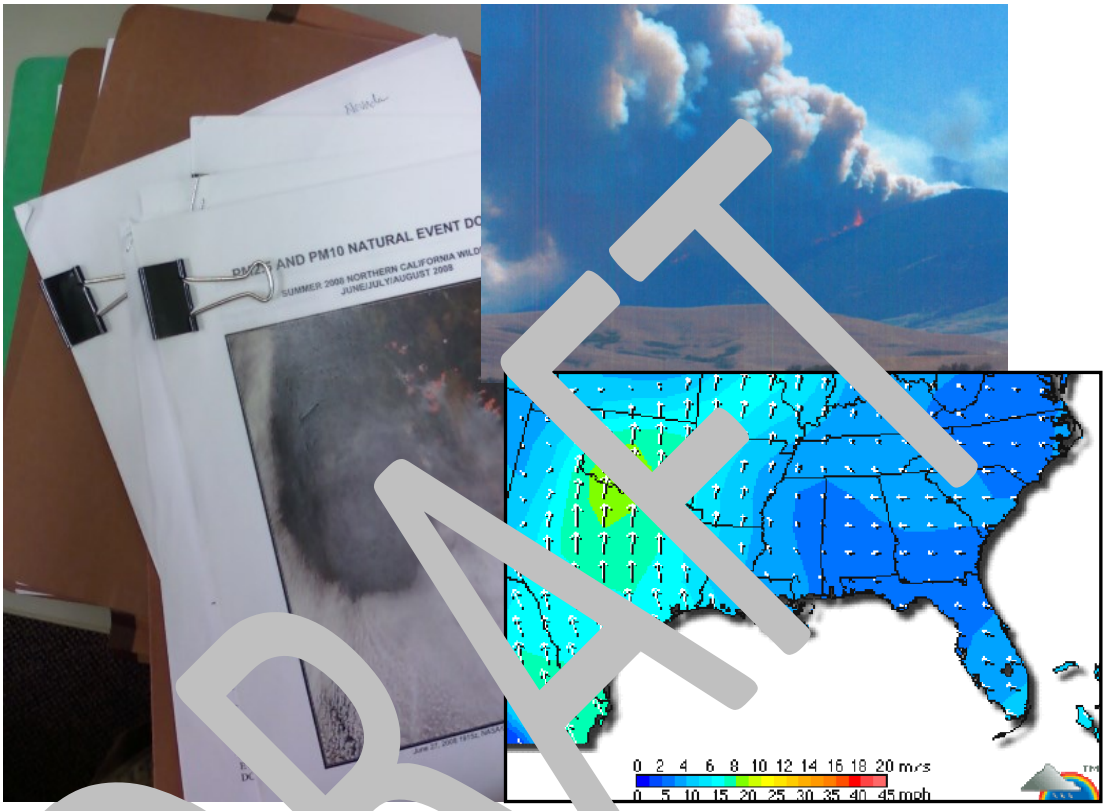
# Exceptional Event Rule Reports on Data Influenced by Wildland Fire Smoke 2007-2012






**Prepared for the**
**National Wildfire Coordinating Group's (NWCG)**

**Smoke Committee (SmoC)**

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# List of Acronyms

BAM- Beta Attenuation Monitor
BLUESKY- BlueSky framework of models for demonstrating smoke conditions
CMAQ- Congestion Mitigation and Air Quality Improvement Program
DEQ- Department of Environmental Quality
EER- Exceptional Events Rule
EPA- Environmental Protection Agency
GASP- GOES Aerosol/Smoke Product
ICS-209- Wildfire Incident Status summary
HYSPLIT- hybrid Single Particle Langrangian Integrated Trajectory Model
MODIS- Moderate Resolution Imaging Spectroradiometer)
NAAQS- National Ambient Air Quality Standards
NCEP- National Centers for Environmental Prediction
NESDIS- National Environmental Satellite, Data, and Information Service
NIFC- National Interagency Fire Center
SIS- Smoke Impact Spreadsheet, a planning model for the calculation of particulate matter
TEOM- Tapered Element Oscillating Microbalance
VSMOKE- The VSmoke smoke dispersion model

# Executive Summary

The Exceptional Events Rule (EER) provides an avenue whereby states may flag high pollutant concentration measurements resulting from uncommon or exceptional events for possible exclusion from their NAAQS attainment determinations. For this study input from 36 States yielded 34 exceptional event documents which have been submitted. In total over 3400 pages of documentation were reviewed.

In the reports assessed for this review, smoke sources were either derived from prescribed burning in the eastern US, or wildfire in the western US. Smoke transported from across state lines was documented in wildfire cases such as Nevada 2005. Six of 34 reports described a prescribed fire event with an average burn area size of 1,957 acres. These numbers are relatively small compared to the 29 reports highlighting wildfires. Wildfires ranged in size from 531 to 1,980,552 acres and averaged 454,834 acres.

Incident and pollutant comparisons between prescribed and wild fires.

| | **Prescribed Fire** | **Wild Fire** |
|---|---|---|
| Fire acres | 384-4,000 | 531-1,980,552 |
| Average fire acres | 1,957 | 454,834 |
| PM 2.5 concentrations (24 hr average µg $m^{-3}$) | 29.7-112.7 | 7.5-200.2 |
| PM 10 concentrations (24 hr average µg $m^{-3}$) | Na | 71.8-301.9 |
| Ozone concentrations (8 hr average ppm) | 0.91-0.111* | 0.02-0.161 |
| Reports reviewed | 6 | 29 |

**Pollutant Concentrations and sources**

Particulate matter 2.5 is the criteria pollutant most often documented and made up 80% of the examples reviewed here. Ozone and PM 10 reports were less common; we reviewed 8 and 3 report ozone and PM 10 reports, respectively.

**Common demonstration methods**

The most common aids to demonstrating an exceptional event to be the result of fire are satellite imagery of the fire and HYSPLIT or WindRose trajectories to demonstrate smoke transport from the fire to the monitoring sites. To indicate the event is causing greater concentrations than normal several years of data points are often compared. The comparison methods are commonly percentile measurements or statistical analysis of variance. Compilations of news articles are often used to further demonstrate the smoke impacts from fires. Exceedance is most often demonstrated using regression analysis to show what the pollutant levels would have been in the absence of fire. Ozone exceedance is more complex to demonstrate as it is a secondary pollutant. Additional methods to show ozone formation from fires include demonstrating elevations in precursor emissions including carbon monoxide and NOx, and particulate matter to demonstrate these are the result of smoke. Scientific research discussing ozone formation from fire is also often included in these documentations.

