Enclosure: Technical Support Document for EPA Concurrence on O_3 Exceedances Measured in at Five Maryland Monitors on July 21 and 22, 2016 as Exceptional Events

In summer of 2016, the Maryland Department of the Environment (MDE) identified that wildfires in northwestern Canada may have caused ozone (O_3) exceedances at 12 monitoring sites operated by MDE on July 21 and 22, 2016. The aggregate of wildfires in and around the Northwest Territories of Canada produced a smoke plume containing O_3 precursors that was transported eastward and south and subsequently subsided over the Mid-Atlantic United States.

Under the Exceptional Events Rule, air agencies can request the exclusion of event-influenced data, and EPA can agree to exclude these data, from the data set used for certain regulatory decisions. The remainder of this document summarizes the Exceptional Events Rule requirements, the event and EPA's review process.

Exceptional Events Rule Requirements

EPA promulgated the Exceptional Events Rule in 2007, pursuant to the 2005 amendment of Clean Air Act (CAA) section 319. In 2016, EPA finalized revisions to the Exceptional Events Rule. The 2007 Exceptional Events Rule and 2016 Exceptional Events Rule revisions added sections 40 CFR §50.1 (j)-(r), 50.14, and 51.930 to title 40 of the Code of Federal regulations (CFR). These sections contain definitions, criteria for EPA approval, procedural requirements, and requirements for air agency demonstrations. EPA reviews the information and analyses in the air agency's demonstration package using a weight of evidence approach and decides to concur, defer, or not concur. The demonstration must satisfy all of the Exceptional Events Rule criteria for EPA to concur with excluding the air quality data from regulatory decisions.

Under 40 CFR §50.14 (c) (3) (iv), the air agency demonstration to justify data exclusion must include:

A. "A narrative conceptual model that describes the event(s) causing the exceedance or violation and a discussion of how emissions from the event(s) led to the exceedance or violation at the affected monitor(s);"

B. "A demonstration that the event affected air quality in such a way that there exists a clear causal relationship between the specific event and the monitored exceedance or violation;"

C. "Analyses comparing the claimed event-influenced concentration(s) to concentrations at the same monitoring site at other times" to support (B) above;

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D. "A demonstration that the event was both not reasonably controllable and not reasonably preventable;" and

E. "A demonstration that the event was a human activity that is unlikely to recur at a particular location or was a natural event."[1]

In addition, the air agency must meet several procedural requirements, including:

1. Submission of an Initial Notification of Potential Exceptional Event and flagging of the affected data in EPA's Air Quality System (AQS) as described in 40 CFR §50.14(c)(2)(i),

2. Completion and documentation of the public comment process described in 40 CFR §50.14(c)(3)(v), and

3. Implementation of any applicable mitigation requirements as described in 40 CFR §51.930.

For data influenced by exceptional events to be used in initial area designations, air agencies must also meet the initial notification and demonstration submission deadlines specified in Table 2 to 40 CFR §50.14. We include below a summary of the Exceptional Events Rule criteria, including those identified in 40 CFR §50.14(c)(3)(iv).

Regulatory Significance

The 2016 Exceptional Events Rule includes regulatory language that applies the provisions of CAA section 319 to a specific set of regulatory actions. As identified in 40 CFR §50.14 (a)(1)(i), these regulatory actions include initial area designations and redesignations; area classifications; attainment determinations (including clean data determinations); attainment date extensions; findings of state Implementation Plan (SIP) inadequacy leading to a SIP call; and other actions on a case-by-case basis as determined by the Administrator. Air agencies and EPA should discuss the regulatory significance of an exceptional events demonstration during the Initial Notification of Potential Exceptional Event prior to the air agency submitting a demonstration for EPA's review.

Narrative Conceptual Model

[1] A natural event is further described in 40 CFR §50.1 (k) as "an event and its resulting emissions, which may recur at the same location, in which human activity plays little or no direct causal role. For purposes of the definition of a natural event, anthropogenic sources that are reasonably controlled shall be considered to not play a direct role in causing emissions."

