Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement

GUIDANCE DOCUMENT ON ACHIEVEMENT DETERMINATION CANADIAN AMBIENT AIR QUALITY STANDARDS FOR FINE PARTICULATE MATTER AND OZONE

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The Canadian Council of Ministers of the Environment (CCME) is the primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern.

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FOREWORD

On October 20, 2010 the Canadian Council of Ministers of the Environment (CCME) agreed to move forward with a new collaborative Air Quality Management System (AQMS) to better protect human health and the environment, building on the multi-stakeholder work done on the Comprehensive Air Management System (CAMS)[1]. Ministers directed officials to develop the major elements of the system in 2011, with implementation expected to begin in 2013.

The AQMS contains several key elements, including the development of new Canadian Ambient Air Quality Standards (CAAQS) for fine particulate matter ($PM_{2.5}$) and ozone, the delineation of air zones and airsheds, the development and implementation of Base Level Industrial Emissions Requirements (BLIERs) for industry, and an Air Zone Management Framework. The CAAQS will replace and be more stringent than the *Canada-wide Standards* (CWS) *for Particulate Matter and Ozone*[2].

Under the AQMS, provinces and territories will be delineated into a number of air zones which will provide a focal point for stakeholders and governments to work together in order to maintain air quality, achieve the CAAQS, and drive continuous improvements in air quality. An air zone is a finite geographic area that typically exhibits similar air quality issues and trends throughout. It will be up to provinces and territories to delineate and manage their air zones based on local circumstances. Air zones will reside fully within a given province or territory. Canada will also be delineated into *regional airsheds*, which will serve as the basis for coordinating action among jurisdictions on transboundary/inter-jurisdictional air quality issues.

This Guidance Document is intended as a reference tool for jurisdictions and the public, providing information, methodologies, criteria and procedures for reporting on achievement of the CAAQS for PM and ozone. It also provides the guidelines for ensuring consistency and comparability of data when meeting other CAAQS reporting requirements.

The *Guidance Document on Air Zone Management* will describe the actions to be undertaken by jurisdictions (federal, provincial and territorial governments) depending on the management level the air zone is in.

[1] Details of the CAMS process can be found at the following link on the CCME web site: http://www.ccme.ca/assets/pdf/cams_proposed_framework_e.pdf

[2] http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf

EXECUTIVE SUMMARY

Canadian Ambient Air Quality Standards (CAAQS) for fine particulate matter ($PM_{2.5}$) and Ozone have been developed through a collaborative process involving the federal, provincial and territorial governments and stakeholders, as directed by the Canadian Council of Ministers of the Environment (CCME) in October, 2010. The CAAQS will replace the Canada-wide Standards (CWS) for $PM_{2.5}$ and Ozone [3] that were established in 2000.

The proposed CAAQS for the year 2015 and 2020 are indicated in the table below.

Fine Particulate Matter ($PM_{2.5}$) and Ozone CAAQS

Pollutant	Averaging time	Standards (concentration)		Metric
		2015	2020	
$PM_{2.5}$	24-hour (calendar day)	28 $\mu g/m^3$	27 $\mu g/m^3$	The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations
$PM_{2.5}$	annual (calendar year)	10.0 $\mu g/m^3$	8.8 $\mu g/m^3$	The 3-year average of the annual average concentrations.
Ozone	8-hour	63 ppb	62 ppb	The 3-year average of the annual 4th-highest daily maximum 8-hour average concentrations.

The standards, which are the indicated concentration numbers, have an associated time-averaging period and a statistical form which is described by the *metric*. For example, for $PM_{2.5}$ there is both a 24-hour standard and an annual standard; for ozone there is only an 8-hour standard. To compare the measured concentrations of $PM_{2.5}$ and ozone to a given standard, the concentrations have to be first transformed in the same metric as the corresponding standard. Measured concentrations of $PM_{2.5}$ and ozone calculated to be in the same statistical form of the standards are referred to as *metric values* of the corresponding standard.

The purpose of this *Guidance Document for the Achievement Determination* (GDAD) *for the Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* is to provide provinces, territories and the public with information on methodologies, procedures, and requirements for calculating the metric values corresponding to each standard. The *air zone metric value* will be used to determine the achievement status of a given standard and the management level for that air zone.