**EPA Concurrence**

Of the data points reported for the various exceptional events approximately one third received concurrence, with the majority of these being PM 2.5 points. Of the ozone data points, a small fraction received concurrence due to a fire which over-ran the monitoring stations. The remaining 8 data points were from a severe wildfire season in California in 2008. Reasons for which reports did not receive concurrence included lack of adequate documentation to demonstrate impacts from fire when citing transport smoke as the reason for the exceedance, and lack of a smoke management plan when demonstrating an ozone event.

**Costs of Reporting**

Exceptional event reports vary in the time needed to produce them. The time to complete a report was reported to range from 24 hours for one event in which a report template is already in use, to 450 staff hours. An estimate for an ozone report in Region 9 is 940 staff hours. Based on the annual salary for an Air Quality Specialist at the GS-11 pay scale, this would produce a per-report cost range of $629 to $24,618. This does not include the extraneous costs of lab analysis or services are contracted out by the agency.

# Introduction

The Clean Air Act is the foundation on which the Environmental Protection Agency builds its policies with regard to protection of human health and welfare from air pollutants. Smoke from planned (prescribed) and unplanned (wild) fires is made up of fine particulate matter and compounds that can result in ozone formation. The goal of the Clean Air Act is to limit criteria pollutants such as ozone and particulate matter to levels established by National Ambient Air Quality Standards (NAAQS) (Table 1). States continually monitor air quality to determine whether they are meeting the NAAQS.

**Table 1.** National Ambient Air Quality Standards for ozone and particulate matter.

| Pollutant | Level | Averaging time |
|---|---|---|
| Ozone | 0.075 ppm | 8 hour |
| | 0.12 ppm | 1 hour |
| Particulate Matter 2.5 | 35 $\mu g\ m^{-3}$ | 24 hour |
| | 15.0 $\mu g\ m^{-3}$ | Annual |
| Particulate Matter 10 | 150 $\mu g\ m^{-3}$ | 24 hour |

The Exceptional Events Rule (EER) promulgated in 2007 by the U.S. Environmental Protection Agency (EPA) provides an avenue whereby states may flag pollutant exceedances resulting from uncommon or exceptional events to be omitted from their NAAQS attainment determination. For data to be omitted, it must be reviewed and concurred upon by the EPA. Data considered under this rule must satisfy the following criteria (EPA 2007):

- The event must not be reasonably controllable or preventable.
- There must be a clear casual relationship between the measurement under consideration and the event that is claimed to have affected the air quality in the area.
- The event is associated with a measured concentration in excess of normal historical fluctuations, including background.
- There would have been no exceedance or violation but for the event.

Numerous exceptional events demonstrations have been submitted as a result of wildland fire since the 2007 EER was finalized. Each state air regulatory agency may submit these materials to their respective EPA regional office for consideration. The regional nature of this process makes it difficult to know the levels of pollutants and level of documentation being submitted as exceptional events due to wildland fire nationwide. The purpose of this review is to characterize EER reports to the EPA for states within the contiguous U.S. This review evaluates exceptional event reports from numerous states to compile a snap-shot of EER submissions from fire. The results will focus on the following details:

- Pollutants, concentrations, and sources (planned or unplanned ignitions)
- Complexity, length, and methodology of reporting documents
- EPA determination and reasons for or against concurrence.
- Cost of reporting

# Methods

To evaluate the report details and the EPA's determination, two documents were requested; (1) the States' submitted report to the EPA describing the event, and (2) the EPA's response letter to the State outlining its determination. To obtain this information air program offices in the contiguous US were contacted via phone and email. Additional exceptional event information was taken from state air program web pages.

Thirty five states responded to the inquiry and indicated whether or not they have had an exceptional event, and if so, where those records could be found (Figure 1). Documentation from 16 states was obtained. Thirty nine reports were compiled and 34 are analyzed herein. The omitted reports either had not been submitted or were not reviewed by the EPA. Each of the 34 exceptional event reports was reviewed with regard to its geographic location, pollutant of concern, concentration of pollutants, fire type, burn area, and report details such as demonstration methodology, report length, and EPA response (when available). For very early events submitted under EER, the event itself may have occurred prior to 2007 rule proclamation, however because these events were submitted under the current EER they are included in this review.

This assessment includes reports that had been concurred upon by EPA, reports that were not concurred upon, and reports that were still pending decision. The percentage of exceptional events which received concurrence is described by compiling the outcome of individual data points flagged. Each report, its contents, and methodology are tabulated for easy reference. Each report, excluding pending examples, is described in one to three paragraphs in the results section.