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The 2016 Exceptional Events Rule directs air agencies to submit, as part of the demonstration, a narrative conceptual model of the event that describes and summarizes the event in question and provides context for analyzing the required statutory and regulatory technical criteria. Air agencies may support the narrative conceptual model with summary tables or maps. For wildfire O_3 events, EPA recommends that the narrative conceptual model also discuss the interaction of emissions, meteorology, and chemistry of event and non-event O_3 formation in the area, and, under 40 CFR §50.14 (a)(1)(i), must describe the regulatory significance of the proposed data exclusion.

Clear Causal Relationship and Supporting Analyses

EPA considers a variety of evidence when evaluating whether there is a clear causal relationship between a specific event and the monitored exceedance or violation. For wildfire O_3 events, air agencies should compare the O_3 data requested for exclusion with seasonal and annual historical concentrations at the air quality monitor to establish a clear causal relationship between the event and monitored data. In addition to providing this information on the historical context for the event-influenced data, air agencies should further support the clear causal relationship criterion by demonstrating that the wildfire's emissions were transported to the monitor, that the emissions from the wildfire influenced the monitored concentrations, and, in some cases, air agencies may need to provide evidence of the contribution of the wildfire's emissions to the monitored O_3 exceedance or violation.

For wildfire O_3 events, EPA has published a guidance document that provides three different tiers of analyses that apply to the "clear causal relationship" criterion within an air agency's exceptional events demonstration. This tiered approach recognizes less evidence to satisfy the rule requirements. If a wildfire/O_3 event satisfies the key factors for either Tier 1 or Tier 2 clear causal analyses, then those analyses are the only analyses required to support the clear causal relationship criterion within an air agency's demonstration for that particular event. Other wildfire/O_3 events will be considered based on Tier 3 analyses.

- Tier 1: Wildfires that clearly influence monitored O_3 exceedances or violations when they occur in an area that typically experiences lower O_3 concentrations.
    - *Key Factor:* seasonality and/or distinctive level of the monitored O_3 concentration. The event-related exceedance occurs during a time of year that typically has no exceedances, or is clearly distinguishable (*e.g.,* 5-10 ppb higher) from non-event exceedances.
    - In these situations, O_3 impacts should be accompanied by clear evidence that the wildfire's emissions were transported to the location of the monitor.

- Tier 2: The wildfire event's O_3 influences are higher than non-event related concentrations, and fire emissions compared to the fire's distance from the affected monitor indicate a clear causal relationship.

- *Key Factor 1:* fire emissions and distance of fire(s) to affected monitoring site location(s). Calculated fire emissions of NO_x and reactive-VOC in tons per day (Q) divided by the distance from the fire to the monitoring site (D) should be equal to or greater than 100 tons per day/kilometers ($Q/D \geq 100$ tpd/km). The guidance document provides additional information on the calculation of Q/D.
- *Key Factor 2:* comparison of the event-related O_3 concentration with non-event related high O_3 concentrations. The exceedance due to the exceptional event:
  - Is in the 99th or higher percentile of the 5-year distribution of O_3 monitoring data, OR
  - Is one of the four highest O_3 concentrations within 1 year (among those concentrations that have not already been excluded under the Exceptional Events Rule, if any).
- In addition to the analysis required for Tier 1, the air agency should supply additional information to support the weight of evidence that emissions from the wildfire affected the monitored O_3 concentration.

- Tier 3: The wildfire does not fall into the specific scenarios (*i.e.,* does not meet the key factors) that qualify for Tier 1 or Tier 2, but the clear causal relationship criterion can still be satisfied by a weight of evidence showing.
  - In addition to the analyses required for Tier 1 and Tier 2, an air agency may further support the clear causal relationship with additional evidence that the fire emissions caused the O_3 exceedance.

