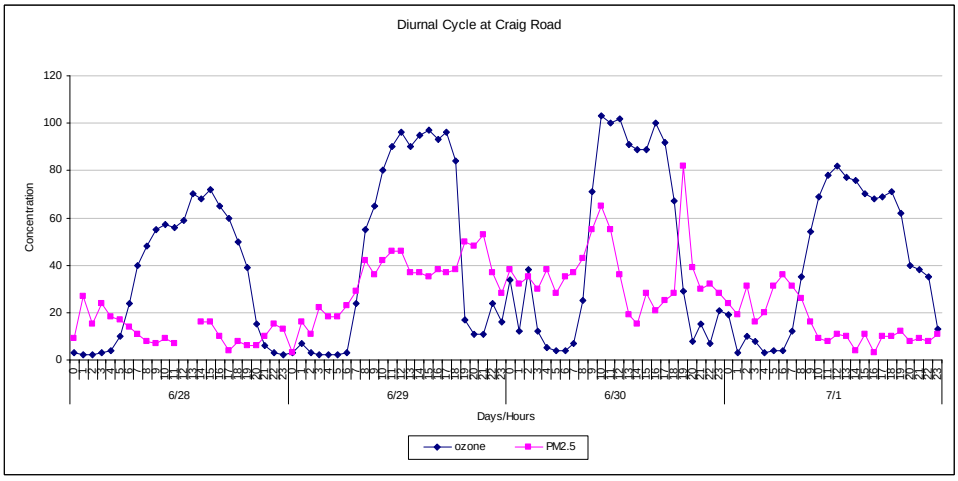


Figure 3-38. Diurnal Cycle at E. Craig Road.

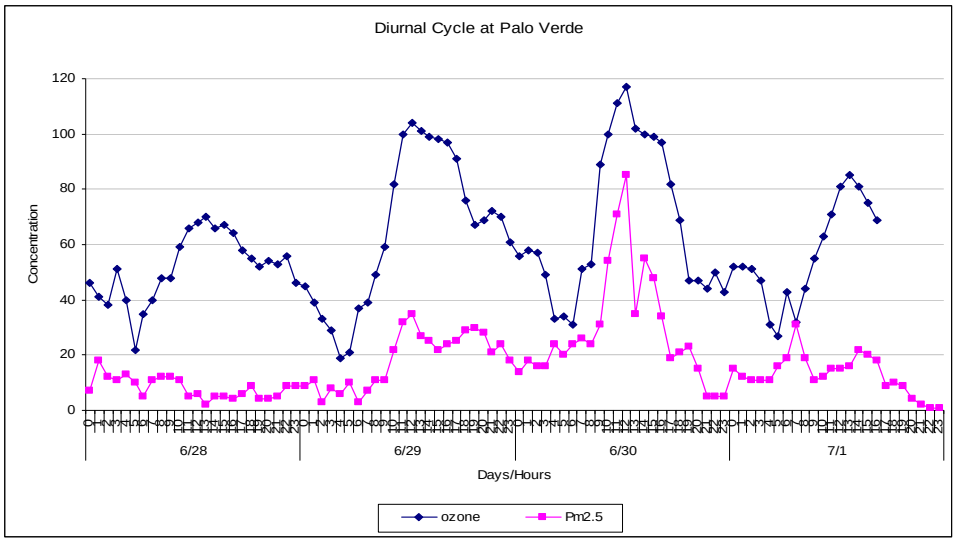


Figure 3-39. Diurnal Cycle at Palo Verde.

Table 3-5 lists AQI values for O_3, CO, and $PM_{2.5}$ between June 22 and July 7, 2005. Figure 3-40 shows the increase in pollutant concentrations during wildfire days, and Figure 3-41 demonstrates how well the AQI values for ozone**,** $PM_{2.5}$ and CO tracked wildfire impacts. Concentrations of the three pollutants were elevated on wildfire days, providing strong evidence of contributions from the wildfires. The average concentration of O_3 during the two fire days increased by 91 percent; concentrations of CO and $PM_{2.5}$ increased by 75 percent and 61 percent, respectively. The correlation between O_3 and CO is 0.75 for June 28 through July 1. Similarly, there is a 0.99 correlation between O_3 and $PM_{2.5}$ and a 0.79 correlation between CO and $PM_{2.5}$ for the same period.

Table 3-5. Pollutant AQI Values

Date	O_3	CO	$PM_{2.5}$
6/22	48	14	70
6/23	61	14	59
6/24	72	15	72
6/25	54	17	35
6/26	85	10	29
6/27	51	10	33
6/28	61	10	34
6/29	140	20	89
6/30	151	27	100
7/1	92	24	59
7/2	101	14	47
7/3	106	9	49
7/4	79	13	113
7/5	79	14	111
7/6	92	13	57
7/7	85	11	56

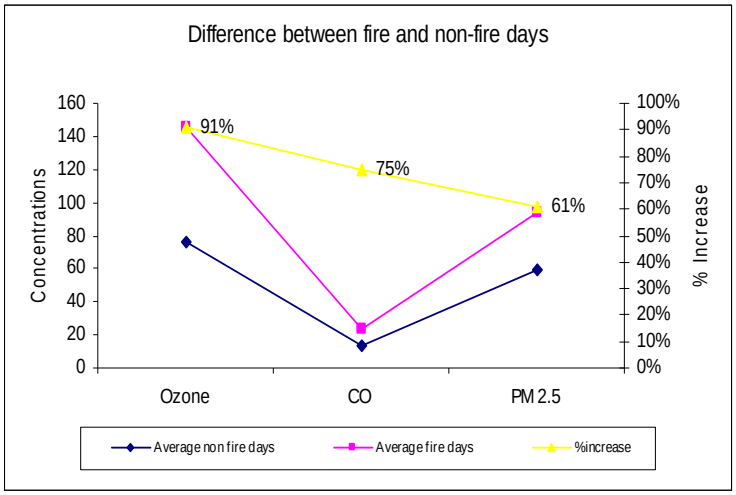


Figure 3-40. Fire and Nonfire Days.

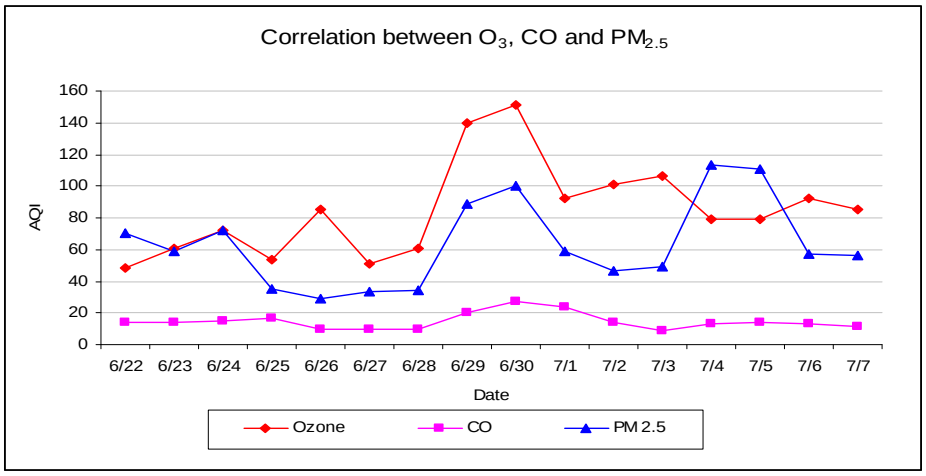


Figure 3-41. Correlation for 6/22/05 through 7/7/05.

3.3 OZONE CONCENTRATIONS RELATIVE TO HISTORICAL FLUCTUATIONS

In the preamble to the final EER, EPA states that the magnitude of measured concentrations on days affected by an exceptional event relative to historical, temporally adjusted air quality levels can guide the level of analysis and documentation needed to demonstrate that the event affected air quality. For example, EPA acknowledges that for extremely high concentrations relative to historical values (e.g., concentrations greater than the 95th percentile), less documentation or evidence may be required to demonstrate that the event affected air quality. This "weight of evidence" approach reflects how the EPA has historically treated exceptional events.

In Figures 3-40 and 3-41, the AQI is used to display the relationships between different pollutants. In the following text and figures, the highest AQI value for a specific pollutant is considered the AQI value for that day. Figure 3-42 contains the legend for a typical AQI, which is used for public outreach.

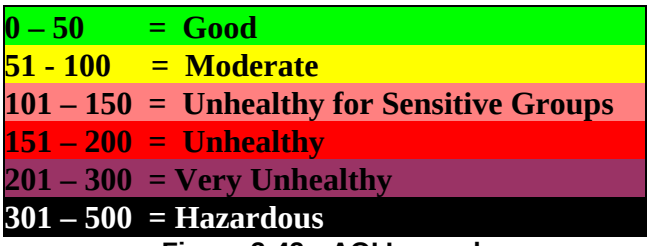


Figure 3-42. AQI Legend.

On June 29 and 30, smoke plumes from wildfires resulted in the highest ozone readings for the season throughout the Clark County air quality monitoring network. Concentrations ranged from 83 to 105 ppb. The National Weather Service reported 7 miles of visibility, down from the normal 70 miles for a summer day in the Las Vegas Valley. All Clark County monitoring sites recorded violations of the NAAQS during these two days, and ozone concentrations were the highest ever recorded at all stations. Table 3-6 shows wildfire impacts on ozone during this exceptional event. Smoke plumes also exacerbated ozone concentrations on July 18, but the impact was not nearly as severe as on June 29 and 30.

Table 3-6. Ozone Levels on Wildfire Impact Days in 2005

Station Name	Rank and Date of Reading							
	1st High	Date	2nd High	Date	3rd High	Date	4th High	Date
S.E. Valley	0.087	6/30/05	0.086	6/29/05	0.080	7/17/05	0.077	7/8/05
E. Craig Road	0.095	6/30/05	0.092	6/29/05	0.083	7/16/05	0.083	6/12/05
Apex	0.098	6/30/05	0.095	6/29/05	0.079	7/16/05	0.078	7/3/05
Mesquite	0.092	6/30/05	0.082	6/29/05	0.075	6/1/05	0.072	6/2/05
Paul Meyer	0.100	6/30/05	0.096	6/29/05	0.080	6/12/05	0.080	6/13/05
Walter Johnson	0.101	6/30/05	0.095	6/29/05	0.089	7/18/05	0.088	6/12/05
Lone Mountain	0.105	6/30/05	0.097	6/29/05	0.095	7/18/05	0.089	6/12/05
Palo Verde	0.101	6/30/05	0.096	6/29/05	0.088	6/12/05	0.088	7/18/05
Joe Neal	0.105	6/30/05	0.099	6/29/05	0.091	7/18/05	0.087	7/3/05
Winterwood	0.100	6/29/05	0.094	6/30/05	0.079	7/17/05	0.079	7/3/05
Boulder City	0.084	6/29/05	0.083	6/30/05	0.079	7/17/05	0.078	6/1/05
Jean	0.092	6/30/05	0.088	6/29/05	0.085	7/2/05	0.083	7/8/05
J.D. Smith	0.098	6/29/05	0.095	6/30/05	0.087	7/18/05	0.082	7/16/05
	= Wildfire Impact Day							

CO and $PM_{2.5}$ were also abnormally high on June 29 and 30. $PM_{2.5}$ concentrations were in the high moderate range on June 29, and exceeded the NAAQS on June 30. CO remained in the good range, but was more than twice as high as normal. Table 3-7 lists AQI values for ozone, $PM_{2.5}$, and CO, with associated meteorology, for June 27 through July 2.

Table 3-7. O_3, $PM_{2.5}$, CO, and Weather Data for 6/27/05 to 7/2/05

Date	Ozone AQI	$PM_{2.5}$ AQI	CO AQI	Max. Temp (°F)	Max. Humidity (%)	Avg. Wind Speed (mph)	Max. Wind Speed (mph)
6/27/05	51	34	9	102	14	10	20
6/28/05	61	40	11	98	17	10	22
6/29/05	140	89	25	100	18	6	16
6/30/05	151	101	23	106	19	5	14
7/1/05	90	59	11	109	16	6	18
7/2/05	101	47	8	108	15	10	21

Ozone concentrations recorded during the wildfire event on June 29-30, 2005, were compared with temporally adjusted (June–August) air quality levels for the previous five years (2001-2005). A five-year historical analysis was considered reasonable because attainment/non-attainment classifications are based on a three-year average, so ozone concentrations before 2001 would not reflect emission control programs implemented recently. Table 3-8 illustrates the results of that analysis, showing that ozone concentrations on June 29-30 were at the 99th percentile relative to the previous five years. Levels that high across the entire air quality monitoring network offer a cogent argument for the role played by wildfire smoke plumes in exacerbating ozone concentrations.

Table 3-8. 2005 8-hr Standard Exceedance Days—All Sites

Date	95%	99%	6/12	6/29	6/30	7/2	7/3	7/8	7/15	7/18	8/6
Apex	76	82	76	95	98	78	78	77	72	77	64
Boulder City	74	81	72	84	83	73	75	72	64	74	66
City Center	68	81	79	87	81	62	69	62	65	82	69
Craig Rd	76	83	83	92	95	74	82	77	74	82	73
JD Smith	76	85	82	98	95	74	78	78	73	87	75
Jean	81	87	79	88	92	85	76	83	67	72	66
Joe Neal	84	92	42	99	105	81	87	86	85	91	
Lone Mt	82	89	89	97	105	81	82	82	86	95	86
Mesquite	70	76	62	82	92	67	70	61	56	62	60
Henderson	75	80	73	86	87	77	76	77	67	71	70
Paul Meyer	78	84	80	96	100	76	76	79	76	80	76
Palo Verde	80	88	88	96	101	81	78	80	86	88	82
W Johnson	80	88	88	95	101	78	79	79	84	89	85
Winterwood	76	83	77	100	94	77	79	76	66	75	67
>84.9999			3	12	11	1	1	1	3	5	2
	>95 percentile										
	>99 percentile										
Note: Percentiles are for June-August 2001-2005 (5 years, temporally adjusted).											