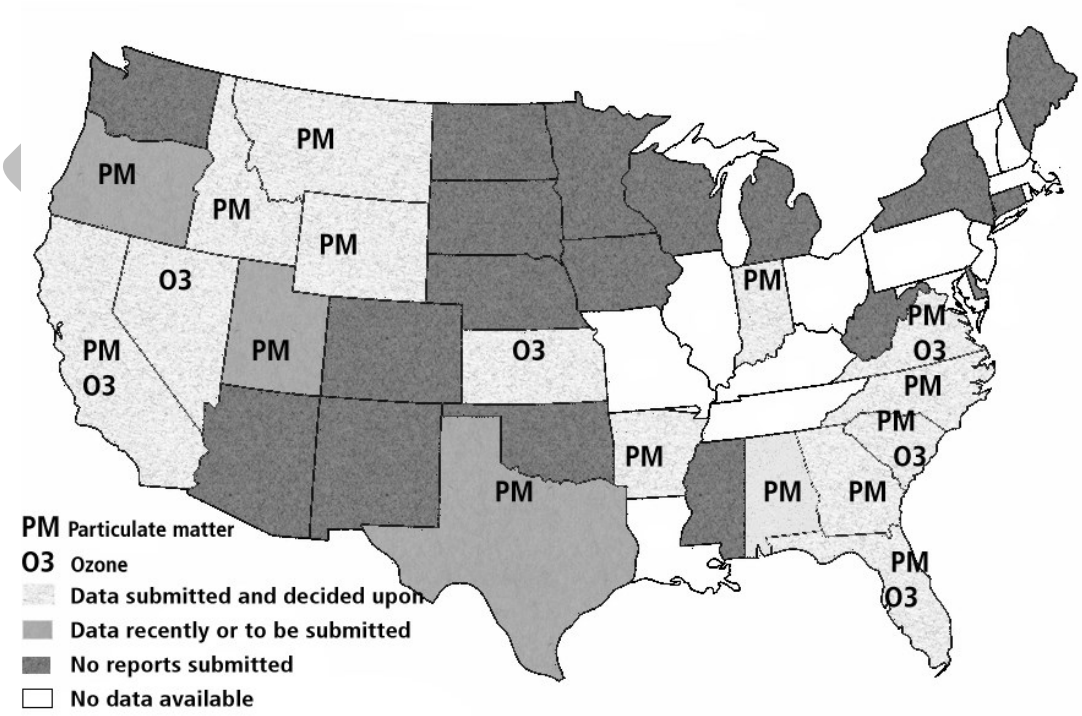


**Figure 1.** Map of the contiguous United States depicting states evaluated for exceptional events in color. States for which no data was collected are shown in white.

# Results and Discussion

### Pollutant sources, concentrations, and severity

In the reports assessed for this review, nearly 20% were written to describe prescribed fire events, while the majority were the result of wildfires. Wildfire reports described incidents covering larger areas and high concentrations of pollutants. Geographically, the eastern and Midwestern states were the sites of the prescribed fire events, and wildfire events were present in both the eastern and western united states, however western states tended to have larger fire incidents (Table 2).

**Table 2.** Incident and pollutant comparisons between prescribed and wild fires.

| | **Prescribed Fire** | **Wild Fire** |
|---|---|---|
| Fire acres | 384-4,000 | 531-1,980,552 |
| Average fire acres | 1,957 | 454,834 |
| PM 2.5 concentrations (24 hr average μg $m^{-3}$) | 29.7-112.7 | 7.5-200.2 |
| PM 10 concentrations (24 hr average μg $m^{-3}$) | Na | 71.8-301.9 |
| Ozone concentrations (8 hr average ppm) | 0.91-0.111* | 0.02-0.161 |
| Reports reviewed | 6 | 29 |

*Burn over-ran monitor

Data points flagged as a result of wildland fire varied widely in their impact. The 24 hour concentrations of PM 2.5, and PM 10 submitted in these reports ranged from 7.5 – 200.2 μg $m^{-3}$ and 71.8-301.9 μg $m^{-3}$, respectively. These values range from below the 24 hour average NAAQS for particulate matter to above. For ozone data points, the average eight hour reported values range from 0.02 to 0.161 ppm. These ranges also vary from below the NAAQS for ozone to above.

### Methods, complexity, and details

Due to the nature of the two pollutants reported, the methodology, length of reporting, and concurrence details will be addressed separately for ozone and particulate matter. Demonstration package details are outlined in Table 3, reporting methods are outlined in Table 4.

#### *Ozone report length and methodology*

Ozone data points were detailed in eight of the 34 documentation packages reviewed. The majority of these are the result of wildfires. Reports vary in length from 35-1021 pages, including appendices. Two very short reports, ~7 pages in length, described situations in which prescribed fire over-ran monitoring sites. A more typical length for these is approximately 100 pages. Ozone exceptional event reporting poses a challenge, as it is not directly emitted from fire. This adds complexity to the documentation process. Methods which have been employed to document ozone often include demonstrating a simultaneous rise in particulate matter levels, and linking the particulates to fire, and demonstrating a rise in precursor emission presence. Methods employed for both ozone and particulate matter include wind trajectories, satellite imagery of smoke plumes, and the inclusion of meteorological data such as wind speed, wind direction, mixing heights, etc.

Specific methods for showing ozone precursor presence as the result of fire include cited increases in CO via published emission factors, and increases in NOx demonstrated via both ground and satellite measurements as in the California demonstration for Sacramento County June 23- July 10th 2008. In another example in Clark County Nevada, ozone from 2005 wildfires was measured directly in the smoke plume via aerial mounted monitors, though this is not a common method. In the examples from California and Nevada, the case for ozone formation from fires is often supported via scientific literature included either as an appendix, or as a summary with cited references within the main report.

Statistics to indicate unusually high concentrations of pollutants have been run on one to 10 years of data, though a range of 4-8 years is more common. Statistical methods have included a comparison of average levels for the dataset assembled, as well as regression analysis to indicate unusually high concentrations. A similar method was employed by California for their June 23 to July 10$^{th}$ 2008 ozone exceedance demonstration; surrogate days, with similar meteorology that did not take place during the fire, were used to show what ozone levels likely would have been in the absence of fire.

For atypical circumstances, such as when a fire overruns a monitor site the requirement may be much lower. For example, EPA concurred with two instances involving prescribed fires that burned into the area where the monitors were placed, these were just 7 pages in length (South Carolina 2007 and 2008). The documentation was straight forward and comprised almost entirely of photographs and fire reports.

***Particulate report length and methodology***

Particulate matter reports comprise nearly 80% of the reports included in this assessment to date. All but two of these describe impacts from wildfire. Reports vary in length from 25-369 pages with an average length of 77 pages. In all cases these consist of direct measurements of particulate matter. The most common means of demonstrating an event as the result of fire is with maps of the incident, satellite imagery of smoke plumes, and wind trajectories. Further support is commonly provided in the form of local news articles describing the fire, and information taken from fire reports either from NIFC, or the agency on whose land the fire burned.

Data ranges varying in length from several days to 20 years have been used in statistical analysis though four years is the most common length of time for these analyses. The statistical methods used to demonstrate the exceedance often include concentration levels above the 98$^{th}$ percentile for the day the data was collected and linear regression analysis.