[3] http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf

The contents of the GDAD include the following:

CAAQS Reporting Stations. Provinces and territories will identify air monitoring stations to report on the achievement status of the CAAQS in air zones; these stations are referred to as *CAAQS reporting stations*. All communities with population of 100,000 are to have one or more CAAQS reporting stations. Jurisdictions also have flexibility of using existing and any future stations in smaller communities and rural areas as CAAQS reporting stations.

Calculation of Metric Values. *Metric values* will be calculated on a monitoring station basis for each standard. The GDAD specifies the calculation procedures that are to be followed and the data completeness requirements that must be satisfied to calculate a valid metric value.

For the $PM_{2.5}$ metric values, provinces and territories using $PM_{2.5}$ monitors that do not meet the performance criteria specified in the CCME *Ambient Air Monitoring Protocol for* $PM_{2.5}$ *and Ozone* (2011) will flag the reported $PM_{2.5}$ metric values with a footnote specifying this.

Metric Values for Achievement Determination of CAAQS in Air Zones. For air zones with a single CAAQS reporting station, the air zone metric value is the metric value calculated for that station. For air zones with two or more CAAQS reporting stations, the air zone metric value will be the highest metric value of all CAAQS reporting stations. The *air zone metric value* will be used to determine the achievement status of a standard in an air zone. A given CAAQS is achieved in an air zone if the air zone metric value is less than or equal to the corresponding standard, and not achieved if greater than the standard.

Metric Values for Communities. Metric values will be reported for communities with population of at least 100,000. Jurisdictions can also report metric values for smaller communities and rural areas. For communities with more than one CAAQS reporting station, the community metric value will be highest metric value of all CAAQS reporting station in the community. In addition, metric values can also be reported on a station basis to better inform the public of air quality levels in a community and across an air zone.

Accounting for Transboundary Flows and Exceptional Events. There are cases where an air zone does not achieve a given CAAQS because of contributions of pollutants over which jurisdictions have little or no control. These contributions can originate from two broad categories: *transboundary flows* (TF) and *exceptional events* (EE).

Under the Air Quality Management System (AQMS), provinces and territories can report that a given CAAQS would have been achieved in an air zone if not for the influence of TF/EE. Provinces and territories will use a Weight of Evidence (WOE) approach in which a number of analyses are conducted that collectively support the conclusion. The occurrence of TF/EE can have implications from an air zone management perspective.

Reporting Metric Values. Metric values for air zones and communities will be reported based on the actual measured concentrations of $PM_{2.5}$ and ozone. That is, any influence of TF and EE on the measured concentrations is not to be considered when reporting the metric values for air zones and communities. For air zones, where the WOE analyses supports the conclusion that a given standard would have been achieved in an air zone if not for the influence of TF/EE, provinces and territories can specify this. For communities with metric values above a given standard, provinces and territories can also specify that the metric value would have been below or equal to the standard if not for the influence of TF/EE as applicable.

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ACRONYMS AND ABBREVIATIONS

AQMS	Air Quality Management System
AZMF	Air Zone Management Framework
CAAQS	Canadian Ambient Air Quality Standards
CCME	Canadian Council of Ministers of the Environment
CMA	Census Metropolitan Area
CRM	Canadian reference method for measuring $PM_{2.5}$ concentrations
CSD	Census sub-divisions
CT	Census tract
CWS	Canada-wide Standard for PM and Ozone
daily 8hr-O_3-max	Daily maximum 8-hour average ozone concentration (in ppb)
daily 24hr-$PM_{2.5}$	Daily 24-hour average $PM_{2.5}$ concentration (in $\mu g/m^3$)
EE	Exceptional events
EPA	Environmental Protection Agency (U.S.)
FEM	Federal Equivalent Method (EPA)
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than or equal to 2.5 microns in diameter, also called fine particles
ppb	Parts per billion (by volume)
RSA	Reporting Sub-Area
TF	Transboundary flows
$\mu g/m^3$	Micrograms per cubic metre

1. PURPOSE AND CONTENT OF DOCUMENT

Under the Air Quality Management System (AQMS), provinces and territories will need to determine if a given air zone achieves the Canadian Ambient Air Quality Standards (CAAQS). The purpose of this *Guidance Document for the Achievement Determination for the Canadian Ambient Air Quality Standards for Fine Particulate Matter*[4] *and Ozone* (GDAD) is to provide provinces, territories and stakeholders with information on methodologies, procedures, and requirements that need to be satisfied to determine the achievement status of the CAAQS in air zones.