The following technical analyses, combined with documentation on the location and extent of wildfires and laboratory analysis of $PM_{2.5}$ samples showing high concentrations of wildfire markers on June 29 and 30, 2005, demonstrate that elevated concentrations of ozone on these two dates are exceptional relative to historical fluctuations and were caused by wildfire impacts.

Figures 3-43 through 3-51 depict five years of ozone data from nine ozone monitoring sites in Clark County, and show that concentrations on June 29 and 30 reflect an exceptional event. Wildfires are common in the Southwest, and elevated ozone concentrations in 2003 were caused in part by smoke plume impacts from wildfires. Calendar year 2004 was quiet with respect to wildfires, so the ozone data for that year reflect significantly lower concentrations compared to other years.

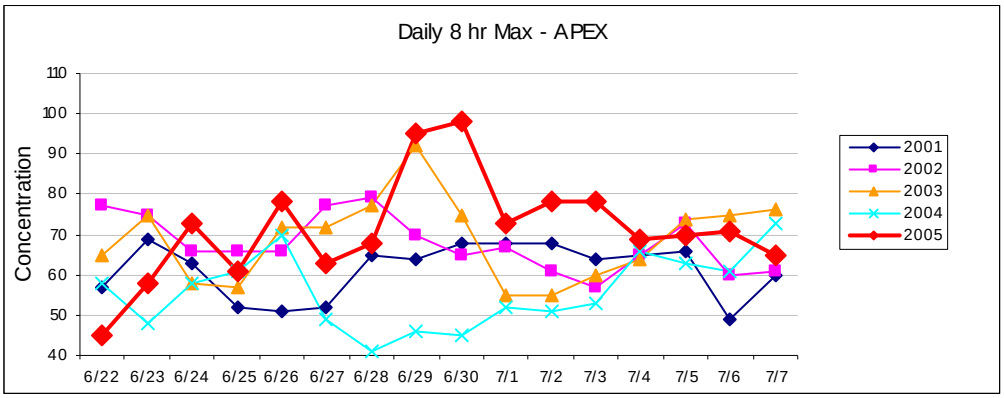


Figure 3-43. Four-Year Comparison for Apex.

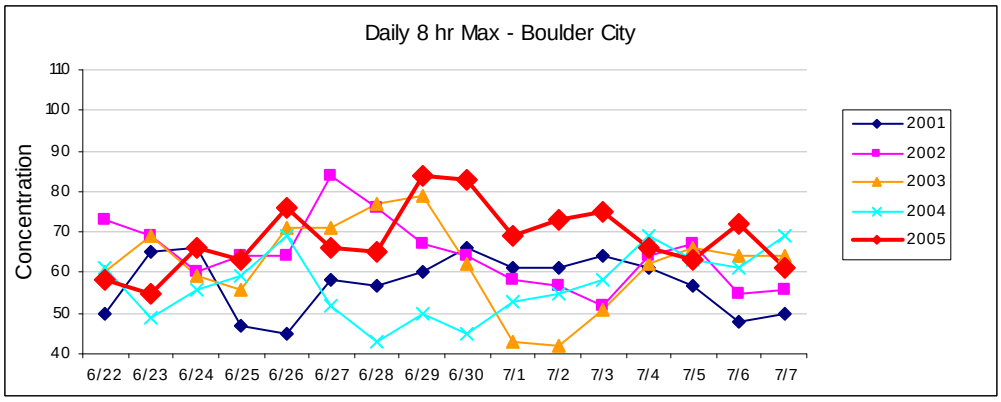


Figure 3-44. Four-Year Comparison for Boulder City.

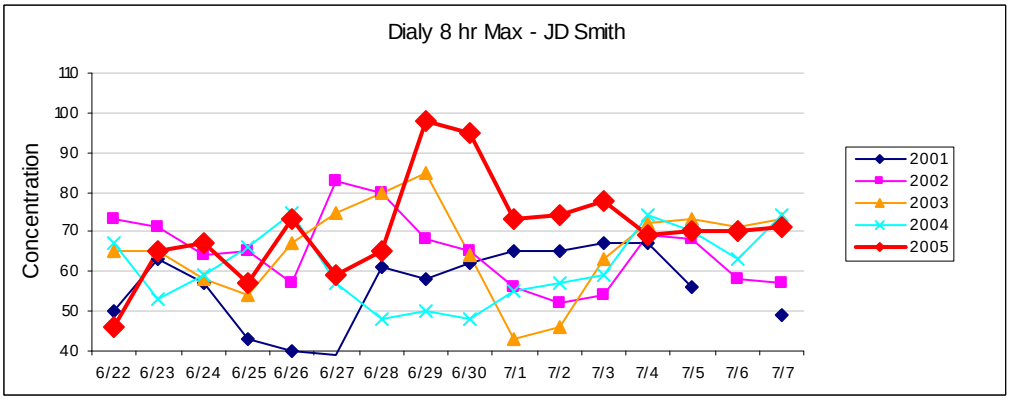


Figure 3-45. Four-Year Comparison for J.D. Smith.

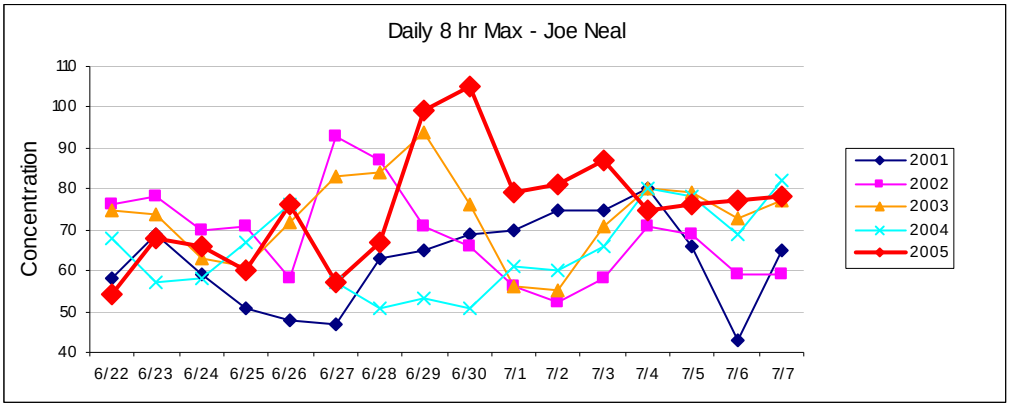


Figure 3-46. Four-Year Comparison for Joe Neal.

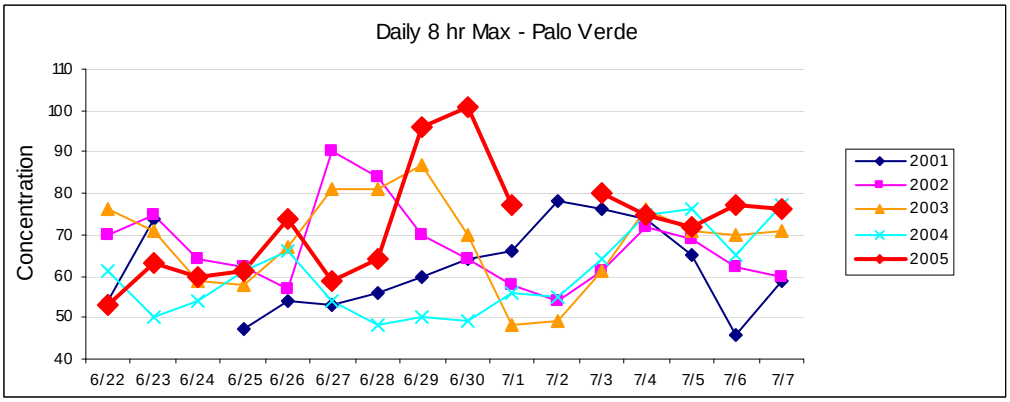


Figure 3-47. Four-Year Comparison for Palo Verde.

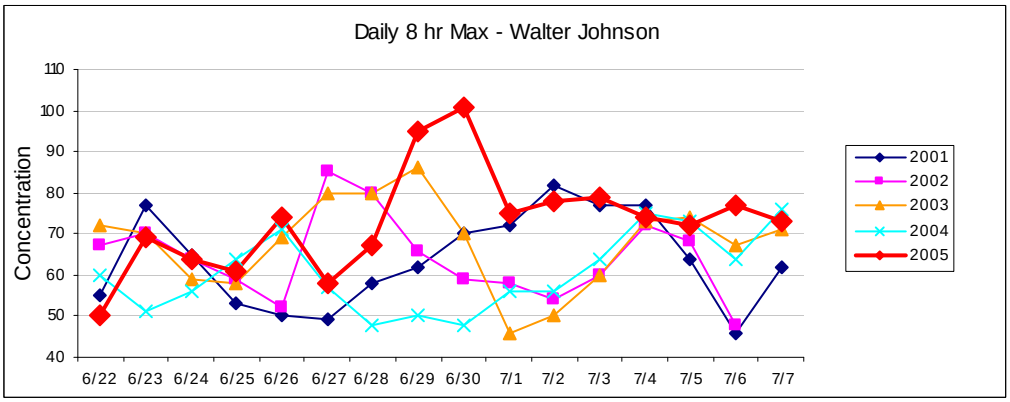


Figure 3-48. Four-Year Comparison for Walter Johnson.

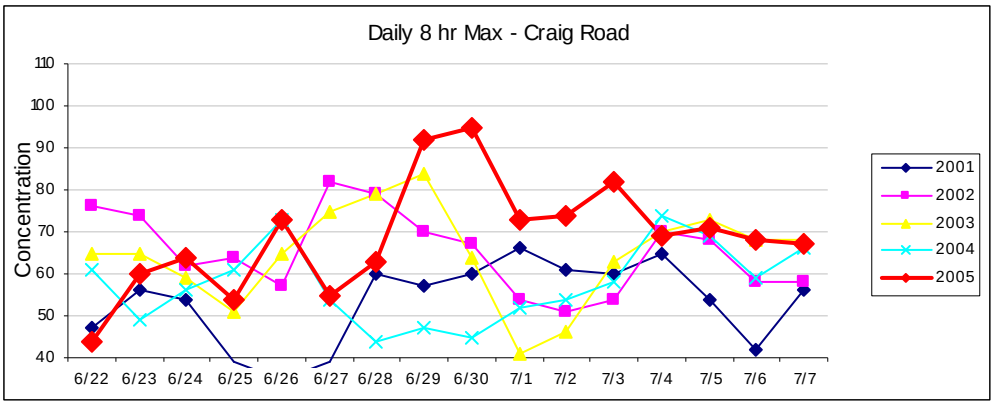


Figure 3-49. Four-Year Comparison for E. Craig Road.

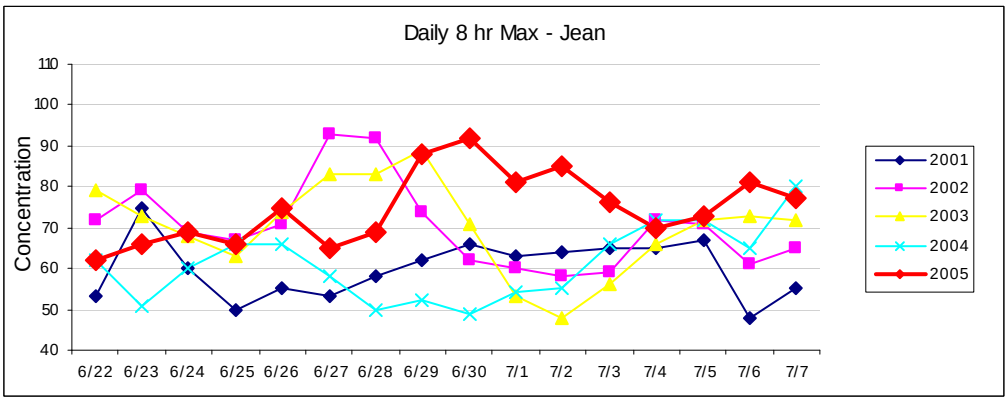


Figure 3-50. Four-Year Comparison for Jean.

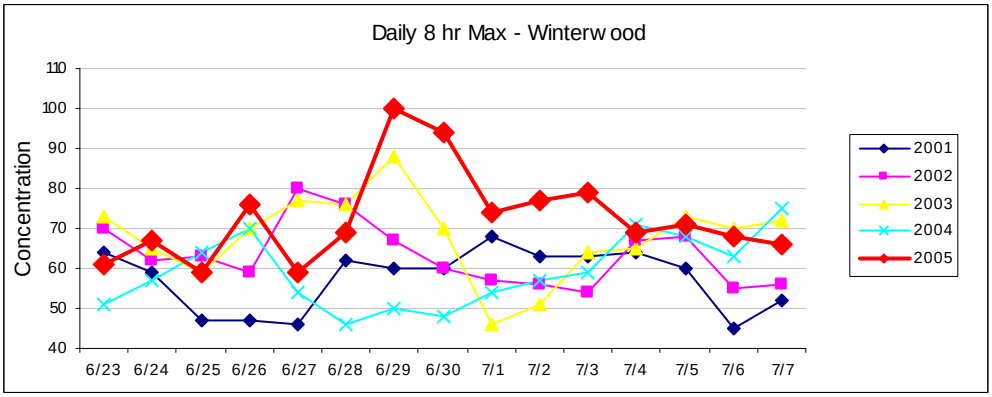


Figure 3-51. Four-Year Comparison for Winterwood.