**Table 3.** Exceedance values represent individual data points, or the range of individual data points flagged within the report, unless timed averages were specified. 'Ustd' refers to values which were not stated within the document.

| EPA Region, State | Event Date | Fire Type and Approximate Burned Acres | | Monitoring Data Requested for exclusion | | | | | | | | | Pgs | EPA Concurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PM 2.5 (24-hr) | | | PM 10 (24-hr) | | | Ozone (8-hr) | | | | |
| | | Rx | Wildfire(s) | values | days | Data points | values | days | Data points | values | days | Data points | | |
| 4 FL | 2007 | | 550,459 | 7.5-87.9 | 53 | 278 | 71.8-178-8 | 2 | 2 | 0.02-0.114 | 2 | 4 | 163 | Yes PM2.5 (140/294)<br>Yes PM 10 (1/2)<br>No Ozone (0/89) |
| 4 GA | 2007 | 4000+ | 564,000 | 29.7-112.7 | 12 | 16 | | | | | | | 178 | Yes (12/16) |
| 4 NC | Mar. 22 2007 | 1,644 | | 43.4 | 1 | 1 | | | | | | | 45 | Yes |
| 4 NC | Jun. 19 2007 | 1,800 | | 43.17 | 1 | 1 | | | | | | | 29 | Yes |
| 4 NC | Aug. 5 2007 | | 282,140 | 37.08-42.25 | 3 | 3 | | | | | | | 89 | No |
| 4 NC | Aug. 4 2007 | | unstated | 35.8 | 1 | 1 | | | | | | | 47 | No |
| 4NC | Aug. 17 2007 | | 1,927,791 | 38.2 | 1 | 2 | | | | | | | 68 | Pending |
| 4 NC | May 3 2007 | | 517,000 | 36.25 | 1 | 1 | | | | | | | 31 | Yes |
| 4 NC | Aug. 7 2007 | | 531 | 40.208 | 1 | 1 | | | | | | | 28 | - |
| 4 NC | Jun. 11 2007 | | 5,400 | 60.58 | 1 | 1 | | | | | | | 37 | Yes |
| 4 NC | Jun. 14 2007 | | 5,400 | 61.04 | 1 | 1 | | | | | | | 35 | Yes |
| 4 NC | Jun. 2008 | | 41,060 | 36.6-99.0 | 4 | 8 | | | | | | | 40 | Yes |
| 4 NC | Mar. 31 2008 | | ≥1000 | 41.7 | 1 | 1 | | | | | | | 25 | Yes |
| 4 SC | 03/29/07 | 384 | | | | | | | | 0.091 | 1 | 1 | 7 | Yes |
| 4 SC | 02/20/08 | unstated | | | | | | | | 0.111 | 1 | 1 | 7 | Yes |
| 4 SC | 2007 | | unstated | 36.0-46.7 | 5 | 16 | | | | | | | 41 | Yes (6/16) |
| 4 VA | Jun 6- Jul 5 2008 | | 45,944 | 38.2-85.7 | 12 | 21 | | | | .076-0.11 | 4 | 8 | 109 | YES PM, NO ozone |
| 5 IN | May 23- Jun. 2 2007 | | ≥233,718 | 22.8-41.5 | 11 | 153 | | | | | | | 165 | YES (19/153) |
| 6 AR | May 24 2007 | 0 | 663,700 | 36.4-46.5 | 1 | 2 | | | | | | | 38 | Yes |
| 7 KS | April 7-8 2009 | ≥7,500 | | | | | | | | 0.079-0.095 | 2 | 4 | 35 | No |
| 8 MT | 2007 | | Unstated | 35.4- | 11 | 38 | | | | | | | 369 | Yes |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 195.3 | | | | | | | | | | |
| 8 UT | Jul. 9 2007 | | Unstated | 44.3 | 1 | 1 | | | | | | | 27 | Yes |
| 8 WY | Aug. 15 2006 | | ≥31,052 | 39.2 | 1 | 1 | | | | | | | 31 | Yes |
| 8 WY | Aug. 2007 | | Unstated | 27.4-34.8 | 2 | 4 | | | | | | | 61 | Pending |
| 8 WY | Aug. 4 2008 | | ≥15,089 | 49.8 | 1 | 1 | | | | | | | 42 | Yes |
| 9 CA | Jun 23 - Jul 10 2008 | | ≥1,000,000 | | | | | | | 0.126-0.161 | 3 | 8 | 1021 | Yes |
| 9 CA | Oct. 22-23 2007 | | Unstated | | | | | | | 0.079-0.086 | 2 | 4 | 21 | Pending |
| 9 CA | Sep. 6-9 2007 | | 65,000 | 36 & 45 | 2 | 2 | | | | | | | 264 | Pending |
| | | | | | | | | | | | | | | |
| 9 CA | Jul. 8 2007 | | 25,000 | 41 | 1 | 1 | | | | | | | 62 | Yes |
| 9 CA | Jul. 17 2007 | | 20,000 | | | | 205 | 1 | 1 | | | | 69 | Pending |
| 9 CA | Jun 22-Aug 16 2008 | | 1,157,930 | 18-200.0 | 25 | 133 | 176.9-301.9 | 7 | 9 | | | | 81 | Yes, 13/133 PM 2.5 |
| 9 NV | Jun. 29-30 | | ≥1,313,870 | | | | | | | 0.083-0.105 | 2 | 28 | 92 | No |
| 10 OR | Sep. 25 2009 | | ≥14,560 | 62.5 | 1 | 1 | | | | | | | 47 | Yes |
| 10 ID | Aug 4- Sep 12 2007 | | ≥1,980,552 | -37.4-172.3 | 6 | 6 | | | | | | | 36+14 | Yes |