In some cases, an air zone may be unable to achieve a given standard because of influences that jurisdiction have little or no control over, such as transboundary flows (TF) and exceptional events (EE) (see section 6). If an air zone is unable to achieve a standard because of the influences of TF/EE, the province/territory in which the air zone is located has the option to consider these influences when implementing management actions within the air zone. As such, the GDAD also includes the procedures to follow to demonstrate that an air zone was unable to achieve a given standard because of TF/EE.

Adherence to the GDAD is important to ensure that consistent procedures are used across Canada to determine the achievement status of the CAAQS in air zones.

Below is an outline of the sections and content of the GDAD.

Section 2: This sections presents the fine particulate matter ($PM_{2.5}$) and ozone CAAQS.

Section 3: This section discusses the CAAQS reporting stations and $PM_{2.5}$ and ozone monitoring within air zones and communities. CAAQS reporting stations are the monitoring stations that jurisdictions will use to determine the achievement status of a given standard.

Section 4: This section provides the detailed calculation procedures and requirements that need to be satisfied to obtain valid metric values for each of the three standards on a monitoring station basis.

Section 5: This section provides the procedures to determine the achievement status of the CAAQS in air zones.

Section 6: This sections addresses the reporting of metric values for communities.

Section 7: This section provides the detailed procedures to make the demonstration that an air zone would have achieved a standard if not for the influence of TF/EE.

Section 8: This section describes the reporting of metric values for air zones and communities.

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[4] Fine particulate matter is also referred to as *fine particles*.

To help in understanding the GDAD and the AQMS, the GDAD should be read in conjunction with the following document:

Guidance Document on Air Zone Management (available at www.ccme.ca)

2. THE CANADIAN AMBIENT AIR QUALITY STANDARDS

This section presents information on the $PM_{2.5}$ and ozone CAAQS. The CAAQS consist of three related components:

i. A time-averaging period for the $PM_{2.5}$ and ozone concentrations

ii. A *numerical value* for each of $PM_{2.5}$ and ozone for the associated time-averaging period, referred to as the ***standards***

iii. A *statistical form* of each standards, referred to as the ***metric***

Standards have been developed for 2015 and 2020 and are presented in Table 1. For $PM_{2.5}$, there is both a 24-hour average standard and an annual average standard. For ozone there is an 8-hour average standard.

Table 1: $PM_{2.5}$ and Ozone CAAQS

Pollutant	**Averaging time**	**Standards** (concentration)		**Metric**
		2015	**2020**	
$PM_{2.5}$	24-hour (calendar day)	28 $\mu g/m^3$	27 $\mu g/m^3$	The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.
$PM_{2.5}$	annual (calendar year)	10.0 $\mu g/m^3$	8.8 $\mu g/m^3$	The 3-year average of the annual average concentrations.
Ozone	8-hour	63 ppb	62 ppb	The 3-year average of the annual 4th-highest daily maximum 8-hour average concentrations.

The $PM_{2.5}$ and ozone concentrations in the form of the metrics are referred to as *metric values*. Metric values are calculated from the measured ambient concentrations of $PM_{2.5}$ and ozone, and it is the metric values which will be used to determine the achievement status of a standard and the management level for a given air zone.

The procedures for calculating metric values on a monitoring-station basis are discussed in section 4. The procedures for determining the achievement status of a standard for air zones are discussed in section 5.

3. MONITORING IN AIR ZONES

This section provides guidance for establishing *CAAQS reporting stations* in air zones. CAAQS reporting stations are monitoring stations that provinces and territories will use to determine the achievement status of the standards and management levels in their air zones. Guidance for establishing CAAQS reporting stations includes spatial variability in the $PM_{2.5}$ and ozone levels, siting criteria, and the minimum population of communities where CAAQS reporting has to be established. For air zones with limited or having no monitoring stations, there are qualitative methods and tools that can be used to obtain a preliminary indication of the air quality across the air zone.

The measured ambient concentrations (or levels) of $PM_{2.5}$ and ozone at CAAQS reporting stations serve different purposes:

- **i.** To evaluate the achievement status of the CAAQS in an air zone
- **ii.** To assist in identifying air management levels in an air zone and associated actions
- **iii.** To identify parts of the air zones with elevated $PM_{2.5}$ and/or ozone concentrations
- **iv.** To communicate to the public their local $PM_{2.5}$ and ozone air quality conditions and trends
- **v.** To assist in identifying the spatial variability in $PM_{2.5}$ and ozone levels across the air zone.