For a statistical perspective, average ozone concentrations were calculated for all monitoring stations in Clark County over the four-year period of 2001–2004. Then the percentage increase between the four-year average and the average for the two-day event on June 29-30, 2005, was calculated. The concentration increases on June 29 ranged from 27 percent at Jean to 51 percent at Winterwood (Figure 3-52). The concentration increases on June 30 ranged from 40 percent at Boulder City to 69 percent at Lone Mountain (Figure 3-53).

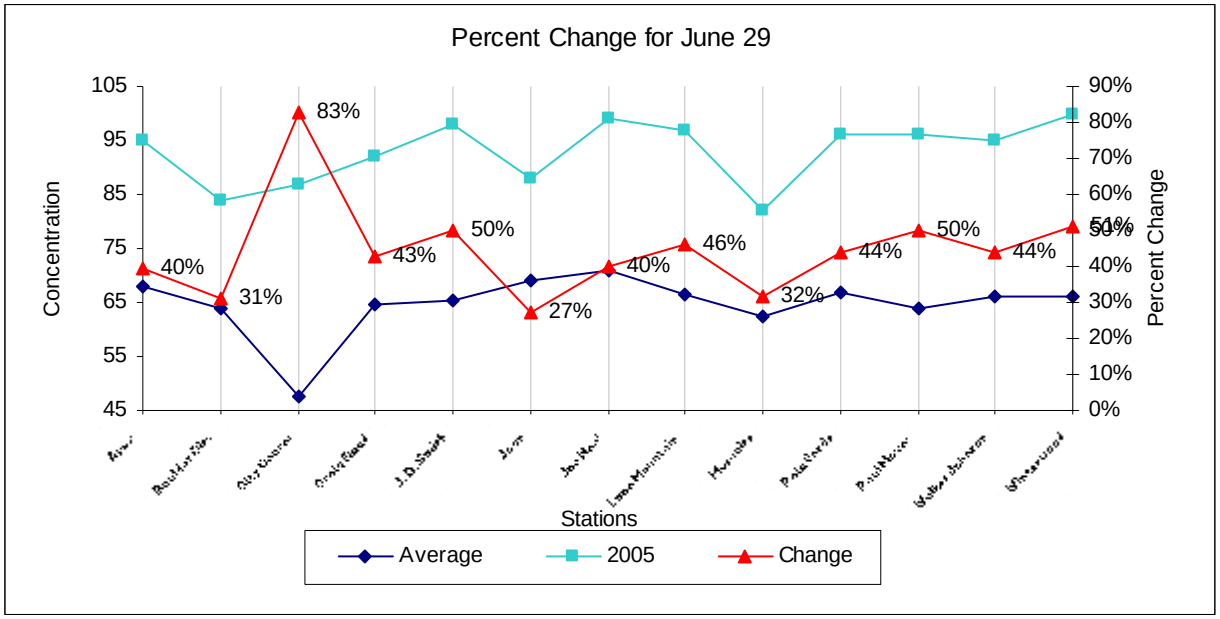


Figure 3-52. Percentage Increase in Ozone Concentrations on 6/29/05 compared to Average Ozone Concentrations in 2001-2004.

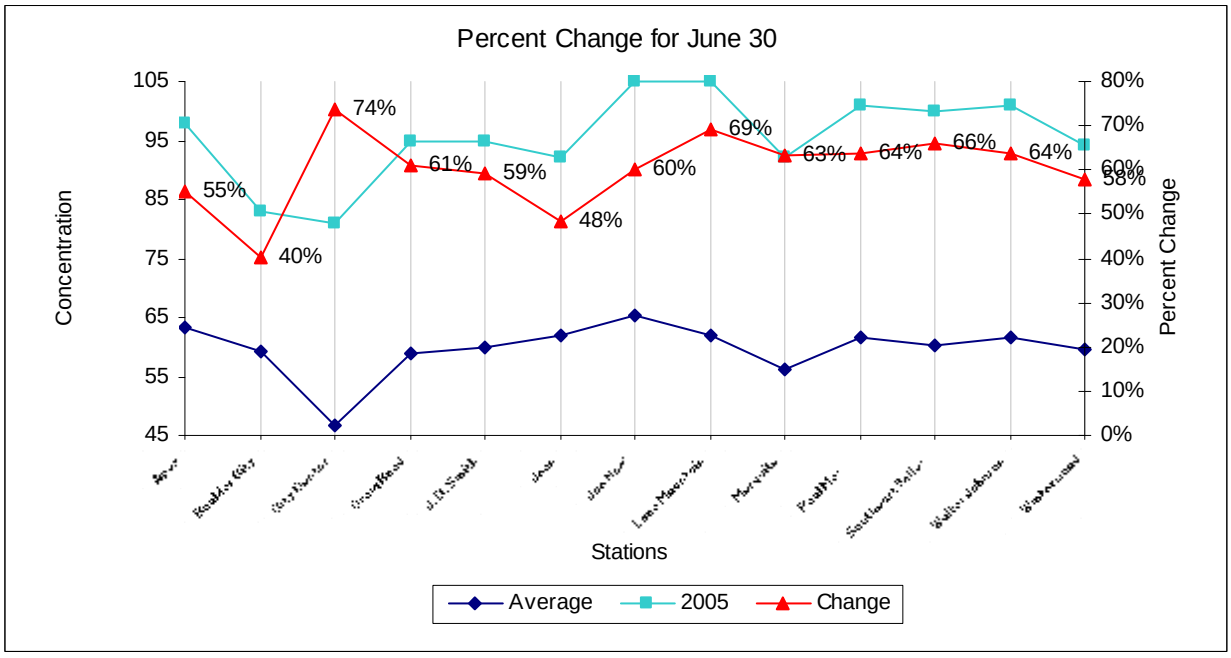


Figure 3-53. Percentage Increase in Ozone Concentrations on 6/30/05 compared to Average Ozone Concentrations in 2001-2004.

The following figures (3-54 through 3-58) show the AQI values for O_3, $PM_{2.5}$, and CO from June 22 to July 7 of each year during a 5-year period. As noted in previous sections, some years were impacted by significant interbasin transport, including smoke from wildfires (Section 2.3); how-

ever, O_3, $PM_{2.5}$, and CO never reached the AQI values they reached in 2005. The data show that the events of June 29 and 30 were exceptional.

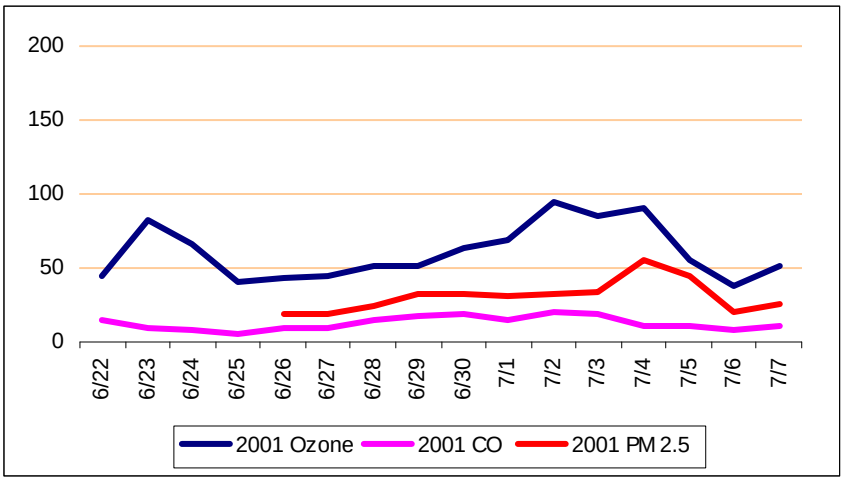


Figure 3-54. O_3, CO, and $PM_{2.5}$ Concentrations in 2001.

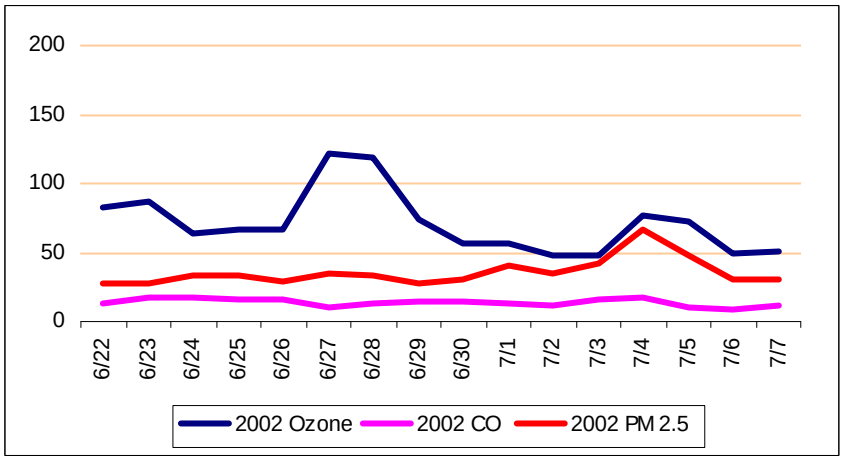


Figure 3-55. O_3, CO, and $PM_{2.5}$ Concentrations in 2002.

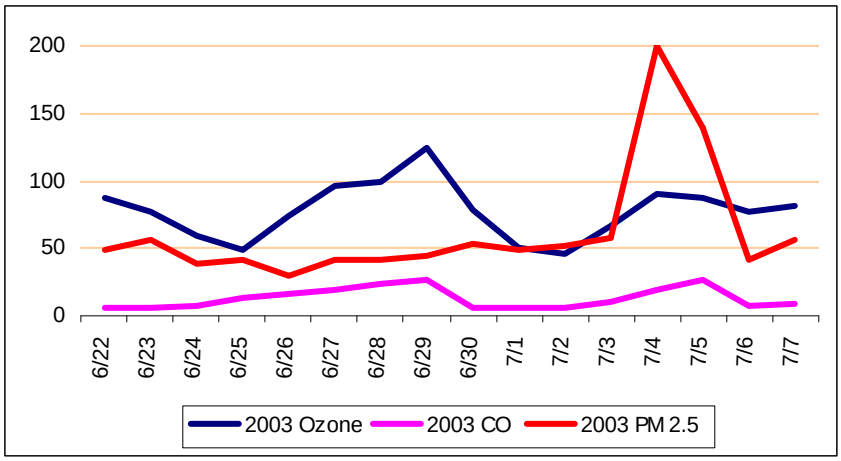


Figure 3-56. O_3, CO, and $PM_{2.5}$ Concentrations in 2003.

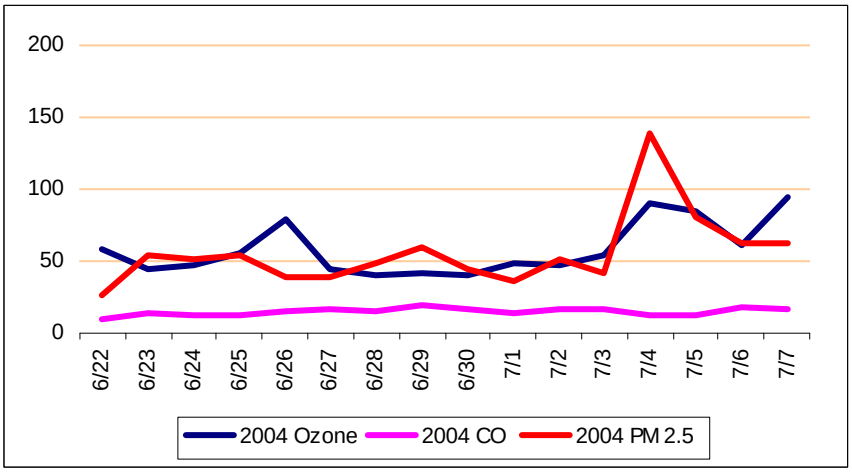


Figure 3-57. O_3, CO, and $PM_{2.5}$ Concentrations in 2004.

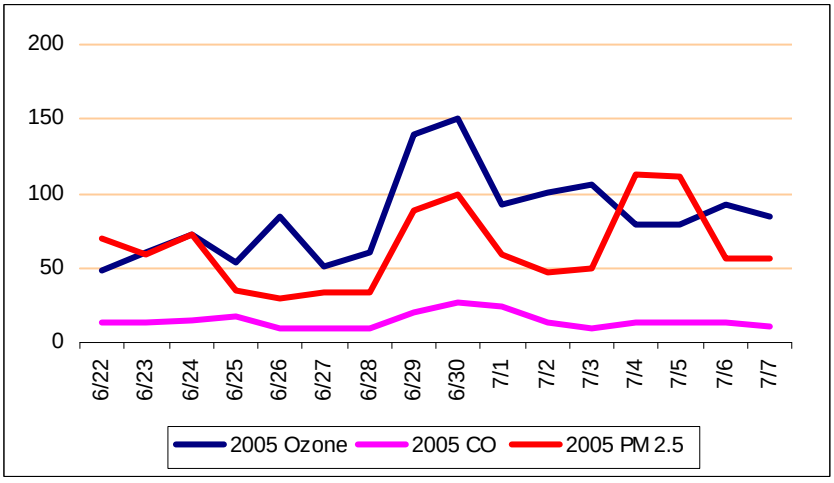


Figure 3-58. O_3, CO, and $PM_{2.5}$ Concentrations in 2005.