**Table 4.** Methodology used by states as evidence of an exceptional event (PM indication represents PM 2.5 and PM 10).

| Region | State | Prescribed Fire | Wildfire | PM | Ozone | Meteorological data | News reports | Particle speciation | Photography | Trajectory (HYSPLIT, other) | Satellite imagery | Percentile method | Line Graph | Comparison of means | Years of analysis data | Analysis of Variance | Organic Mass Index | Regression/surrogate days | Linear modeling | CMAQ modeling | Bluesky Modeling | Air advisory | Hazard reports | State or Fed. Fire Report | BSMP cited in document | Smoke Mgt Plan cited | Other elevated pollutants | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | FL | | • | • | • | | • | | | | • | | • | | 2 | | | | | | | • | • | | | | | PM (141/296) , No Ozone |
| 4 | GA | • | • | • | | • | • | • | | • | • | | | • | 5 | | | | | | | • | | | | | | Yes (12/16) |
| 4 | NC | • | | • | | • | | | | • | | • | | | 4 | • | | | • | | | | | | • | | | Yes |
| 4 | NC | • | | • | | • | | | | • | | • | | | 4 | • | | | | | | | | • | | | | Yes |
| 4 | NC | | • | • | | | | | | • | • | • | | | 4 | • | | | | | | | | • | | | | No |
| 4 | NC | | • | • | | | | • | | • | • | • | | | 4 | • | | | | | | | | • | | | | No |
| 4 | NC | | • | • | | • | | | | • | • | • | | | 3 | | | | | | | | | • | | | | Pending |
| 4 | NC | | • | • | | • | • | | | • | • | • | | | 4 | • | | | | | | | | | | | | Yes |
| 4 | NC | | • | • | | • | • | | | • | | • | | | 4 | • | | | | | | | | | | | | Pending |
| 4 | NC | | • | • | | | • | | | • | | • | | | 4 | • | | | | | | | | • | | | | Yes |
| 4 | NC | | • | • | | • | • | | | • | | • | | | 4 | • | | | | | | | | | | | | Yes |
| 4 | NC | | • | • | | • | • | | | • | • | • | | | 4 | | • | | • | | | | | | | | | Yes |
| 4 | NC | | • | • | | • | | | • | • | | • | | | 4 | | • | | • | | | | | | | | | Yes |
| 4 | SC | • | | | • | | | | • | | | | | | - | | | | | | | | | | | | | Yes |
| 4 | SC | • | | | • | | | | • | | | | | | - | | | | | | | | | | | | | Yes |
| 4 | SC | | • | • | | | | | | • | | | | | - | | | | | | | | | | | | | Yes (6/16) |
| 4 | VA | | • | • | | | | | | | • | • | | | 4-8 | | | | • | • | • | • | | • | | | | Yes |
| 4 | VA | | • | • | • | | | | | | | | | | 4-8 | | | | • | • | • | • | | • | | | • | Yes PM, No Ozone |
| 5 | IN | | • | • | | • | | • | | • | | • | | | 8 | | | | | | | | | | | | | Yes |

| Region | State | Prescribed Fire | Wildfire | PM | Ozone | Meteorological data | News reports | Particle speciation | Photography | Trajectory (HYSPLIT, other) | Satellite imagery | Percentile method | Line Graph | Comparison of means | Years of analysis data | Analysis of Variance | Organic Mass Index | Regression/surrogate data | Linear modeling | CMAQ modeling | Bluesky Modeling | Air advisory | Hazard reports | State or Fed. Fire Report | BSMP cited in document | Smoke Mgt Plan cited | Other elevated pollutants | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | AR | | • | • | | • | • | | • | • | • | • | | | 3 | | | | | | | • | | • | | • | | Yes |
| 7 | KS | • | | | • | • | • | | | | • | | | • | 1 | | | | | | | | | | | | • | No |
| 8 | MT | | • | • | | | | | • | | • | | | • | 3 | | | | | | | • | | • | | • | | Yes |
| 8 | UT | | • | • | | | | • | | • | • | • | | • | 10 | | | | | | | • | | | | | | Yes |
| 8 | WY | | • | • | | | • | • | • | | • | | | • | 1 | | | | | | | | | • | | | | Yes |
| 8 | WY | | • | • | | | • | | • | • | • | | | • | 1 | | | | | | | • | | • | | | | Pending |
| 8 | WY | | • | • | | • | • | • | | • | • | | | • | 1 | | | | | | | | | • | | | | Yes |
| 9 | CA | | • | | • | • | • | • | | • | • | | | | 7 | | | • | | | | • | | | | | • | Yes |
| 9 | CA | | • | | • | • | | | | | • | | | | | | | | | | | • | | | | | • | Pending |
| 9 | CA | | • | • | | • | • | | | • | • | • | | • | 7 | | | | | | | • | | • | | | | Pending |
| 9 | CA | | • | • | | | • | • | | • | • | • | | • | 7 | | | | | | | • | | • | | | | Yes |
| 9 | CA | | • | • | | • | • | | | • | • | • | | • | 20 | | | | | | | • | | | | | | Pending |
| 9 | CA | | • | • | | • | | | | • | • | • | | • | 8 | | | | | | | • | | • | | | | Yes |
| 9 | NV | | • | | • | • | | • | | • | • | | | • | 5 | | | • | | | | | | | | | • | No |
| 10 | ID | | • | • | | | • | | • | • | • | | | • | .66 | | | | | | | | | | | | | Yes |
| 10 | OR | | • | • | | • | • | | • | • | • | | | • | 8 | | | | | | | | | | | | | Yes |

# Examples with EPA determinations - Ozone

**California (June 23 - July 10 2008)**

In the summer of 2008 over 1.1 million acres burned in wildfires, impacting numerous reference monitors throughout the state of California. The resulting emissions impacted eight data points over three days with ozone levels ranging from 0.126 to 0.161ppm in Folsom CA. Initial information about the circumstances surrounding the fires was presented with details on ozone formation from smoke, and satellite images of plumes form the fires. Impact from fires was shown with transport patterns indicated with satellite imagery, elevated PM 2.5 levels in conjunction with the elevated ozone levels, particulate speciation to show these were the result of wild fire. Elevated precursor emissions of NOx were also indicated during the days covered in the report.

'Surrogate days' were used to indicate the levels of ozone that were likely to have occurred in the absence of fires. These surrogate days were determined by using the concentrations on days during which similar meteorological conditions as the exceptional event days existed, however air quality was known to be good. The main report is composed of 85 pages with 927 pages of supporting information, including a 118 page meteorology section, public advisories, news reports, and regression analysis. EPA concurred with the state to flag these data points as exception. EPA technical support guidance indicates the causal relationship was clearly demonstrated with meteorological conditions conducive to transport of emissions, satellite imagery of smoke in the monitoring area, documented increases in PM 2.5, particles consistent with burning biomass, and demonstration that emissions from the fire reached ground level monitors. The use of 'surrogate days' developed with previous air and meteorological data and regression analysis, demonstrated the levels of ozone recorded during the fire were significantly greater than they would have been in the absence of the fires.

**Nevada ( June 29-30 2005)**

The Clark County demonstration was another detailed example of ozone impacts, in this case EPA did not concur with the state. In 2005 eight wildfires over 40,000 acres in size were uncontained during the event. The total area burned would eventually surpass 1.3 million acres. The ozone exceedance was documented in 28 data points over two days and ranged from 0.083-0.105 ppm.