Not Reasonably Controllable or Preventable

The Exceptional Events Rule requires that air agencies establish that the event be both not reasonably controllable and not reasonably preventable at the time the event occurred. This requirement applies to both natural events and events caused by human activities; however, it is presumed that wildfires on wildland will satisfy both factors of the "not reasonably controllable or preventable" element unless evidence in the record clearly demonstrates otherwise.[2]

Natural Event or Event Caused by Human Activity that is Unlikely to Recur

[2] A wildfire is defined in 40 CFR §50.1(n) as "any fire started by an unplanned ignition caused by lightning; volcanoes; other acts of nature; unauthorized activity; or accidental, human-caused actions, or a prescribed fire that has developed into a wildfire. A wildfire that predominantly occurs on wildland is a natural event." Wildland is defined in 40 CFR §50.1(o) as "an area in which human activity and development are essentially non-existent, except for roads, railroads, power lines, and similar transportation facilities. Structures, if any, are widely scattered."

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According to the CAA and the Exceptional Events Rule, an exceptional event must be "an event caused by human activity that is unlikely to recur at a particular location *or* a natural event" (emphasis added). The 2016 Exceptional Events Rule includes in the definition of wildfire that "[a] wildfire that predominantly occurs on wildland is a natural event." Once an agency provides evidence that a wildfire on wildland occurred and demonstrates that there is a clear causal relationship between the measurement under consideration and the event, EPA expects minimal documentation to satisfy the "human activity that is unlikely to recur at a particular location or a natural event" element. EPA will address wildfires on other lands on a case-by-case basis.

EPA Review of Exceptional Event Demonstration

On February 1, 2017, MDE submitted an Initial Notification of Potential Exceptional Event for 7 exceedances of the 2008 8-hour O_3 standard that occurred at Aldino (AQS: 240259001), Beltsville CASTNET (AQS: 240339991), Fair Hill (AQS: 240150003), Glen Burnie (AQS: 240031003), HU-Beltsville (AQS: 240330030), PG Eq Cntr (AQS: 240338003), and Edgewood (AQS: 240251001), and 8 exceedances of the 2015 8-hour O_3 standard at Aldino (AQS: 240259001), Edgewood (AQS: 240251001), Essex (AQS: 240053001), Frederick (AQS: 240210037), Furley (AQS: 245100054), Hagerstown (AQS: 240430009), and Padonia (AQS: 240051007) on July 21 and 22, 2016.

Regulatory Significance

EPA reviewed MDE's Initial Notification of Potential Exceptional Event and determined that the exclusion of 8-hour O_3 measurements from some of the monitors included had regulatory significance for the 2008 and 2015 8-hour O_3 standard. EPA worked with MDE to identify any other relevant exceedances and monitors that may have been impacted by the event and affected regulatory determinations. Ultimately, monitor days without immediate or possible regulatory significance were also requested by MDE in their final demonstration and were either deferred or non-concurred by EPA. Table 1 summarizes the exceedances and EPA's decisions.

Table 1. EPA 8-hour O_3 Exceedance Summary

Exceedance Date	Site Name	AQS ID	8-hour Max. (ppb)	NAAQS Standard Affected	EPA Decision
July 21, 2016	Edgewood	240251001	72	2015	Concur
July 21, 2016	Furley	245100054	74	2015	Concur
July 21, 2016	Glen Burnie	240031003	76	2015	Concur
July 22, 2016	Edgewood	240251001	82	2008	Concur
July 22, 2016	Fair Hill	240150003	87	2008	Concur
July 22, 2016	PG Eq Cntr	240338003	76	2008	Concur
July 21, 2016	Aldino	240259001	77	TBD	Defer

July 21, 2016	Essex	240053001	75	TBD	Defer
July 21, 2016	Frederick	240210037	75	TBD	Defer
July 21, 2016	Hagerstown	240430009	74	TBD	Defer
July 21, 2016	HU-Beltsville	240330030	78	TBD	Defer
July 22, 2016	Aldino	240259001	72	TBD	Defer
July 22, 2016	Essex	240053001	72	TBD	Defer
July 21, 2016	Beltsville CASTNET	240339991	78	NA	Non-concur
July 21, 2016	Padonia	240051007	73	NA	Non-concur

Narrative Conceptual Model

MDE's demonstration provided a narrative conceptual model to describe how emissions from northwestern Canada caused O_3 exceedances at the affected monitoring stations. The conceptual model included a general overview of typical O_3 formation in Maryland, a literature review of studies that examine the role of wildfires on downwind O_3, and the meteorology, O_3, and NO_x concentrations and satellite smoke observations for the days leading up to, during, and after the exceptional event dates.