3.4 "BUT FOR" ARGUMENT

Meteorology is an important variable affecting air quality. Wind patterns maintained smoke plume impacts in southern Nevada for several days preceding the June 29-30, 2005, ozone violations: the weather data in Figure 3-59 show a remarkably consistent weather pattern before and after the exceptional event. Local anthropogenic emissions of ozone precursor pollutants did not exceed normal weekday or weekend levels. The difference during this period is the accumulation of wildfire smoke plumes in southern Nevada, exacerbating ozone concentrations in Clark County.

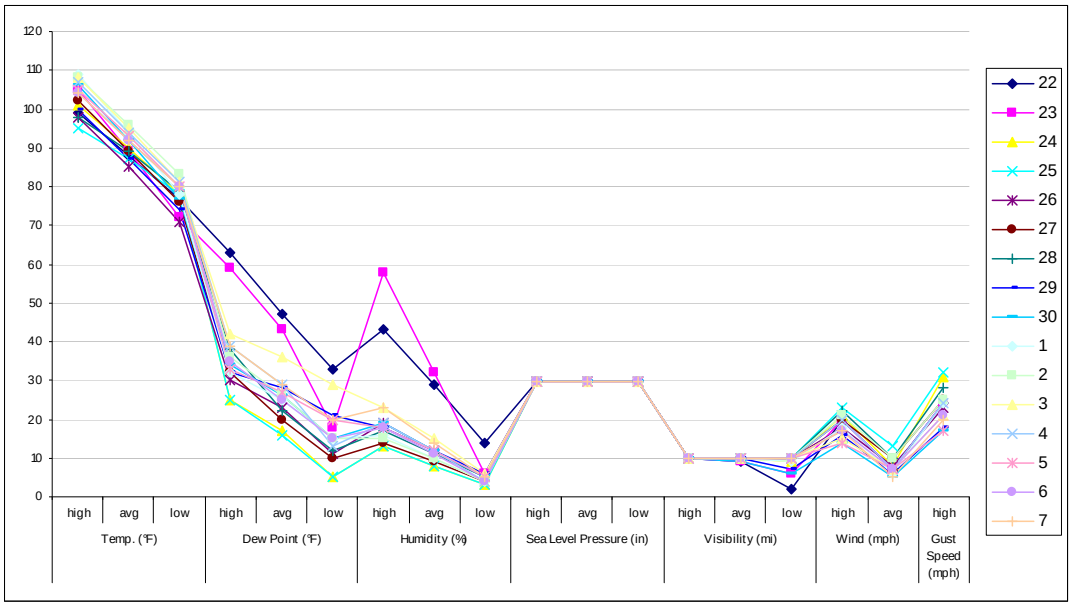


Figure 3-59. Weather Data for 6/22-7/7, 2005.

Three methods demonstrate that NAAQS violations on June 29-30, 2005, would not have occurred but for smoke plume impacts from wildfires.

3.4.1 Assumed Ozone Concentration Calculations

In this method, the average daily ozone concentration is calculated for each monitoring site, excluding June 29-30, for the period of June 22 to July 7. This calculated average concentration is a reasonable surrogate value for what would have occurred on June 29-30 given consistent weather patterns and normal anthropogenic local emissions, but no smoke impacts. Table 3-9 provides the average calculated concentrations for June 29-30. Under this approach, average ozone concentrations for the exceptional event days vary from 64–81 ppb throughout the monitoring network.

Table 3-9. Calculated Averages for June 29-30, 2005

Date	AP	BC	CC	CR	JD	JN	JO	LO	MQ	PV	PM	PL	WJ	WW
6/22	56	65	52	54	62	69	60	64	53	64	60	58	64	58
6/23	68	62	72	70	75	77	78	80	60	77	81	67	83	67
6/24	86	74	67	79	79	84	82	80	61	74	79	77	79	79
6/25	70	67	54	63	65	68	65	65	62	66	71	62	67	63
6/26	84	80	74	83	81	77	86	83	74	79	79	78	80	82
6/27	68	69	47	66	68	70	67	72	63	71	69	66	71	68
6/28	74	70	58	72	74	73	73	73	64	70	70	70	72	78
6/29	***75***	***71***	***64***	***75***	***75***	***78***	***81***	***80***	***65***	***78***	***77***	***72***	***79***	***74***
6/30	***75***	***71***	***64***	***75***	***75***	***78***	***81***	***80***	***65***	***78***	***77***	***72***	***79***	***74***
7/1	79	75	68	82	81	84	88	86	82	85	80	76	83	81
7/2	82	77	68	80	79	90	94	91	75	78	82	80	85	84
7/3	82	78	75	90	85	77	96	91	73	86	82	78	88	84
7/4	71	70	68	73	71	73	82	83	62	87	78	70	82	71
7/5	79	72	61	82	79	77	87	85	58	81	81	74	83	77
7/6	78	77	67	78	78	87	87	88	62	86	82	78	86	72
7/7	72	64	65	71	75	86	86	85	62	83	77	69	80	70

3.4.2 Ozone Concentration Interpolations

Interpolation is a method of constructing new data points within the range of a set of known data points. This application assumed that the data points for June 29 and 30 were missing and used linear interpolation to estimate their values. As shown in Table 3-10, this method yields the following concentrations:

- June 29: minimum 61 ppb, maximum 79 ppb.
- June 30: minimum 65 ppb, maximum 83 ppb.

Table 3-10. Interpolated Values for June 29-30, 2005

Date	AP	BC	CC	CR	JD	JN	JO	LO	MQ	PV	PM	PL	WJ	WW
6/22	56	65	52	54	62	69	60	64	53	64	60	58	64	58
6/23	68	62	72	70	75	77	78	80	60	77	81	67	83	67
6/24	86	74	67	79	79	84	82	80	61	74	79	77	79	79
6/25	70	67	54	63	65	68	65	65	62	66	71	62	67	63
6/26	84	80	74	83	81	77	86	83	74	79	79	78	80	82
6/27	68	69	47	66	68	70	67	72	63	71	69	66	71	68
6/28	74	70	58	72	74	73	73	73	64	70	70	70	72	78
6/29	***76***	***72***	***61***	***75***	***76***	***77***	***78***	***77***	***70***	***75***	***73***	***72***	***76***	***79***
6/30	***77***	***73***	***65***	***79***	***79***	***80***	***83***	***82***	***76***	***80***	***77***	***74***	***79***	***80***
7/1	79	75	68	82	81	84	88	86	82	85	80	76	83	81
7/2	82	77	68	80	79	90	94	91	75	78	82	80	85	84
7/3	82	78	75	90	85	77	96	91	73	86	82	78	88	84
7/4	71	70	68	73	71	73	82	83	62	87	78	70	82	71
7/5	79	72	61	82	79	77	87	85	58	81	81	74	83	77

Date	AP	BC	CC	CR	JD	JN	JO	LO	MQ	PV	PM	PL	WJ	WW
7/6	78	77	67	78	78	87	87	88	62	86	82	78	86	72
7/7	72	64	65	71	75	86	86	85	62	83	77	69	80	70

3.4.3 Regression Model

The third method is the use of a statistical regression model to predict ozone levels during the days of the exceptional event. An EPA statistical model was used as the initial framework for a generalized additive model, in which the sum of the functions of various predictor variables is used to predict daily maximum 8-hour ozone concentrations. The model does not assume that peak ozone is a linear function of each predictor, but rather uses natural splines to model the functional dependence of ozone on predictor variables other than "day of week" and "year." The original EPA model was modified through an iterative process to reflect local conditions in Clark County. The following predictor variables were incorporated into the regression model:

- Maximum temperature
- Midday average relative humidity
- Afternoon average wind speed
- Transport distance (HYSPLIT 24-hour back trajectory)
- Transport direction (HYSPLIT 24-hour back trajectory)
- Julian day
- Year
- Fire occurrence
- Solar radiation
- Regional-scale minimum peak O_3
- Previous-day peak O_3
- Maximum site east-west (using Universal Transverse Mercator Easting).

The equation was applied to historical meteorological data (2004-2008) to calculate a predicted ozone value based on meteorological conditions, fire occurrence, and regional peak ozone. Table 3-11, along with Figures 3-60 and 3-61, show the calculated descriptive statistics for the regression modeling results. Estimated wildfire impacts on peak ozone concentrations on June 29-30, 2005, were 19 ppb and 18 ppb, respectively. Model uncertainties ranged from 1.2–6.9 ppb, averaging 2.1 ppb. The predicted peak ozone concentrations for June 29 and 30 were 81.4 ppb and 75.9 ppb, respectively.

Table 3-11. Regression Model Results

Date	Peak 8-hour O_3 (ppb)	Predicted Peak 8-hour O_3 (ppb)[1]	Predicted Wildfire Effect (ppb)	Uncertainty of Predicted Wildfire Effect (ppb)	Predicted Peak 8-hour O_3 w/o Fire (ppb)
6/29/2005	100	100.3	19	5.4	81.4
6/30/2005	105	93.5	18	5	75.9

[1]Predicted ozone concentrations include wildfire impacts.

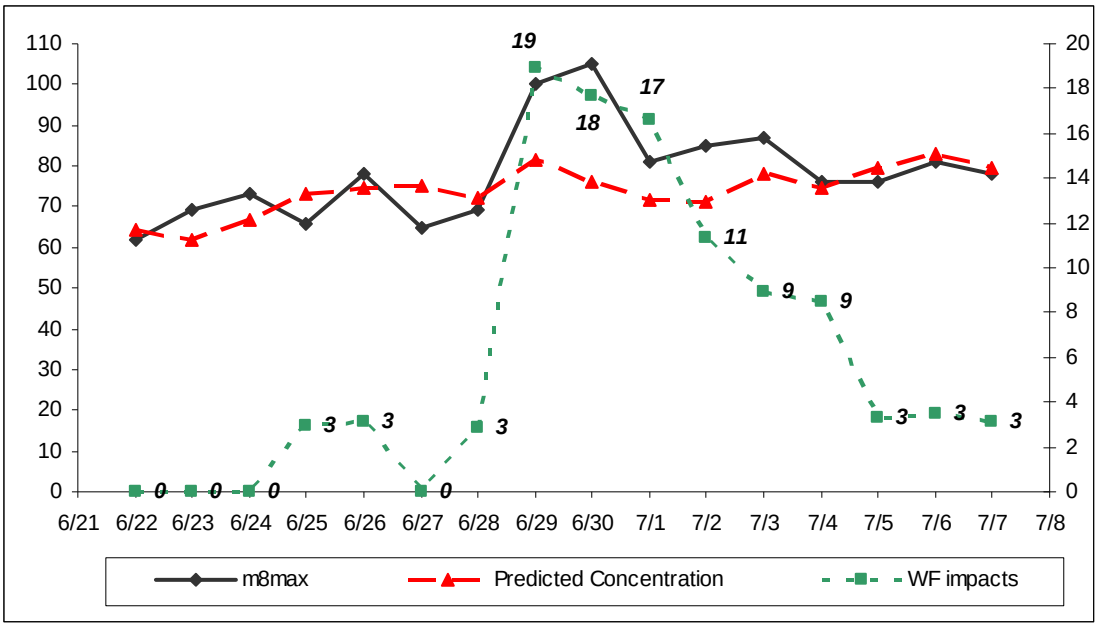


Figure 3-60. Wildfire Impacts during Wildfire Event (ppb).

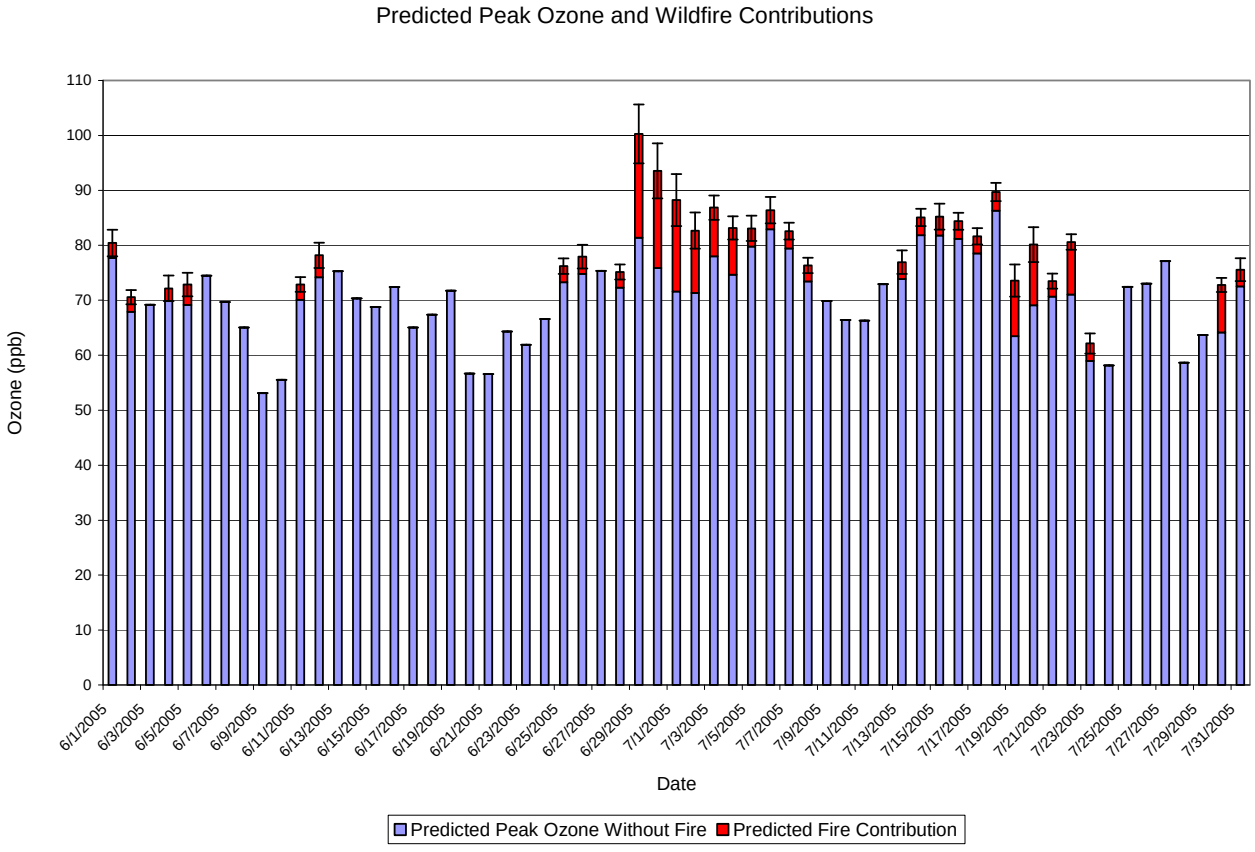


Figure 3-61. Wildfire Contributions.