Clark County documented the exceedance in a 92 page report demonstrating increases in ozone coinciding with increasing PM 2.5 concentrations. Speciation was used to show that the particulates were consistent with biomass burning. The report included 14 pages of meteorological data and smoke plume trajectory model outputs via AirNow Tech. Satellite imagery was used to show smoke plumes during the event. Five years of monitoring data prior to and during the event year are displayed for nine monitoring sites showing the highest impact occurred during the event date. Regression modeling was used to demonstrate that emissions would have been approximately 20 ppb less on the event days in the absence of fire.

**Kansas (April 7-8 2009)**

In April of 2009 a ≥7,500 prescribed fire in the Flint Hills region impacted monitors in Kansas City and Wichita. The 35 page demonstration requested flagging for four datapoints over two days ranging from 0.079-0.095. Elevated particulate levels were tracked with elevated ozone levels to indicate the increase in ozone was due to the fire. Also included in the report was satellite imagery showing smoke over the monitoring locations, a map of fires in the region, meteorological data for the days during the event and HYSPLIT back and forward trajectories with directions consistent with the smoke transport.

In the EPA response letter, the primary reason cited for not concurring with the exclusion points was a lack of demonstration showing a state smoke management program, or best management burn practices, which is required for prescribed burns.

**South Carolina ( March 29 2007 & February 20 2008)**

On March 29th 2007 a 384 acre prescribed fire burned into the Congaree Bluff air monitoring site in Congaree National Park SC. The resulting 7 page report demonstrated the hourly spike in ozone data along with a fire report and burn map. The report was concurred upon by EPA and was one of two filed for SC in 2007 that were the result of fire burning into a monitoring site. The other report was also 7 pages in length and contained a similar level of detail.

**Virginia (June-July 2008)**

On 6 June 2008 smoke from the Evan's Road NC fire drifted into Virginia. The Henrico monitor in Richmond County recorded a 0.110 ppm 8-hour ozone exceedance that day which was reported to be flagged by the VA Department of Environmental Quality.

Within the report ozone monitoring data for seven years was compared to the 6/62008 datapoint. The fire was documented using photo NIFC incident reports and photographs of the resulting smoke plume. Smoke drift was documented using MODIS satellite imagery, and further documentation was provided with the aid of HYSPLIT trajectories, chemical analysis of particulates, and CMAQ and BlueSky modeling outputs. Information on the VA smoke management practices was also supplied. The EPA did not concur this datapoint.

# Examples with EPA determinations - Particulate matter

**North Carolina prescribed fires**

***Bryson City (March 22 2007)***

On March 22nd 2007 a 1,644 acre prescribed fire impacted the Bryson City fine particulate monitor creating a PM 2.5 24 hour average of 43.3 $\mu g/m^3$. The event was described in a 45 page report by the NC Division of Air Quality. The circumstances leading to the smoke reaching the monitor were described using HYSPLIT trajectories, MODIS satellite imagery, fire reports and meteorological details including temperature, wind speed, mixing height, humidity and dispersion index. VSmoke modeling output was also provided to indicate the particulate measurements were likely to have been much smaller 'but for' the event. Statistical analysis on three preceding years of data indicated the measurement exceeded the 95th percentile of past measurements by 110%.

***Raleigh (June 19 2007)***

On June 19th 2007 a 1,800 acre prescribed fire impacted the Raleigh Millbrook fine particle monitor producing a 24 hour PM 2.5 average of 43.17 $\mu g/m^3$. The event was described in a 29 page report by the NC Division of Air Quality. HYSPLIT trajectories, wind speeds and fire reports described the event which led to the monitor impact. A description of the smoke management actions was also included. Statistical analysis on three preceding years of data indicated the measurement exceeded the 95th percentile of past measurements by 82%.

The EPA concurred and flagged the data point as exceptional for both the Bryson City and Raleigh monitoring points. The HYSPLIT models, smoke management plans, and statistical analysis provided sufficient evidence to suggest causal relationship between the prescribed fire and stated values. Smoke-GIS smoke dispersion modeling provided values that indicated the levels would have been below NAAQS 'but for' the event.

**North Carolina wild fires**

***Raleigh, Hickory, and Greensboro (August 5 2007)***

On August 5th 2007 particle monitors in Raleigh, Hickory, and Greensboro each recorded an elevated PM 2.5 24 hour averages ranging from 37.08 to 42.25. In an 89 page report the NC Division of Air Quality indicates smoke transport from a large concentration of wildfires in Idaho, Montana, and Canada during this time. This wildfire event was documented by NIFC incident maps, MODIS satellite imagery, and smoke advisories issued by the Montana Department of Environmental Quality. Transport was demonstrated using HYSPLIT trajectory modeling. Atypically elevated PM concentrations were demonstrated by analyzing data from 2004-2006 in comparison with the 2007 data points. The results indicated the measurements exceeded the 95th percentile by 5%.

The EPA did not concur with this flagged event stating that a clear causal relationship between the event and exceedance was not sufficiently proven.

***Lexington (August 4 2007)***

On August 4th 2007 the particle monitor in Lexington recorded a PM 2.5 24 hour average of 35.8 $\mu g/m^3$ and reported in a 47 page report by the NC Division of Air Quality. This elevation was attributed to smoke transport from fires burning in Kentucky, Pennsylvania, Ohio, and the Lexington areas. Fires were documented with MODIS satellite imagery and NIFC incident reports and maps. Transport was demonstrated using HYSPLIT modeling and documenting mixing heights. Additionally, particle speciation indicated the particulate matter collected by the monitors was consistent with burning biomass. Unusually high PM concentrations were demonstrated by analyzing data from 2004-2006 in comparison with 2007. The data point in this report was shown to exceed the 95th percentile by 15%.

The EPA did not concur with the flagged event; higher sulfate values during this period were indicative of regional haze which could have impacted the monitoring values, therefore the 'but for' argument could not be met.

***Lumberton (May 3 and June 11 2007)***

On May 3rd 2007 the Linkhaw particle monitor in Lumberton recorded a 24 hour average PM 2.5 concentration of 36.25 $\mu g/m^3$. In the resulting 31 page report the NC Division of Air Quality compared this point with three years of prior data. During this time extensive wildfires in GA and FL were burning. This was supported with new articles and MODIS satellite imagery. Transport from these fires was demonstrated with HYSPLIT trajectory modeling. Statistical analysis with data from 2004-2006 indicated that the reported measurement exceeded the 95th percentile by 64%.

The EPA concurred and flagged this event citing the HYSPLIT trajectory models, maps, news releases, and data analysis as having provided sufficient evidence to establish a causal relationship between the flagged values and the wildfire events.