In the demonstration, MDE explained that under typical airmass composition, O_3 formation in Maryland occurs "due to the photolization of volatile organic compounds (VOCs) and a combination of regional and locally sourced anthropogenic NO_x in the presence of sunlight." While Maryland has urban pollution plumes, MDE's demonstration explained that "these emissions alone regularly fall short of producing ozone capable of [maximum daily 8-hour average ozone] concentrations above 70 ppb".

In 2016, A dry spring promoted fire prone conditions throughout northwestern Canada. During the week of July 13-20, 2016, 205 fires started in northwestern Canada and burned 109,724 hectares. An area of low pressure over northwestern Canada, created northwesterly winds that transported O_3 precursors southeast. A weak cold front then pushed through Maryland and behind it, an area of high pressure moved in over the Mid-Atlantic, causing the O_3 precursors to subside to the surface. The next day (July 21, 2016), the photochemically aged airmass was at the surface over Maryland and elevated O_3 was observed across Maryland. Long-range forest fire effects on O_3 concentrations are not unheard of, and MDE cited several similar studies where, "Canadian wildfires have increased ozone concentrations in Houston, TX and as far away as Europe".

Table 2. Documentation of Narrative Conceptual Model

Exceedance Date	Demonstration Citation	Quality of Evidence	Criterion Met?
July 21, 2016	Section 2: p 15-49	Sufficient	Yes
July 22, 2016	Section 2: p 15-49	Sufficient	Yes

Clear Causal Relationship and Supporting Analyses

MDE's demonstration included multiple analyses to demonstrate a clear causal relationship between the northwestern Canadian fires and the monitored exceedances. A selection of these analyses is listed and further discussed below.

Trajectory Analysis

MDE included 72-hour forward and backward trajectories between July 17th and 20th, 2016 using the National Oceanic and Atmospheric Administration's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. The forward trajectories originating around the location of the smoke plume generally showed transport south and east toward the northeast United States. The backward trajectories beginning in central Maryland, indicated transport from the northwest. These trajectories were consistent with the conceptual model presented earlier in the demonstration.

Satellite Imagery of Plume with Evidence of Plume Impacting Ground

Satellite retrievals of total column carbon monoxide (CO) over North America from July 18th to 21st, 2016 showed a plume of CO over northwestern Canada on July 18 that initially traveled southeast and reached Maryland by July 20th. In this analysis, total column CO was used as a wildfire smoke indicator, and the track of the plume corresponded well with the proposed track of O_3 precursors in the conceptual model. At the surface, several CO monitors measured elevated CO concentrations, including one site (Horn Point) that measured the highest CO concentrations for the month of July on July 20th. The timing of the peaks in surface CO monitor concentrations was consistent with the timing of the CO plume entering the Mid-Atlantic, as detected from satellite retrievals.

Q/d Analysis

While required for Tier 2 & 3 demonstrations, MDE felt that, "the [required] 100 [tpd/km] value is not representative for long-range east-coast smoke events". However, MDE included the required Q/d analysis which yielded an estimate of 1.8 tpd/km from the central point of the fires in northwestern Canada to Fair Hill, Maryland. The Q/d estimate was much lower than the required 100 tpd/km. While the results of this analysis did not satisfy the Q/d value requirements, MDE's additional analyses included in this demonstration were able to satisfy the requirement of a clear causal relationship between the wildfires and O_3 exceedances in Maryland.

Comparison of Event O_3 Concentrations with Non-event

Of the 12 monitors for which MDE requested data exclusion, three of those monitors on July 21, 2016, and two on July 22, 2016 observed 8-hour O_3 concentrations that exceeded the 99th percentile for 2012-2016. The Fair Hill and Edgewood monitors were the two that exceeded the

99th percentile 8-hour O_3 on July 22, 2016. If the year of 2012 was excluded, The Furley monitor met or exceeded the 99th percentile on July 21, 2016, and the Edgewood, Fair Hill, and PG Eq Cntr monitor exceeded the 99th percentile 8-hour O_3 on July 22, 2016.