The results of these three methods show that ozone concentrations on June 29-30 would have been well under the NAAQS but for the wildfire event. Table 3-12 and Figure 3-62 summarize the combined results from the three methods.

Table 3-12. Observed and Modeled[1] Ozone Concentrations

Date	Observed Maximum 8-Hour Concentration (ppb)	Assumed Ozone Concentration Calculations	Ozone Concentration Interpolations	Regression Model
6/29/2005	100	81	79	81
6/30/2005	105	81	83	76

[1]Modeled concentrations reflect expected ozone air quality on June 29-30, 2005, without wildfire impacts.

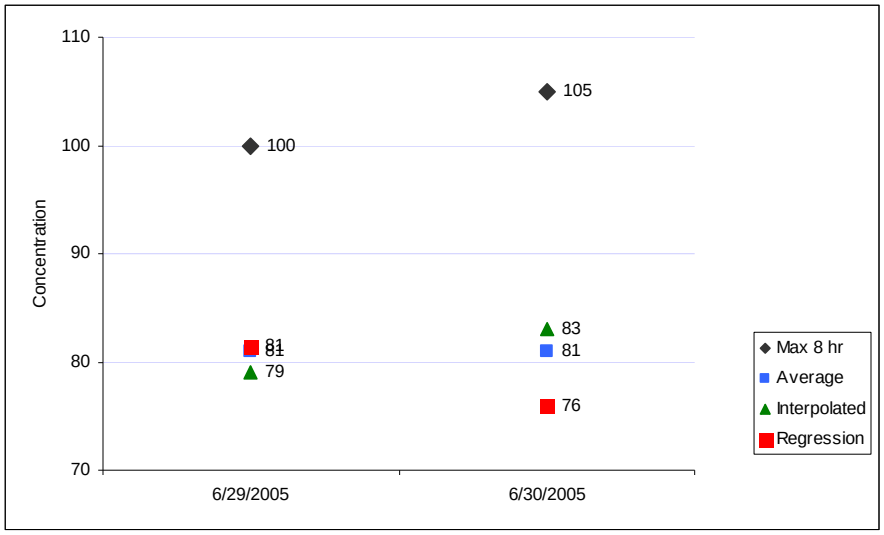


Figure 3-62. Maximum 8-hour Concentrations vs. Predicted Values.

3.5 PUBLIC OUTREACH AND EDUCATION IN RESPONSE TO THE EXCEPTIONAL EVENT

DAQEM has in place an education program to protect the public from adverse health problems associated with elevated pollutant levels. Its goals are to inform and educate the public on topics that include:

- How they can avoid exposure and minimize health impacts.
- How they can reduce their contributions to concentrations of the pollutant.
- What types of exceptional events may affect the area's air quality.
- When an exceptional event is imminent or occurring.

To meet these goals, DAQEM conducts a comprehensive program that engages in local outreach events to provide information to the public. These include:

- Media press releases issued to the community as needed.
- School and youth outreach programs with classroom and youth group presentations, teacher training, and air quality information packets.
- Participation in community events (e.g., the Clark County Fair, Henderson Parade, Clark County Health and Wellness Fair).
- A Medical Advisory Committee comprised of physicians who work with DAQEM and the Southern Nevada Health District to provide health-related information to the public before, during, and after exceptional events.
- Training in air quality reporting for local weather anchors.
- Activities with city, county, and local environmental/health professionals to improve methods for reaching and educating the community.

DAQEM also developed a notification system to contact at-risk populations, including:

- The Clark County School District.
- The Southern Nevada Health District.
- The Clark County Parks and Recreation Department.
- Local municipalities, i.e., the cities of Henderson, Las Vegas, North Las Vegas, and Boulder City.
- Local media (e.g., newspapers, radio and television stations).
- Physicians and sensitive individuals (through a notification service).

DAQEM has formed two broad-based stakeholder groups to provide for public review of the justification packages for exceptional events, the Ozone Working Group and the PM Working Group. The groups include members from the following:

- Alpine Geophysics, LLC
- Associated General Contractors
- AVESTOR
- Chemical Lime, Inc.
- City of Boulder City
- City of Henderson
- City of Las Vegas
- City of North Las Vegas

- Clark County Department of Aviation
- Desert Research Institute, Division of Atmospheric Sciences
- Environmental Quality Management, Inc.
- ExxonMobil
- Las Vegas Paiute Tribe
- Nevada Department of Agriculture
- Nevada Department of Transportation
- Nevada Division of Environmental Protection
- Nevada Environmental Coalition
- Nevada Motor Transport Association
- NV Energy, Inc.
- Regional Transportation Commission of Southern Nevada
- Sierra Club, Toiyabe Chapter
- Silver State Materials Corp.
- Southern Nevada Home Builders Association.

DAQEM also presents reports on justification packages to the Technical Advisory Committee, and posts the packages on its Web site.

Comments received during the public comment period:

From: victor.m.dugan@exxonmobil.com
Sent: Friday, August 17, 2007 11:03 AM
To: William Cates
Cc: John Koswan
Subject: Re: Ozone Working Group review of Demonstration of Wildfire Impacts on Ozone Concentrations in 2005

I have reviewed the demonstration of the exceptional event in 2005 and have no comments or suggestions. The demonstration looks good to me.

Vic Dugan
ExxonMobil
13501 Katy Freeway
CORP-EMCC-L3-536
Houston, Texas 77079
Phone - 281/870-6006; Fax - 281/588-2522 Email; victor.m.dugan@exxonmobil.com

From: Joe Pantuso [joe@snhba.com]
Sent: Friday, August 17, 2007 11:47 AM
To: William Cates
Cc: John Koswan; Irene Porter
Subject: Wildfire Impacts to Air Quality in Clark County, June 29-June 30, 2005.
William Cates
DAQEM

Bill,

I have had an opportunity to review the report "Demonstration Package Justifying Data Exclusion Due to Wildfire Impact to Air Quality in Clark County, Nevada, June 29 and June 30, 2005". The clear causal relationship between wildfires and the exceedences on these dates is well demonstrated and is systemically supported with the hard data.

The text is well written and to the point. I would suggest a re write of the conclusion section on page 48. It needs a bit of reorganization to allow a better presentation of the several topics that do not fit together in the paragraphs as written. Separating themes in this section will assist the reader in reaffirming the conclusions of the report more readily. If you wish, I can take a stab at it in early next week and forward my suggestions to you.

Joe

Dr. Joseph A. Pantuso
SNHBA
794.0117

4.0 CONCLUSIONS AND RECOMMENDATION

There is no dispute that wildfires, or other kinds of biomass burning, can increase ozone levels in downwind areas. However, it is difficult to Quantify the relationship between elevated ozone concentrations and wildfires with certainty because of significant information gaps on the complex temporal relationships between emissions of ozone precursor pollutants during wildfires, meteorological variables, and ozone chemistry. DAQEM has used three different methods to minimize this uncertainty in demonstrating that a wildfire exceptional event caused the ozone NAAQS violations in Clark County on June 29 and 30, 2005.

This revised demonstration attempts to address, to the extent practicable, the issues of concern raised by EPA's Region 9 office in its review of the first submittal. As a result of this weight-of-evidence demonstration, DAQEM concludes that ozone concentrations exceeding the NAAQS on June 29 and 30, 2005, were due to an exceptional event and recommends that EPA concur with this conclusion.

5.0 REFERENCE

DAQEM 2006a. *Ozone Characterization Study.* Las Vegas, Nevada: Clark County Department of Air Quality and Environmental Management.

DAQEM 2006b. *Clark County Regional Ozone & Precursors Study.* Las Vegas, Nevada: Clark County Department of Air Quality and Environmental Management.

DAQEM 2008. *Southwest Desert/Las Vegas Ozone Transport Study (SLOTS).* Las Vegas, Nevada: Clark County Department of Air Quality and Environmental Management.

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Pace, T.G., and Pouliot, G. 2007. "EPA's Perspective on Fire Emission Inventories—Past, Present, and Future." Paper presented at the 16th Annual International Emission Inventory Conference, *Emission Inventories: Integration, Analysis, and Communications,* in Raleigh, NC on May 14-17, 2007.

Pfister, G.G.; Wiedinmyer, C.; and Emmons, L.K. 2008. "Impact of the 2007 California Wildfires on Surface Ozone: Integrating Local Observations with Global Model Simulations." *Geophysical Research Letters*, 35, L19814. doi:10.1029/2008GL034747.

6.0 APPENDIX A

Public Communications ■ 500 S. Grand Central Parkway, 6th Fl., Las Vegas, NV 89155-1111 ■ Fax: (702) 455-3558

Contact: **Stacey Welling**
Sr. Public Information Officer

Phone: **(702) 455-3201**
Cell: **(702) 249-3823**
E-mail: stac@**co.clark.nv.us**

For Immediate Release Thursday, June 30, 2005

Ozone Advisory Issued For Today, Friday

Visit Online Forecast Page For Updates on Advisory's Status

Clark County Air Quality officials are advising residents that weather conditions and existing levels of other pollutants due to smoke from area wildfires may trigger a buildup of ground-level ozone in Southern Nevada today and Friday afternoon and evening.

At this time, unhealthy levels of ozone are not occurring. Air Quality officials will continue to monitor the situation and will post an alert on the forecast page of the Department of Air Quality and Environmental Management's website section if unhealthy levels of ozone actually occur. A link to the forecast page is located on the front page of Clark County's website at www.accessclarkcounty.com.

ADDITIONAL INFORMATION:

Ozone is a gas that occurs naturally in the upper atmosphere and protects earth from the sun's harmful ultraviolet rays. At ground level, ozone is a key ingredient of urban smog during the hottest months of the year in Clark County. Ground-level ozone can build up during the afternoon hours due to a combination of several factors, including strong sunlight, hot temperatures, and pollutants from automobiles and other sources. Unhealthy doses of ground-level ozone can reduce lung function and worsen respiratory illnesses such as asthma or bronchitis. Exposure to ozone also can induce coughing, wheezing and shortness of breath, even in healthy people. When ozone levels are elevated, everyone should limit strenuous outdoor activity, especially people with respiratory diseases.

Smoke from area wildfires also is impacting local air quality. Health officials say exposure to smoke may trigger allergy-like symptoms, especially for people with chronic respiratory conditions. Officials suggest the following tips if you're concerned about exposure to smoke:

- If you work outdoors, consider wearing a painter's mask or surgical mask. This will help reduce your exposure to dust and particulates.

- Limit outdoor exertion. Exercise, for example, makes you breathe heavier and increases the amount of particulates you're likely to inhale.

- Keep windows closed. Run your air conditioner inside your house and car. Your air conditioner filters out dust and particulates.

- Consider changing your indoor air filters if they are dirty.

- Use your prescription allergy medication or over-the-counter hay fever or sinus medications if you experience symptoms of itchy eyes, a runny nose or congestion.

In addition, these tips help reduce the formation of ground-level ozone on a daily basis:

- Fill up your gas tank after sunset.
- Try not to spill gasoline when filling up, and don't top off your gas tank.
- Combine several errands into one trip.
- Keep your car well maintained.
- Use mass transit or carpool.
- Don't idle your car engine.
- Mow your lawn after sunset.

Detailed air quality conditions are posted in the monitoring section of the Air Quality website. You can receive air quality advisories via your pager or email through the county's free Direct Connect service. Subscription information is available on the Public Communications pages of the county's website.

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Thursday, June 30, 2005

WILDFIRE EFFECTS: Blazes! It's a stew out there

Elevated levels of ozone and wood smoke particles spark health alert

By KEITH ROGERS
REVIEW-JOURNAL

The Stratosphere tower is silhouetted against the sunset Wednesday. Visibility estimates ranged from seven miles to 22 miles, down from the usual 70 miles in June. Photo by Craig L. Moran.

Smoke from wildfires in Southern Nevada, Arizona and as far as New Mexico drifted into Las Vegas on Wednesday, shrouding the city in an atmospheric stew of fine particles and ozone that triggered a health alert from air quality officials.

Clark County's Department of Air Quality and Environmental Management posted the alert on its air quality forecast Web site at 4:30 p.m. It said wildfires and a shift in low-level winds had caused elevated and unhealthful levels of ozone.

Mike Sword, the department's air quality engineering manager, said that besides ground-level ozone, which is a component of smog, the hazy skies contained levels of fine particulate matter from wood smoke that were four to six times greater than normal.

"My preliminary sense of it is that smoke is contributing to higher levels of ozone than we would typically see," he said.