Spruce Pine

On June 11th 2007 the Spruce Pine particle monitor recorded a 24 hour average PM 2.5 concentration of 60.5 $\mu g/m^3$. A few days later on the 14th a 24 hour concentration of 61.04 was recorded at the same station. The two exceedances were described in separate reports, 37 and 35 pages in length, respectively. The NC Division of Air Quality compared these points with three years of prior data. Smoke from the wild fire at Linville Gorge which by June 10th had consumed over 250 acres, and over 900 acres by the 14th. Fire reports and news articles documented the fire, and HYSPLIT trajectory modeling was used to show transport. Both measurements were compared with data from 2004-2006 and shown to be over the 95th percentile of normal historic fluctuation. The EPA concurred and flagged this event citing sufficient evidence in the form of HYSPLIT trajectory models, maps, news releases, and data analysis.

**South Carolina (2007)**

From March 13th to August 8th 2007 the state of South Carolina flagged 16 PM 2.5 data points over 5 days. The 24 hour averages ranged in exceedance from 36.0-46.7 $\mu g/m^3$. The South Carolina Department of Health and Environmental Control submitted a 41 page document to describe these and other data points. The exceedances from smoke were attributed to the FL and

GA wildfires during the summer of 2007 and were demonstrated using smoke plume maps, HYSLPLIT modeling, and windroses. The EPA concurred on 6/16 data points to be flagged.

**Virginia (June – July 2008)**

Prolonged drought conditions contributed to the Evans Road and South 1 fires which impacted monitors in Charlottesville and Hampton Roads. Initially the Virginia Department of Environmental Quality's Air Division produced a 68 page demonstration package to EPA describing both particulate and ozone exceedances for all the flagged data points. A NIFC large incident map and MODIS satellite imagery were used to show the two fires. Unusually high values were shown by plotting the average monitor outputs for 2008 particulate and ozone with the average of seven years of previous data. Smoke plumes over the monitoring areas were shown with satellite imagery and HYSPLIT wind trajectories demonstrating drift from the fire sites to the monitoring sites.

Upon request two additional documents were furnished to the EPA by the Air Division. The first, a 14 page document, dealt with nine PM 2.5 points. This document further demonstrated the flagged values to be atypical by demonstrating that they were all occurring between the 95$^{th}$ and 100 percentile when considering the last three years of data. Further evidence of the fires' impact was demonstrated with CMAQ modeling output to show what the particulate levels would have looked like based upon projections from previous years.

The second document, 27 pages in length, described 12 PM 2.5 and one ozone datapoint. Demonstration was shown in a manner similar to the above, using percentiles and CMAQ modeling output for both pollutants. Additionally, chemical analysis on the particles showed high carbon content consistent with biomass emissions. Bluesky modeling runs were used to compare emissions with and without fire. EPA approved the particulate matter data points but not the ozone datapoint.

**Indiana (June 29-30 2007)**

In Spring 2007 the Bugaboo fires in Florida and Georgia produced smoke that drifted into Indiana and impacted 42 monitoring sites over a period of 11 days with 24 hour average PM 2.5 values ranging from 22.8 - 41.5 $\mu g\ m^{-3}$. In response the state of Indiana cited 153 data points as being influenced in 2007. Their document of 165 pages used back and forward HYSPLIT trajectories, NOAA smoke maps, wind roses and speciation data of particulates to support their flagging.

EPA Region 5 concurred on 19/153 points. Concurrence was not given where the impact did not contribute to exceedance, or where the impact source (several hundred miles away) did not appear to impact area monitors equally. Concurrence was also not granted for datapoints where the background level in the absence of fire emissions was over the NAAQS. In this latter method, the high carbon content particulate mass, indicative of burned biomass, was subtracted from the total particulate mass indicated by certain monitoring stations to determine what the background level would have been in the absence of these high carbon particulates.

**Montana (2007)**

In the summer of 2007 large wildfires burned in Montana. Particulate monitors detected elevated 24 hour average concentrations of PM 2.5 ranging from 35.4-195.3 μg $^{m-3}$. The state of Montana flagged 38 data points over 11 days. The fires were documented photographically and with satellite imagery and fire reports. Smoke programs and practices were outlined by the state in the 2008 Montana Natural Events Action Plan for the Mitigation of Public Health Impacts Caused by Smoke from Wildfire Events. The EPA concurred on the events flagged within this report; Photos, satellite images, forest fire smoke reports and smoke impact forecasts demonstrated a clear causal relationship. Spreadsheet comparison of measured values to 2004-2006 well below those measured during the fire, and statements indicating the lack of other contributors to particulate matter during this time period sufficiently demonstrated the exceedance would not have occurred 'but for' the event.

**Utah (July 9 2007)**

On July 9$^{th}$ 2007 wildfires in California, Nevada, Oregon, and Idaho produced smoke which impacted the Lindon UT particulate monitor. A PM 2.5 24 hour average of 44.3 μg m$^{-3}$ was produced. The state of Utah supplied documentation which included map locations of the wildfires, satellite imagery of smoke, and a back trajectory using HYSPLIT, EDAS, and GIS mapping. The year of 2007 was compared with 10 years of prior data. Information on smoke management practices was also included in the documentation. The EPA concurred with the report and flagged the event as exceptional.

**Wyoming (August 15 2006)**

During the summer of 2006 wildfires near Pinedale burned over 31,000 acres and produced smoke which impacted the Pinedale particulate monitor; A PM 2.5 24 hour average of 39.2 μg m$^{-3}$ was recorded during this time. The documentation package described the event cause as wildfire, which was supported in the 31 page document with photographic and satellite imagery, USFS incident reports and unplanned burning reports, local news articles, and speciation of the particulates showing they were consistent with those produced by burning biomass. One year of data was evaluated. The EPA concurred with this report in January 2008 based on a the completeness of evidence that the event was wildfire driven based on wind direction, fire location, and analysis of particles collected from the monitor.

**California ( July 8 2007)**

On July 5$^{th}$ 2007 dry lightning ignited several wildfires on the Plumas National Forest which became the Antelope/Wheeler Complex Fire. The resulting smoke impacted the Portola particulate monitor in Plumas County, producing a 24 hour average PM 2.5 measurement of 41.0 μg m$^{-3}$. A 50 page letter documenting the event was sent to Region 9 EPA which included a map of the burn area, GOES-11 satellite imagery, HYSPLIT forward and backward trajectories, statistics for 7 years of data, and comparison of concentrations when the reading was removed. Public information was highlighted by attaching public health notices that were distributed in response to the event, and additional information was provided by attaching news releases, and NOAA satellite imagery descriptions.