Evidence of Changes in Spatial/Temporal O_3 and/or NO_x Patterns

Figures included in MDE's demonstration showed Hazard Mapping System (HMS) analyzed smoke moving southeast in the event time frame and accompanying pockets of elevated O_3 (albeit lower concentrations than those recorded on July 21st and 22nd in Maryland). On July 18th and 19th, 2016, maximum 8-hour O_3 concentrations in Maryland were between 40 and 60 ppb. On July 20, smoke from the northwestern Canadian wildfires arrived in Maryland and on July 19th and 20th, maximum 8-hour O_3 concentrations ranged from 65-85 ppb.

NO_x concentrations recorded during the event time frame were the highest observed in the month of July, 2016. MDE plotted the ratio of maximum 8-hour average ozone concentration to total NO_x output from Pennsylvania and Maryland. O_3 to NO_x ratios during the event were the 24th and 13th highest ratios in July since 2010. Because MDE used only local NO_x emissions for the ratio, "The higher than typical ratio suggested ozone production was beyond classic event production and was likely aided by other constituents".

Concentrations of Supporting Ground-Level Measurements

In addition to the elevated CO concentrations discussed above, MDE included analyses of fine particles ($PM_{2.5}$), total non-methane organic compounds (TNMOC), and O_3 to NO_x ratios. Like the observed CO concentrations, the other ground-level measurements were slightly higher than non-event concentrations. The statewide 6-hour average $PM_{2.5}$ concentration peaked at 15 $\mu g/m^3$ during the event period, which was the highest measurement of the month. TNMOC also peaked during the event period, with the 24-hour moving average of TNMOC in July being the highest during the event period.

Photochemical Model

The Community Multi-Scale Air Quality (CMAQ) O_3 model can predict quantitatively and spatially O_3 concentrations. For this demonstration, MDE ran CMAQ without including 2016 wildfire emissions in the O_3 chemical creation mechanism. Therefore, the model results can be compared to the observed O_3 concentrations, and if CMAQ underpredicts daily maximum 8-hour O_3, it is indicative of O_3 sources not accounted for by CMAQ.

Similar to the plume of CO discussed above, MDE's demonstration included figures showing an area of underpredicted maximum daily 8-hour O_3 in Ohio on July 19, 2016. The area of underprediction moved east into Maryland on July 20th, and expanded further east on July 21. By July 22nd, the area of underprediction over Maryland was much smaller. The areas of underprediction ranged from 5 to 15 ppb as the plume moved from Ohio to Maryland. The underprediction of O_3 by CMAQ (suggesting unexpected O_3 source(s)) is underscored in MDE's demonstration by how, as MDE wrote, "it tends to slightly over-forecast ozone concentrations".

Conclusions

MDE stated that the evidence presented demonstrates, "that the wildfire events affected air quality in such a way that there exists a clear causal relationship between the specific event (fires in northwestern Canada) and the monitored ozone exceedance on July 21 and 22, 2016 and thus satisfies the clear causal relationship criterion for recognition as an exceptional event".

The analyses included in the demonstration, specifically the spatial changes in O_3 analysis and comparison of modeled (without fire emissions) with observed O_3 concentrations, sufficiently demonstrated a clear causal relationship between the emissions generated the northwestern Canadian wildfires and the exceedance measured at the affected monitors.