Last year, Clark County was among urban areas in 31 states that were found to be in violation of the Environmental Protection Agency's eight-hour standard for ozone pollution. Though the county was in the least serious of the five designation tiers and has been developing plans to curb the problem, Wednesday's unhealthful levels could push it into a more serious category, Sword said.

Only one of the department's two visibility meters was operating Wednesday, he said. The other was down for annual maintenance.

Sword said haze from wood smoke at 2 p.m. had dropped visibility to 22 miles around Henderson and downtown Las Vegas, when it is usually as high as 70 miles in June.

But the National Weather Service reported that visibility in North Las Vegas was down to seven miles, and the monitoring station at McCarran International Airport recorded visibility at 10 miles for most of the day, dipping to seven miles for a brief period.

Brian Fuis, a National Weather Service spokesman, said light easterly winds pushed a smoke layer over Las Vegas Valley at 4,000 feet above ground. "Some of it trickled down. The lion's share is probably still aloft," he said Wednesday afternoon.

Most of the smoke plumes were from wildfires in Arizona and the Mesquite complex, but some flowed in from Farmington, N.M., where it was carried over the Grand Canyon and across Northern Arizona. One plume originated near Prescott, Ariz.

A shift in overnight wind direction was expected to blow some of the smoke out of the Las Vegas Valley.

"If things turn around a bit, it should be blowing back out of here," Fuis said.

Despite the smoke-related air pollution that filled the Las Vegas basin, a Clark County Health District official said surveys of emergency departments in the valley found no increases in recent days for respiratory complaints.

"Typically they do see small spikes when there are changes in air quality," said Dr. Lawrence Sands, a public health physician who is director of the district's community health division.

He acknowledged that smoke from wildfires can affect ground-level ozone, causing people with respiratory problems to have worse symptoms, such as coughing or shortness of breath.

"Others may have allergy symptoms, and others may have burning of the eyes or the throat," Sands said.

The fine particulate matter that makes up smoke acts as an irritant, he said. People with concerns about being outside in such conditions should check the air quality Web site and decide accordingly, he said.

"People basically have to go by what they are comfortable with. For most healthy people, it shouldn't be a problem," Sands said, adding, "People with respiratory problems might want to stay inside."

One Las Vegan who routinely spends time outside said that like many in the valley, his senses alerted him to the unusual conditions.

"I walked out this morning, and the first thing I noticed was the smell, the forest fire smell," said Von Winkel, a restoration ecologist for the Las Vegas Valley Water District at Springs Preserve.

"I certainly noticed the visibility. I couldn't see Sheep Mountains and could barely see Sunrise Mountain. Everything was obscured by the smoke."

Though the smoky conditions didn't affect him, he said, he had concern for his children, who have lung problems. "They could have complained about it, but they didn't," Winkel said.

Sands said that if wildfires persist during the summer and smoke continues to flow into the valley, greater precautions might be needed.

"It's going to vary from day to day. It's hard to predict. It's not just the smoke itself, it depends on what the weather conditions are," he said.

"I think the clue or prompt for people who have health conditions is to check the Web site."

June 30, 2005
Health issues seen as fires darken skies
Ozone alert in effect in hazy Clark County
By Launce Rake <lrake@lasvegassun.com>
LAS VEGAS SUN
Smoke from nearby wildfires has again blanketed Las Vegas with a thick cover of haze and, along with rising ozone levels, could cause health problems for some people.
The Clark County Air Quality and Environmental Management Department issued an ozone alert Wednesday afternoon warning sensitive people to avoid strenuous exercise, especially outdoors, through Friday. Mike Sword, Air Quality engineering manager, said while ozone was a primary component of the bad air, the haze was actually a product of a mix of different noxious pollutants.
Particulate matter, which is usually fine dust kicked up from the desert but in this case the airborne detritus from the wildfires in the Southwest, contributed to haze, Sword said.
He said particulate matter, although not exceeding federal air quality limits Wednesday, was about four to five times what is usually is in the Las Vegas Valley.
Sword said Air Quality scientists did not completely agree on the source of the particulate matter and ozone. Some believed it was more of a product of Las Vegas heat and urban activity, while others said the wildfires were the culprit.
Ozone, while itself invisible, is a primary component of smog and becomes a concern in Las Vegas during the hot summer months. Bright sunlight, stagnant air and pollution from cars and other sources combine to create ozone at ground level.
Unhealthy levels can impair lung function and exacerbate respiratory problems such as asthma, and induce coughing, wheezing or shortness of breath in health people, the department reports.
"When we're at this level, it's unhealthy for sensitive groups," Sword said. "It's a level at which most people should exercise some precautions."
The hot desert sun will continue producing the gas through interactions with the wildfire smoke and Las Vegas' own pollution, he said.
"As long as the sun is up, we're going to have elevated levels of ozone."
Brian Fuis, a spokesman with the Las Vegas office of the National Weather Service, said the haze and bad air could last for several days. He said wildfires burning near Mesquite and scattered throughout Arizona are teaming up to throw smoke toward Las Vegas.
He said the haze was "pretty thick and constant over the valley" Wednesday, but was not thick enough to impact aviation. However, it could contribute to impressive sunsets, Fuis said.
The federal Bureau of Land Management, which oversees land on which fires are burning, detailed a number of ongoing fires Wednesday. Among them:

- The Mount Bangs Complex, 15 miles south of Mesquite, that has burned 29,600 acres in the Virgin Mountains and is 70 percent contained.
- The Tweedy Fire that has burned 19,400 acres in Arizona about 32 miles south of St. George, Utah. There is no estimate of containment.
- The 1,500-acre Last Chance Fire, 35 miles south of St. George, and is about 10 percent contained.

All the fires were started by lightning.
The fire-related air pollution problems contribute to an ongoing problem with ozone in Southern Nevada. The Las Vegas Valley does not now comply with federal standards for the potentially dangerous gas.

The Air Quality department is working to draft a plan to control ozone and win federal approval for the plan, which could be in place by 2007. Approved plans already are in place for control of carbon monoxide and particulate matter.
County officials say simple efforts could significantly affect the amount of ozone in the air. Among their suggestions:

- Fill up car gas tanks after sunset. Try not to spill gasoline when filling up, and don't top off tanks. Combine several errands into one trip. Keep cars well maintained. Use mass transit or carpool. Don't idle car engines.
- Avoid using household products with high levels of volatile organic compounds. Use water-based paints and solvents instead of products packaged in aerosol cans. Use electric instead of gas-powered lawn equipment.
- Don't use charcoal lighter fluid when barbecuing. Use a charcoal chimney, electric starter or propane grill.

NEVADA'S FORK FIRE OVER 81,000 ACRES

JULY 01 -- LAS VEGAS, NV:

Suwyn's Type 2 team on the Fork Fire, 50 miles east of Las Vegas, puts containment at 87 percent this morning for the 81,700-acre fire, which is burning in piñon and grass. Better GPS mapping reduced the reported size of the fire, which yesterday was estimated at over 157,000 acres. The fire was ignited by lightning on Tuesday, and has threatened the Lake Mead National Recreation Area, mining claim improvements, Lime Canyon and Jumbo Springs wilderness areas, Million Hills wilderness study area, communication sites, and federally protected desert tortoise habitat.

Extreme rates of spread and high flamelengths were reported yesterday at the head of the fire, but crews made good progress with firing operations along the north end of the fire. Goals include containing the fire between two forks of Lake Mead. Krugman's Type 1 team is taking over management of the fire.

The fire has contributed to a smoky haze over Las Vegas, and the Las Vegas Sun reported that the county Air Quality and Environmental Management Department issued an ozone alert Wednesday afternoon warning sensitive people to avoid strenuous exercise, especially outdoors, through Friday.

http://wildfirenews.com/archive/070805.shtml

HOT TIMES AT CEDAR CITY

JUNE 29 -- CEDAR CITY, UTAH: The tanker base at Cedar City has been a busy place the last week or so, with airtankers flying in and out on a shifting list of fires around the region. David Ricks, assistant retardant manager at the base, told the Salt Lake Tribune he's been loading tankers more than 60 times a day.

Most of the runs this week have been on the Blue Spring Fire, burning on the Dixie National Forest adjacent to Interstate 15. The fire evacuated most of the town of New Harmony Monday night, and has repeatedly closed the highway.

The fire last night was 50 percent contained at 12,260 acres.

Tankers out of Cedar City also worked the Red Fire and West Side Complex.

The 10,000-gallon retardant tanks are refilled six times daily from tanker trucks. "I use about 122,000 gallons of retardant a day," said Ricks. Five heavy airtankers have been flying out of Cedar City, along with six SEATs, three helicopters, and lead planes.

Cliff Naveaux, a lead plane pilot, has worked 32 years in fire, and flown a lead plane for the last 18 years. He was a smokejumper, but began flying after he lost a leg in 1987 in an avalanche accident.

"At the time I lost my leg I had some aviation experience and wanted to stay in fire," he said. Based in New Mexico, Naveaux flies a twin-engine King Air for the BLM.

All available heavy tankers have been flying lately, mostly in the Southwest, and more will come on contract in the next few weeks.

Naveaux says the pilots have been busy. "You want to lay the retardant faster than the fire is burning," he said. "If you can't out-gun the fire, then you are playing catch-up."

Cliff Naveaux, reputedly "the best lead plane pilot out there." Photo ©1993 courtesy Mike Lynn.

BLUE SPRING FIRE EVACUATES UTAH TOWN, CLOSES FREEWAY

JUNE 28 -- NEW HARMONY, UTAH: Fresh crews rolled into town today to relieve crews that had worked through most of the night to protect the town of New Harmony from the 12,260-acre Blue Spring Fire. Muir's Type 2 team puts the fire tonight at 50 percent containment.

The Deseret News reported that five airtankers were on the fire yesterday.

Good progress was made on the fire today, with crews helped out by a little precipitation, cooler weather, and lighter winds. Fire managers said local initial attack crews were supported by air resources, with over 760 personnel on the fire tonight.

Most of New Harmony, about 30 miles northwest of St. George in Utah's southwest corner, was evacuated last night, with about 100 residents leaving 27 homes. The evacuation orders for Harmony Heights were lifted this evening.

Firefighters yesterday worked in the neighborhoods past mid-night, drawing water from a local reservoir. David Boyd, team information officer, said airtankers dropped on the fire till dark. "It played a significant role in protecting the homes," said Boyd.

He said four helicopters also worked the fire; they worked the fire all day, and one of the heavies stayed on till about 9 p.m. with a number of engines and hotshot crews on the ground.

Muir said the fire was was pushed by high winds and running hot yesterday evening, burning northward six miles in just two hours. Some residents were at a community fire meeting last night when they were told to go home and evacuate immediately.

The fire burned an 8-mile stretch along Interstate 15, causing intermittent closures for the safety of travelers and firefighters.

Burning on Dixie National Forest land on the west side of I-15, the fire forced the Utah Highway Patrol to close down the freeway in both directions several times on Sunday. Airtankers dropped retardant along the fire perimeter to keep it from jumping the highway.

Several large powerlines were burned, but power had already been diverted.

An early morning lightning storm started two new wildfires in the area. The town of Motoqua, a cluster of 12 homes about 25

Randy Lanain of the Dalton Hotshots is silhouetted by nighttime flames working the Blue Spring Fire in Utah. photo ©2005 Scott G. Winterton, courtesy of Deseret Morning News

An airtanker drop on Sunday north of St. George helps keep the Blue Spring Fire from Interstate 15. photo ©2005 Scott G. Winterton, courtesy of Deseret Morning News

miles west of St. George, was put under a one-hour evacuation order as flames moved to within 1½ miles of the town.

Thursday, June 30, 2005

WILDFIRES STALL: Light winds, terrain help

Firefighters see end in sight for blazes that have scorched 500,285 acres

REVIEW-JOURNAL

Weather and geography on Wednesday stalled the massive wildfires in Lincoln County that had burned to within several miles of the town of Caliente.

Hundreds of firefighters labored under a hot sun trying to quash hot spots and widespread fires in grass that stood a foot or two high, said Forest Service spokeswoman Kathy Jo Pollock.

Although temperatures were high, officials found an ally in relatively light winds. The Meadow Valley fire reached terrain inaccessible by land, slowing the arrival of firefighters, who had to be airlifted to the blazes, but reducing the danger to Caliente, officials said.

"It's getting into a series of steep canyons, and it's kind of stalling the fire up there," Forest Service incident commander Buzz Vanskike said.

One day after fire officials met with Caliente residents to allay their fears, Pollock stressed, "There is no threat and has been no threat to Caliente. It is not any closer than it was yesterday."

However, flames threatened the Utah town of Motoqua on Wednesday morning when the fire pushed toward the state border and climbed a ridge west of town, fire information officer David Chevalier said.

Fire crews took positions between the town and the flames to protect structures, but the fire never got closer, he said.

With more cooperation from the weather, officials were optimistic the end was in sight for the blazes. In all, the group of fires known as the Southern Nevada Complex have burned 500,285 acres.

"We should have the resources to go ahead and finish this up if we keep the weather this way," Pollock said. "But the weather has got to cooperate."

Winds in Clark and Lincoln counties are expected to be relatively mild over the next several days.

Wildfires in Nevada this month have charred 10 times the area affected by blazes during all of last year combined.

Fire officials say the extraordinary precipitation earlier this year increased vegetation and created conditions favorable for the fires.

The largest Lincoln County wildfires, the Duzak and Halfway fires, measured roughly 264,000 acres combined on Wednesday, while the nearby Meadow Valley fire had shrunk to about 142,000 acres, officials said.