3.1 Factors to Consider for Establishing CAAQS Reporting Stations

The number of CAAQS reporting stations in an air zone may vary depending on such factors as spatial variability in levels across the air zone (which partly depends on the area covered by the air zone) and the number and population of communities within the air zone. Depending on the location of the monitoring stations, the air quality data collected at the stations may be representative of different qualitative size scales, as discussed in Appendix A. This section discusses some of the factors that could be considered in establishing CAAQS reporting stations.

3.1.1 Consideration of Spatial Variability

If the air zone has uniform levels of $PM_{2.5}$ and ozone, a single CAAQS reporting station may provide air quality information which is sufficiently representative of the entire air zone, especially if the air zone is small in area coverage. However, if it is known or suspected that the levels are non-uniform, jurisdictions are encouraged to deploy a sufficient number of monitoring stations to adequately capture the variability, as allowed by financial and human resources. The existing monitoring networks in Canada do not encompass a large number of monitoring stations to quantitatively define what constitutes "spatial variability". Provinces and territories may collaborate with the federal government to assess the adequacy of their monitoring networks if necessary.

3.1.2 Consideration of Community and Rural Areas

All communities with population of 100,000 or more are to have at least one CAAQS reporting station. Provinces and territories also have the flexibility of using existing and future stations in smaller communities and rural areas as CAAQS reporting stations, especially if the $PM_{2.5}$ and ozone levels are non-uniform across the air zone. If these stations are not used as CAAQS reporting stations, it is recommended that the information from these stations be reported in the air zones report that each province and territory will prepare to better inform the public of the air quality conditions that prevail across the air zone.

To assist provinces and territories with the identification of communities which are to have at least one CAAQS reporting station, Statistics Canada geographic units can be used. Statistics Canada utilises geographic units for grouping of municipalities that are closely interconnected with integrated economies. These geographic units include Census Metropolitan Areas (CMAs) and Census Agglomerations (CAs). All CMAs have a population of more than 100,000. Most CAs have a population of less than 100,000 but a few have a population over 100,000. Appendix B provides a list of the CMAs/CAs in Canada along with their population.

3.2 Siting Criteria for CAAQS Reporting Stations

CAAQS reporting stations in communities should be located in areas that reflect the "neighbourhood" or "urban scale". For rural or remote areas, the CAAQS reporting stations should reflect the "regional" scale, if there is adequate spatial homogeneity in the levels at the regional scale. Descriptions of neighbourhood, urban and regional scales are discussed in Appendix A.

Neighbourhood or urban scale monitors should be located in residential, commercial and industrial or other areas where people live, work and play. Community-oriented monitoring sites should not, however, be unduly influenced by nearby emission sources. For example, monitoring stations should not be located in close proximity to the fence line of an industrial facility or next to a major roadway. Community-oriented monitoring will assist air quality managers in designing appropriate control strategies to reduce broader community-wide exposure to $PM_{2.5}$.

For ozone, monitoring stations could also be located in areas of expected maximum ozone concentrations, where possible. In large metropolitan areas, some of the highest ozone concentrations commonly occur beyond the urban core, and the lowest ozone concentrations typically occur in the urban core[5]. The CCME *Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone for the CWS*[6] should be consulted for greater detailed information on the criteria for siting $PM_{2.5}$ and ozone monitors.

3.3 $PM_{2.5}$ and Monitoring Methods at CAAQS Reporting Stations

In the past, the $PM_{2.5}$ concentration was measured with manual samplers in which particles segregated by size are collected on a pre-weighed filter medium over a 24-hour period (midnight to midnight local time). Beginning in the mid-nineties, monitoring agencies in both Canada and the U.S. began to deploy continuous monitors which measure $PM_{2.5}$ concentrations using indirect methods such as optical properties, beta attenuation or inertial properties, and provide concentration measurements in near real-time (hourly or less).

Most agencies in Canada have transitioned to continuous monitors, but a limited number of manual samplers continue to be operated across Canada, collecting samples on a one-in-three or one-in-six day schedule for chemical analysis. In 2004, these manual samplers were designated as the NAPS[7] Reference Method (NRM) for $PM_{2.5}$ measurements against which the measurements from continuous monitors are compared.