Table 3. Documentation of Clear Causal Relationship and the Supporting Analyses

Exceedance Date	Demonstration Citation	Quality of Evidence	Criterion Met?
July 21, 2016	Section 3: p 48-88	Sufficient	Yes
July 22, 2016	Section 3: p 48-88	Sufficient	Yes

Not Reasonably Controllable or Preventable

The Exceptional Events Rule presumes that wildfire events on wildland are not reasonably controllable or preventable (40 CFR §50.14(b)(4)). MDE's demonstration provided evidence that the wildfire event meets the definition of a wildfire. Specifically, MDE stated that the wildfires relevant to this event, "were likely due to lightning, were outside of the United States, and were therefore neither reasonably controllable or preventable by the state of Maryland. No policy that Maryland enacted could have prevented the fire or the smoke which it caused, to enter the United States or Maryland. MDE was not aware of any evidence clearly demonstrating that prevention or control efforts beyond those actually made would have been reasonable. Therefore, emissions from these wildfires were not reasonably controllable or preventable and meet the criterion for treatment as an exceptional event".

Table 4. Documentation of not Reasonably Controllable or Preventable

Exceedance Date	Demonstration Citation	Quality of Evidence	Criterion Met?
July 21, 2016	Section 5: p 88	Sufficient	Yes
July 22, 2016	Section 5: p 88	Sufficient	Yes

Natural Event or Event Caused by Human Activity that is Unlikely to Recur

The definition of "wildfire" at 40 CFR §50.1(n) states, "A wildfire that predominantly occurs on wildland is a natural event". MDE's demonstration includes documentation that the event

meets the definition of a wildfire and occurred predominantly on wildland. "The fires across the Northwest Territories and west-central areas of Canada qualify as a natural event because lightning activity was suspected as the cause…Wildfire emissions affecting ozone concentrations in Maryland were generated predominantly from sparsely populated forested areas, meeting the definition of wildland". MDE has therefore shown that the event was a natural event.

Table 5. Documentation of Natural Event

Exceedance Date	Demonstration Citation	Quality of Evidence	Criterion Met?
July 21, 2016	Section 4: p 88	Sufficient	Yes
July 22, 2016	Section 4: p 88	Sufficient	Yes

Schedule and Procedural Requirements

In addition to technical demonstration requirements, 40 CFR §50.14(c) and 40 CFR §51.930 specify schedule and procedural requirements an air agency must follow to request data exclusion. Table 6 outlines EPA's evaluation of these requirements.

Table 6. Schedules and Procedural Criteria

Criterion	Reference	Demonstration Citation	Criterion Met?
Did the agency provide prompt public notification of the event?	40 CFR §50.14 (c)(1)(i)	Section 6: p 88	Yes
Did the agency submit an Initial Notification of Potential Exceptional Event and flag the affected data in EPA's Air Quality System (AQS)	40 CFR §50.14 (c)(2)(i)	NA	Yes
Did the initial notification and demonstration submittals meet the deadlines for data influenced by exceptional events for use in initial area designations, if	40 CFR §50.14 Table 2 40 CFR §50.14(c)(2)(i)(B)	May 31, 2017	Yes

applicable? Or the deadlines established by EPA during the Initial Notification of Potential Exceptional Events process, if applicable?			
Was the public comment process followed and documented? • Did the agency document that the comment period was open for a minimum of 30 days? • Did the agency submit to EPA any public comments received? • Did the state address comments disputing or contradicting factual evidence provided in the demonstration?	40 CFR §50.14 (c)(3)(v)	Section 6: p 88	Yes
Has the agency met requirements regarding submission of a mitigation plan, if applicable?	40 CFR §50.1930(b)	NA	NA

Conclusion

EPA has reviewed the documentation provided by MDE to support claims that smoke from wildfires in northwestern Canada caused exceedances of the 2008 8-hour O_3 standard at the Glen Burnie monitoring site on July 21, 2016, the 2015 8-hour O_3 standard at the Furley and

Edgewood monitoring sites on July 21, 2016, and the 2008 8-hour O_3 standard at the Fair Hill and PG Eq Cntr monitoring sites on July 22nd, 2016. EPA has determined that the flagged exceedances at these monitoring sites satisfy the exceptional event criteria: the event was a natural event, which affected air quality in such a way that there exists a clear causal relationship between the event and the monitored exceedance, and was not reasonably controllable or preventable. EPA has also determined that MDE has satisfied the procedural requirements for data exclusion.

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