Meanwhile, the 33,569-acre Goodsprings fire southwest of Las Vegas was reduced to one smoldering hot spot in the mountains by Wednesday, fire information officer Pam Sichting said. Crews expected to completely contain the wildfire by today and will continue monitoring the area for flare-ups, she said.

Officials said they had contained two of three other Clark County wildfires that have burned 45,000 acres.

The largest, the Fork fire, was not contained. The Fork fire is a collection of five different blazes on 36,000 acres, burning about 35 miles south of Mesquite on an arm of Lake Mead.

At a fire "spike camp" in the historic town of Elgin, south of Caliente, fire crews and pilots hustled through the day to airlift about 80 firefighters about six miles to the north end of the Meadow Valley fire.

Among the firefighters in Elgin yesterday was Forest Service division supervisor Brent Olson from Hungry Horse, Mont. Olson has been fighting the Duzak and Meadow Valley fires for six days.

He agreed the area of flames closest to Caliente had slowed. But, he said, they are far from extinguished.

"There's still a lot of heat up there. This fire still has a lot of potential."

Shawn Pearson, another Forest Service supervisor, said crews are gaining the upper hand by working long into the night and staying mobile.

"We've been playing catch-up for days, just trying to stay out of its way," he said. "It's just now that we're able to get ahead of it a little."

Forest Service captain Robert Chavez waited in the shade of an apple tree Wednesday morning with his 20-person crew for an airlift into the Meadow Valley fire.

He said that even after 15 years as a firefighter, this year's Nevada fires had something to teach him.

"With the deep grass and the fire moving so fast, you better keep one foot in the black and one in the green as an escape route," he said.

Friday, July 01, 2005

Smoke from wildfires keeps Las Vegas residents in haze

By JENS MANUEL KROGSTAD
REVIEW-JOURNAL
Smoke from area wildfires hovered over Las Vegas again Thursday, decreasing visibility and prompting Clark County air quality officials to issue an ozone alert.

Expecting the unhealthful conditions to continue, Clark County's Department of Air Quality and Environmental Management issued an ozone advisory for today.

Excess ground-level ozone, a key component of smog, can worsen respiratory illnesses such as asthma and bronchitis and can induce coughing, wheezing and shortness of breath in healthy people.

Smoke from wildfires in Southern Nevada, Arizona and as far as New Mexico have combined with strong sunlight, high temperatures and low winds to create the ozone buildup.

But officials were hopeful it would clear up for the holiday weekend.

"We might have some wind that will scour it out, but until then it looks like we'll stick with smoke in the valley," National Weather Service meteorologist Andrew Gorelow said.

County air quality officials said the smoke might clear out this evening.

"We're expecting a wind Friday evening to carry most of the pollutants out of the valley," Mike Sword, the department's air quality engineering manager, said Thursday. "However, if the winds don't come, we could continue to see the same kind of air quality."

In the meantime, Sword urges people, especially those sensitive to air quality changes, to stay indoors, use air conditioners to filter air and limit physical activity. To those people who must work outside, officials recommend wearing a mask.

Reports of air quality-related illnesses by the medical community were mixed on Thursday.

University Medical Center reported more patients with respiratory ailments seeking treatment in the emergency room, but Sunrise Hospital and Medical Center saw no increased activity.

Las Vegas allergist Dr. Joel Katz said he has seen more patients dealing with asthma, nasal congestion and eye irritation in the last week. Because allergy season usually subsides by this time of year, Katz said the probable cause is smoke from wildfires.

The air quality department also has issued a dust advisory for Monday.

Impacts of the fall 2007 California wildfires on surface ozone: Integrating local observations with global model simulations

G. G. Pfister,[1] C. Wiedinmyer,[1] and L. K. Emmons[1]

Received 20 May 2008; revised 4 September 2008; accepted 9 September 2008; published 9 October 2008.

[1] This study quantifies the impact of the fires in California in fall 2007 on regional air quality and especially on surface ozone by analyzing surface observations of ozone concentrations together with global chemistry transport model simulations. The latter include a synthetic tracer providing information about the amount of ozone produced from the fires. It is shown that the global model is well suited for simulating the overall fire impact and a valuable tool for extracting information about the fire influence from the observations. A clear increase in observed ozone is found when the model predicts a strong impact of pollution from the fires, where measured afternoon 8-hour concentrations increased, on average, by about 10 ppb. The findings demonstrate that intense wildfire periods can significantly increase the frequency of ozone concentrations exceeding current U.S. health standards, and might cause violations also during photochemically less active seasons. The study also demonstrates the far-reaching impact of ozone production from the fires. **Citation:** Pfister, G. G., C. Wiedinmyer, and L. K. Emmons (2008), Impacts of the fall 2007 California wildfires on surface ozone: Integrating local observations with global model simulations, *Geophys. Res. Lett.*, *35*, L19814, doi:10.1029/2008GL034747.

1. Introduction

[2] Wildfires are a significant direct source of atmospheric pollutants such as carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter. The gaseous pollutants are precursors for ozone (O_3) production and as a result, wildfires have been proposed to lead to substantial increases in tropospheric O_3 concentrations [*Wotawa and Trainer*, 2000; *Cheng et al.*, 1998; *Crutzen and Andreae*, 1990]. Since O_3 is toxic in nature, elevated concentrations can have negative impacts on human health and plants. In 1997, the U.S. Environmental Protection Agency (EPA) set the 8-hour standard at 0.08 ppm, and in a recent update, which became effective in May 2008, lowered the standard to 0.075 ppm. In order to keep to these limits and help making decisions to reduce O_3 levels in areas where standards are exceeded, it is crucial to understand the individual contributions to the ozone budget.

[3] The major factors contributing to elevated pollution levels in the contiguous US include industry and transportation, but wildfires can also have a significant impact on air quality [*Bravo et al.*, 2002]. Nationwide, California is one of the states with the highest wildfire activity. In 2007, about 13 million acres burned across the US with California accounting for ~10% of the acres burned nationally (http://www.nifc.gov/fire_info/ytd_state.htm). The fire season in California typically starts around mid-May and ends around October, when cooler weather and increased precipitation conditions prevail. In fall 2007, severe drought conditions and hot weather contributed to an extremely intense late fire season. Fires in October were the most destructive of the year and in addition to severe drought conditions and hot weather, the unusually strong Santa Ana winds in Southern California were a major contributor. Numerous fires were ignited by broken powerlines, and the strong winds further hindered the progress of fire fighters.

[4] The purpose of this study is to quantify the impact of the fall 2007 fires in California on surface O_3 levels. Photochemistry is less active later in the year and exceedances of ozone health standards are generally less frequent. However, extreme events like wildfires might still have significant impacts on air quality especially when they occur during periods conducive to ozone formation.

2. Simulations, Observations, and Model Evaluation

[5] The simulations in this study are performed with the global chemistry transport model Model for Ozone and Related Chemical Tracers, version 4 (MOZART-4). Modifications from Version 2 published by *Horowitz et al.* [2003] include, amongst others, a more complete description of anthropogenic hydrocarbon chemistry, the inclusion of tropospheric aerosols (extended from the work of *Tie et al.* [2001, 2005]), and on-line calculations of photolysis rates, dry deposition, water vapor, and biogenic emissions. For a detailed model description we refer to L. K. Emmons et al. (Impact of Mexico City emissions on regional air quality from MOZART-4 simulations, manuscript in preparation, 2008) and for model evaluation to *Pfister et al.* [2005, 2006, 2008].

[6] The simulations were run at T85 (1.4° x 1.4°) spatial resolution using meteorological fields from NCEP-GFS (National Center for Environmental Prediction, Global Forecasting System). The vertical resolution of the model consists of 42 hybrid levels from the surface up to 2 hPa (~45 km). Of those, about 7 are within the lowest kilometer.

[7] Daily emissions of trace gases and particulate matter from the California fires were estimated using the framework described in detail by *Wiedinmyer et al.* [2006]. Using the MODIS thermal anomalies to determine fire location and timing, the emissions of CO_2, CO, NO_x, SO_2, and NH_3 were derived. Emissions of VOCs for the MOZART

[1]Atmospheric Chemistry Division, National Center for Atmospheric Research, Boulder, Colorado, USA.

0094-8276/08/2008GL034747$05.00

Table 1. Mean, Standard Deviation, Median, and Mean Difference *d* for Observed and Modeled 8-Hour Concentrations of O_3 and NO_2 for Individual Types of Monitoring Sites[a]

	Rural			Urban			Suburban		
	Obs	Model	d	Obs	Model	d	Obs	Model	d
				O_3					
all	44 ± 13 (42)	52 ± 13 (50)	8 ± 12	38 ± 12 (36)	53 ± 16 (50)	15 ± 13	41 ± 13 (39)	54 ± 17 (50)	13 ± 14
$O_3^{FIRE} \leq 0.5$ ppb	41 ± 11 (40)	49 ± 12 (48)	8 ± 10	36 ± 10 (35)	50 ± 15 (47)	15 ± 12	38 ± 12 (38)	51 ± 16 (48)	13 ± 13
$O_3^{FIRE} \geq 5$ ppb	51 ± 14 (49)	60 ± 12 (61)	9 ± 13	42 ± 15 (41)	61 ± 15 (62)	15 ± 17	46 ± 17 (45)	62 ± 16 (63)	16 ± 17
				NO_2					
All	7 ± 4 (6)	4 ± 3 (3)	−3 ± 5	13 ± 10 (10)	5 ± 4 (4)	−8 ± 8	14 ± 10 (11)	5 ± 4 (4)	−9 ± 8
$O_3^{FIRE} \leq 0.5$ ppb	7 ± 4 (6)	4 ± 4 (4)	−2 ± 5	13 ± 9 (11)	5 ± 4 (4)	−8 ± 8	14 ± 10 (12)	5 ± 4 (4)	−9 ± 8
$O_3^{FIRE} \geq 5$ ppb	6 ± 4 (5)	5 ± 2 (4)	−2 ± 4	17 ± 15 (10)	6 ± 4 (5)	−11 ± 13	18 ± 16 (11)	6 ± 5 (5)	−11 ± 13

[a]Observed and model median appears in parentheses. O_3 and NO_2 concentrations are in ppb. Results are given for all data and for two subsets of 8-hour O_3^{FIRE} concentrations. Values restricted to averages over 10–18 LT, 11–19T, and 12–20 LT for 1 Sep–30 Nov.

chemical mechanism (Emmons et al., manuscript in preparation, 2008; http://gctm.acd.ucar.edu/mozart) were determined from emitted CO_2 and the type of land cover burned in each fire pixel using emission factors from *Andreae and Merlet* [2001]. A time series of the total fire emissions over California is shown in the auxiliary material.[1] There were two main peaks in fire intensity, one in early September (estimated 5 GgN of emitted NO_x) and the other towards the end of October (estimated 7 GgN of emitted NO_x). In comparison, anthropogenic NO_x emissions over California are 40 GgN/month and global biomass burning emissions for September through December amount to 1950 GgN. California fire emissions for CO for this time period are 366 GgC and for VOCs 65 GgC.

[8] Global emissions from biofuel and fossil fuel combustion, aircraft, lightning, ocean, soil and vegetation are included in the model, primarily from the European Union project POET (Precursors of Ozone and their Effects in the Troposphere) [*Olivier et al.*, 2003]. Asian anthropogenic emissions are from *Ohara et al.* [2007]. Biomass burning emissions for outside California are based on a climatology derived from emission inventories available for previous years [*van der Werf et al.*, 2006]. While all emission inventories are subject to large uncertainties, often more than a factor of 2, [e.g., *van der Werf et al.*, 2006; *Wiedinmyer et al.*, 2006] and can be a major part of model uncertainties, their quantification is beyond the scope of this study.

[9] We incorporated two categories of chemical tracer schemes in the model. The first keeps track of the amount of CO emitted from the California fires (CO^{FIRE}), the other follows the O_3 production from NO emitted from the California fires (O_3^{FIRE}). The latter scheme tags the emitted NO and maintains the tag through all simulated odd nitrogen species (e.g. PAN, nitrates, HNO_3). We also tag the O_3 produced by the photolysis of tagged NO_2 (NO_2^{FIRE}). Except for some minor reactions, O_3 in the MOZART chemical mechanism is only produced through photolysis of NO_2. The scheme is described in greater detail by *Lamarque et al.* [2005], *Pfister et al.* [2006] and *Hess and Lamarque* [2007]. The model simulations are started 1 January 2007, and for September through November the model concentrations of CO, O_3, NO_2, and the respective fire tracers CO^{FIRE}, O_3^{FIRE} and NO_2^{FIRE} are output hourly.

[10] The observational data set includes measured surface O_3 concentrations for September–December 2007 provided by the EPA Aeromatic Information Retrieval System (AIRS) (EPA, U.S. Environmental Protection Agency air quality system data mart, 2008, available at http://www.epa.gov/ttn/airs/aqsdatamart). We use hourly observations from all sites in California and group them dependent on their location setting into rural sites (55), urban sites (38) and suburban sites (72). The model data are interpolated to the time step and location of the observations and both the modeled and observed 1-hour values are averaged into 8-hour concentrations, the standard used by the EPA for assessing ozone violations.

[11] Table 1 lists the mean and median observed and modeled 8-hour concentrations and the mean difference between the model and the observations for the three different site categories. We calculate statistics for the full data set, and also use O_3^{FIRE} to separately derive results for high ($O_3^{FIRE} \geq 5$ ppb) and low fire ($O_3^{FIRE} \leq 0.5$ ppb) impacted subsets. In support of the interpretation, we include a comparison of modeled and observed NO_2 concentrations for monitoring sites where NO_2 measurements are available (30 rural, 21 urban, 46 suburban).