An additional 12 pages of documentation was later provided to the EPA which included additional HYSPLIT trajectories, hourly BAM data that led to the 24 hour average, comparison with un-impacted monitoring site. Region 9 EPA concurred with the documentation for this

event. Given the high concentrations relative to historical levels, wind trajectories, satellite images, and news articles a weight of evidence was determined to support the exceptional event designation.

**EPA Concurrence**

In evaluating individual data points compiled from all the reports reviewed, 33% received concurrence, 64.5% did not, and 2.5% are pending. (Table 5). Event and report details are displayed in Table 3 and methodology for demonstrations is displayed in Table 4.

Of the ozone reports from wildfire reviewed herein, only one has currently received concurrence from EPA, this is the 2008 example from Sacramento. The main portion of Sacramento's report is composed of 85 pages with 927 pages of supporting information, including a 118 page meteorology section, and appendices for public advisories, news reports, and regression analysis. EPA concurred with this document citing the causal relationship was clearly demonstrated with meteorological conditions conducive to transport of emissions, satellite imagery of smoke in the monitoring area, documented increases in PM 2.5, particles consistent with burning biomass, and demonstration that emissions from the fire reached ground level monitors. The use of 'surrogate days' developed with previous air and meteorological data and regression analysis, demonstrated the levels of ozone recorded during the fire were significantly greater than they would have been in the absence of the fires. Other ozone reports are either still pending consideration, or have been declined. In an example from Kansas the report was declined due to the lack of a smoke management program. In other examples the reasons for decline were not made available.

Of the total particulate data points that have been submitted to EPA within this report, approximately 39% have received concurrence. The examples which had not received concurrence for particulate matter data points have been declined for a variety of reasons. Cited reasons have included the presence of other pollutants which may indicate another source for the particulate matter (NC August 4 2007), lack of sufficient evidence to prove that the concentrations were from the fires cited (NC August 5 2005), or the cited values did not exceed the NAAQS (IN 2007).

**Table 5.** Summary of monitoring data points and whether EPA concurred with the exceptional event request.

| Pollutant | Concurred | Not concurred | Pending | Total |
|---|---|---|---|---|
| **Ozone** | 10 | 129 | 4 | 143 |
| **PM 2.5** | 276 | 428 | 7 | 711 |
| **PM 10** | 1 | 1 | 10 | 12 |

**Reporting Costs**

Time and monetary requirements to produce exceptional event reports will vary with the event circumstances, location, monitoring systems in place, and supporting data required. Inquiries into the cost associated with these reports were answered by personnel in EPA Regions 4, 9, and 10. For a particulate event in region 9, such as wind-blown dust, 450 staff hours of effort is estimated. For an ozone exceptional event, presumably from wildfire, the estimated time

investment was 940 staff hours. Based on the annual salary for an Air Quality Specialist at the GS-11 pay scale, this would produce a per-report minimum cost of $11,785 for a dust event and $24,618 for an ozone event.

Report lengths in regions 4 and 10 tended to be shorter in length, which appears to correspond to lower expenses. Estimated costs were approximately $8,000 to document an event in region 10. An estimate from region 4 indicated that the initial documentation took approximately 320 staff hours, however this has since shrunk to 24 staff hours per event as the formatting from prior reports can now be used as a guide.

These numbers indicate that initially undertaking an exceptional event documentation is likely to be a substantial investment in time, which translates to monetary costs via personnel hours. These costs may be greater in cases where services from outside the agency are contracted. For example, a private lab was contracted to do the particle speciation analysis in the Pinedale Wyoming demonstration package, or the collection of news and press releases such as those enclosed in several documentation packets.

# Conclusions

**Pollutant Concentrations and sources**

Particulate matter 2.5 is the criteria pollutant most often documented in exceptional events reports resulting from wildfire, nearly 80% of the examples reviewed here. Ozone and PM 10 reports were reviewed but less common; the researchers reviewed 8 and 3 report ozone and PM 10 reports, respectively. The majority of reports reviewed herein are the result of large wildfires in western states. Exceptional events from prescribed fires were also reported, these tended to originate from the eastern United States. Pollutant concentrations range from below the national standard to well above; the range of PM 2.5 values reported is 7.5-200.2µg $m^{-3}$ and 0.02-0.161 ppm for ozone.

**Common demonstration methods**

The most common aids to demonstrating an exceptional event to be the result of fire are satellite imagery of the fire and HYSPLIT or WindRose trajectories to demonstrate smoke transport from the fire to the monitoring sites. To indicate the event is causing greater concentrations than normal several years of data points are often compared. The comparison methods are commonly percentile measurements or statistical analysis of variance. Compilations of news articles are often used to further demonstrate the smoke impacts from fires. Exceedance is most often demonstrated using regression analysis to show what the pollutant levels would have been in the absence of fire.

Ozone exceedance is more complex to demonstrate as it is a secondary pollutant. Additional methods to show ozone formation from fires include demonstrating elevations in precursor emissions including carbon monoxide and NOx, and particulate matter to demonstrate these are the result of smoke. Scientific research discussing ozone formation from fire is also often included in these documentations.

**EPA Concurrence**

Of the data points reported for the various exceptional events approximately one third received concurrence, with the majority of these being PM 2.5 points. Of the ozone data points, a small fraction received concurrence due to a fire which over-ran the monitoring stations. The remaining 8 data points were from a severe wildfire season in California in 2008. Reasons for which reports did not receive concurrence included lack of adequate documentation to demonstrate impacts from fire when citing transport smoke as the reason for the exceedance, and lack of a smoke management plan when demonstrating an ozone event.

**Costs of Reporting**

Exceptional event reports vary in the time needed to produce them. The time to complete a report was reported to range from 24 hours for one event in which a report template is already in use, to 450 staff hours. An estimate for an ozone report in Region 9 is 940 staff hours. Based on the annual salary for an Air Quality Specialist at the GS-11 pay scale, this would produce a per-report cost range of $629 to $24,618. This does not include the extraneous costs of lab analysis or services are contracted out by the agency.

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