[12] The model matches the observed 8-hour O_3 values generally to within 15 ppb, with correlation coefficients in the range 0.5–0.6. Both observations and model simulations show largest O_3 concentrations for the high fire impacted subset. As a result, the absolute difference between modeled and observed concentrations is higher for this data subset; however, the relative difference does not depend on the estimated degree of fire impact. Yet, the comparison does depend on the monitoring site category (urban, suburban, or rural). The observations show a clear difference between the individual site categories with lowest O_3 and highest NO_2 concentrations at urban sites and highest O_3 and lowest NO_2 concentrations at rural locations. The model in contrast simulates little variability between the mean concentrations for the different site categories. The modeled mean concentrations agree more closely with observations at the rural sites, while they overestimate O_3 and underestimate NO_2 values to a greater extent at urban and suburban sites. This result, however, is not surprising as the model covers California in 35 grid cells. Thus, the model is not able to resolve localized emission sources which are more likely to influence measurements taken in or near urban centers, but is better suited to represent conditions farther downwind from

[1]Auxiliary materials are available in the HTML. doi:10.1029/2008GL034747.

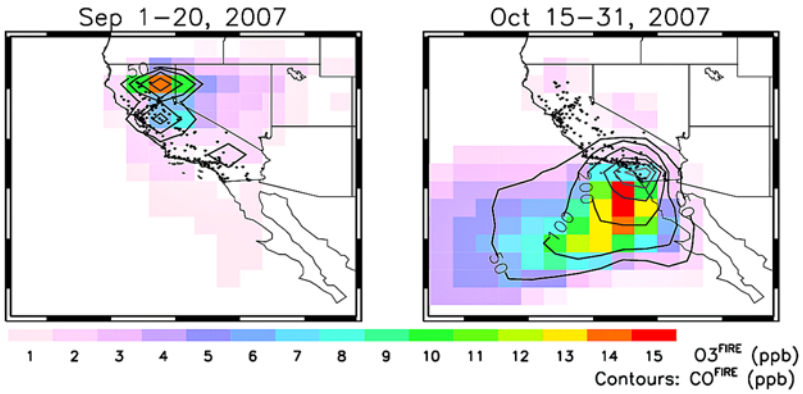

Figure 1. Mean modeled surface mixing ratios (ppb) for O_3^{FIRE} (filled contours) and CO^{FIRE} (contour lines) for (left) September 1–20 and (right) October 15–31. Dots indicate the locations of EPA monitoring sites.

source regions as is more characteristic of the rural monitoring sites.

3. Results and Discussion

[13] During the study period there were two main peaks in fire intensity. Fires during September took place mostly in the northern part of California, while fires in October were concentrated in the southern part of the state. Figure 1 shows the average concentrations of the model fire tracers O_3^{FIRE} and CO^{FIRE} for the two different time periods. The locations of the EPA monitoring sites are indicated in the plots.

[14] Our model tracers are restricted to tagging sources from within California, but it can be clearly seen that the impact of the fires reaches well beyond the state borders. During September, the California fires show a clear impact over large parts of Nevada, adding as much as 5 ppb to the modeled O_3 levels averaged over the fire period. In the October period, most of the fire pollutants were transported out over the ocean by the Santa Ana winds, which mitigated the impact on continental air quality.

[15] An interesting feature seen in Figure 1 is that the region of maximum impact of fire emitted CO does not necessarily co-locate with the maximum in O_3 produced from fire precursors. CO is directly emitted and the maximum impact occurs right over the source region. O_3, however, is chemically produced from fire-emitted precursors and the region of maximum impact is shifted downwind of the source region with the distance dependent on transport times and chemical regime. For October we actually find the region of maximum O_3^{FIRE} concentrations off the coast. Many modeling studies use CO tracers or passive tracers for determining the impacts of selected sources on trace gas budgets, but these results indicate that such a method can have significant shortcomings when looking at photochemically active species and especially when examining smaller spatial scales.

[16] From Figure 1 we find that the average model-estimated amount of O_3 produced from the fires can reach up to ~15 ppb when averaged over the fire period. To obtain an independent estimate, we analyze observations at the EPA monitoring sites along with information about the modeled fire impact. We group the entire data set of modeled and observed 8-hour values into two categories based on the timing of the fires: for one we select all data for 1–30 September, for the other all data for 8 October–8 November. Both time periods are chosen to include the time of most intense burning as well as about 2 weeks afterwards, or as in the case of October, a week before and a week after the fires. The separation of these shorter time periods helps to reduce the impacts of seasonal changes in photochemistry. We then calculate statistics of the observed and modeled 8-hour ozone concentrations binned by values of O_3^{FIRE} concentration, and do this for six subsets of data grouped by the two time periods stated above and by site category. The results are included in Figure 2 showing for both observations and model the absolute deviation from their respective mean concentration. Mean concentrations are calculated separately for each subset. We only include 8-hour concentrations centered in the local afternoon (10–18 LT, 11–19 LT, 12–20 LT) to preclude the results being impacted too strongly by the diurnal cycle in O_3 concentrations.

[17] Both model and observations show an overall increase in O_3 concentrations with increasing estimated fire impact. Best agreement is seen for rural sites, while the increase at urban and suburban sites is subject to higher variability and larger discrepancies between modeled and observed enhancements. This is due to the fact that the global model is less suited to simulating the urban environment (Section 2, Table 1) and for this reason we focus our quantitative analysis predominantly on rural monitoring sites. We find that the mean observed (modeled) enhancement in 8-hour O_3 concentrations for $O_3^{FIRE} > 10$ ppb is 9 ± 14 ppb (8 ± 11 ppb) for September and 8 ± 12 ppb (8 ± 11 ppb) for October. The percentages of data points in these categories are 10% and 7%, respectively. For data corresponding to $O_3^{FIRE} > 20$ ppb, the observed (modeled) enhancements increase to 12 ± 14 ppb (10 ± 10 ppb) for September and 10 ± 13 ppb (12 ± 9 ppb) for October. 5% and 3% of the data fall into these categories, respectively.

[18] Varying conditions of photochemical productivity (e.g. changes in temperature or cloudiness) can have an impact on the above statistics and to test this we repeated the calculations for different limitations of the data subsets by varying the length of the time periods chosen or selecting stations for different latitudinal zones. In either case, the general conclusions remain the same giving confidence that

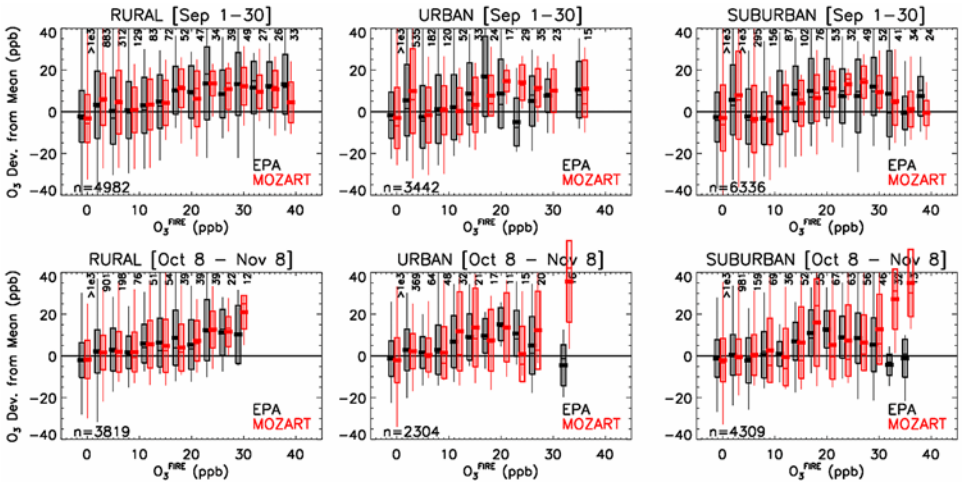

Figure 2. Observed and modeled 8-hour O_3 concentrations for 10–18 LT, 11–19LT and 12–20 LT binned by the fire tracer O_3^{FIRE}. Shown is the deviation from the mean concentrations (ppb); results are shown for rural, urban and suburban sites, and for the two main fire periods (Sep 1–30 and Oct 8–Nov 8). The number of data points in each category is indicated in the upper part of each plot, the total number of data points in the lower left corner. See text for more details.

changes in photochemical conditions have a small impact on the results. We also examined using CO^{FIRE} instead of O_3^{FIRE} as a tracer (not shown here). In that case we also detect a positive trend, but we identify fewer statistically significant results and see a larger variability because of the lack of co-location of peaks in CO^{FIRE} and peaks in O_3^{FIRE}.

[19] At urban and suburban sites, the model shows a tendency to overestimate the magnitude of fire impact on O_3 concentrations, which is in line with the model underestimate of NO_2 at urban and suburban sites (Section 2). The model dilutes the high pollution concentrations in urban environments, mainly due to the coarse model resolution. Adding additional NO_x in a less polluted environment causes a larger ozone increase compared to a NO_x and VOC richer environment. In support of this statement, we show in Figure 3 the modeled relationship between NO_2^{FIRE} and O_3^{FIRE} concentrations for three different NO_x regimes. The latter is estimated by subtracting NO_2^{FIRE} from total NO_2 concentrations. For the same amount of NO_2^{FIRE}, the NO_x poor environment generally gives a larger increase in O_3^{FIRE} compared to a NO_x rich environment. While these statistics point towards a stronger fire impact at rural versus urban sites, we cannot provide clear proof with the available data set.

[20] Finally, we also use the data sets to investigate the frequency of ozone exceedances (8-hour average O_3 > 0.08 ppm). For this purpose we calculate the maximum observed 8-hour O_3 value and the corresponding O_3^{FIRE} tracer value for each day at each rural monitoring site. There are 81 occurrences of O_3^{FIRE} > 15 ppb, and in 17% of these the observed O_3 concentrations exceeded the limit of 0.08 ppm. For O_3^{FIRE} > 10 ppb (n = 116) the frequency of exceedances is 12%, and for O_3^{FIRE} > 1 ppb (n = 434) it is 11%. In comparison, when O_3^{FIRE} < 1 ppb (n = 367), exceedances occur only 5% of the time.

[21] In total there are 66 exceedances for September through October. Only three of them occur in October, the first at the beginning of the month with a small estimated fire contribution (O_3^{FIRE}~1ppb), while the two later in the month occurred during the time of the fires with O_3^{FIRE} > 15 ppb. There might have been more violations if the winds hat not moved a major part of the pollution offshore (Figure 1).

[22] Revising the calculations for the new public health standard of 0.075 ppm, the number of exceedances nearly doubles and measured concentrations exceed the 0.075 ppm level 32% of the time when O_3^{FIRE} > 15 ppb, 17% of the time when O_3^{FIRE} > 1 ppb, and 9% of the time when O_3^{FIRE} < 1 ppb.

4. Conclusions

[23] We used a combination of surface observations of ozone and global model simulations to quantify the impacts of the California fires in autumn 2007 on surface ozone. For this purpose an O_3 fire tracer is incorporated into the model keeping track of the amount of O_3

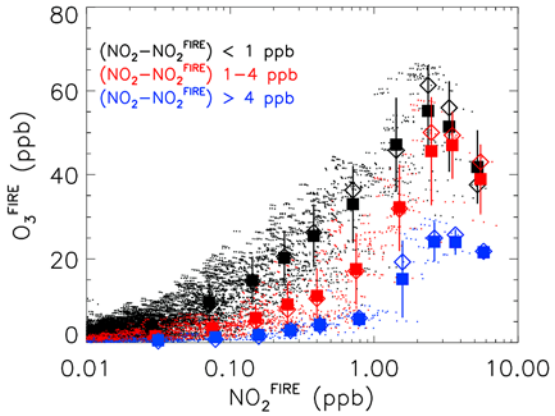

Figure 3. Relationship between surface concentrations of the model fire tracers NO_2^{FIRE} and O_3^{FIRE}. Mean (■), median (◇) and standard deviation of NO_2^{FIRE} bins are plotted over individual data points. Data are grouped into different NO_x regimes estimated by subtracting NO_2^{FIRE} from total NO_2 concentrations. Data set is limited to the month of September and to local afternoon values to limit the impact of temporal changes in photochemistry.

produced from fire-emitted NO and providing essential information for extracting quantitative information from the observations.

[24] Even though the spatial resolution of a global model limits resolving the differences between urban and rural environments, the combination of the modeled fire impact with a set of surface observations has been shown to be valuable in estimating the impact of the fires on surface O_3. We find a clear increase in observed surface O_3 when the model predicts the observations to be impacted by the fires with, on average, an enhancement of about 10 ppb in afternoon 8-hour concentrations for cases of high fire impact. Data and model analysis indicate that the less polluted areas (i.e. low NO_x environment) generally experience a stronger impact, but further studies are needed to confirm this.

[25] A major part of incidences when observed 8-hour concentrations exceeded the public health standards are associated with clearly elevated concentrations of the model O_3 fire tracer: exceedances occurred in 17% of the cases when the fire tracer was larger than 15 ppb and in 11% when the fire tracer was greater than 1 ppb. In comparison, for fire tracer concentrations less than 1 ppb, the frequency of occurrence of exceedances is 5%. Our findings demonstrate a clear impact of wildfires on surface O_3 nearby and potentially far downwind from the fire location, and show that intense wildfire periods frequently can cause O_3 levels to exceed current health standards.

[26] **Acknowledgments.** The authors acknowledge Jean-François Lamarque and Mary Barth for valuable input to the manuscript. The work was supported by NASA grants NNG06GB27G and NNX07AL57G. NCAR is operated by the University Corporation of Atmospheric Research under sponsorship of the National Science Foundation.

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