Because of the very complex nature of the species that make up the $PM_{2.5}$ particles, it is not unusual that $PM_{2.5}$ concentrations from continuous monitors often differ from the NRM concentrations. This issue is not unique to Canada, but also occurs in the U.S. and many other countries.

In 2006, the U.S. Environmental Protection Agency (EPA) amended its national air quality monitoring regulations to incorporate criteria for approval of EPA federal equivalent methods (FEMs) for continuous (Class III) $PM_{2.5}$ monitors[8]. These regulations specify the testing methods and performance criteria that continuous monitors must satisfy to receive the FEM designation.

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[5] The urban core contains much higher emissions of nitric oxide (NO) due to the greater number of vehicles on the roads. The emitted NO reacts with ozone and, in so doing, removes ozone from the air. Further downwind however, the ozone reforms, and hence the higher ozone levels beyond the urban core and surrounding rural areas.

[6] The report is available at:
http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf

[7] NAPS refers to the *National Air Pollution Surveillance network*. It is a collaborative monitoring network operated jointly by federal, provincial, territorial and municipal governments.

[8] Federal Register, Vol. 71, page 61236, October 17, 2006.

NAPS monitoring agencies reviewed the process used for approving the $PM_{2.5}$ Class III FEM instruments and concluded that the testing requirements were sufficiently comprehensive as to include most ambient conditions found at Canadian monitoring locations. As such, the CCME *Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone for the CWS*[9] (the Monitoring Protocol), developed by NAPS agencies, recommends that all new purchases of continuous $PM_{2.5}$ monitors for the NAPS network should be restricted to those that have received EPA Class III FEM designation or any instruments that meet the performance criteria of Class III FEM monitors. The Monitoring Protocol also states that the FEM Class III performance criteria be adopted as the NAPS continuous $PM_{2.5}$ monitor equivalency.

Most provinces have deployed or will be deploying continuous $PM_{2.5}$ monitors that satisfy the EPA Class III FEM designation or that meet the performance criteria. To ensure comparability of $PM_{2.5}$ data across Canada, it recommended that jurisdictions strive to have deployed by December 31, 2012 $PM_{2.5}$ monitors which meet these requirements. This would ensure that the achievement status of the 2015 and 2020 standards in provinces and territories are all based on comparable data.

3.4 Tools to Qualitatively Supplement Ambient Data

In air zones with no monitoring coverage, there are a number of qualitative methods and tools that can be used to obtain a preliminary assessment of the air quality levels in these areas. This information may help to indentify emerging issues, or the need to install quantitative monitoring stations. For clarity, the information provided by these qualitative methods and tools is not to be used for achievement determination of the standards. In larger air zones with few existing monitoring stations, the same qualitative methods and tools may be used to determine if additional monitoring is required in remote parts of the air zone that do not have representative monitoring.

Some of the qualitative methods and tools are described in Appendix C.

4. CALCULATION OF METRIC VALUES FOR MONITORING STATIONS

This section provides guidance on the methods and procedures to use and on the requirements that need to be satisfied in order to obtain valid metric values at CAAQS reporting stations for each of the three standards. These include, for example, data completeness requirements. Jurisdictions are strongly encouraged to implement best practices for data collection to satisfy data completeness requirements. This will ensure that there is no year in which metric values cannot be calculated because of insufficient data.

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[9] The report is available at: http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf

For the $PM_{2.5}$ standards, provinces and territories using $PM_{2.5}$ monitors that do not meet the performance criteria specified in the CCME *Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone (2011)*[10] should flag the reported $PM_{2.5}$ metric values with a footnote specifying this (see section 8). This is important since in some cases the differences in levels between provinces and territories, and even between air zones in the same jurisdiction, could partially be attributed to differences in monitoring methods when reporting metric values for air zones and communities.

It should be noted that section 4 addresses specifically the calculation of metric values for CAAQS reporting stations. The procedures for determining the achievement status of standards in air zones are addressed in section 5.

4.1 Procedures for the $PM_{2.5}$ 24-hour Metric

The $PM_{2.5}$ 24-hour metric is the following:

The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations

The data required to calculate a $PM_{2.5}$ 24-hour metric value for a station therefore includes:

- **i.** The daily average (midnight to midnight local time) $PM_{2.5}$ concentration for each day of a given year; and
- **ii.** The annual 98^{th} percentile value of the daily 24hr-$PM_{2.5}$ for the given year.

The following sections describe the procedures and methodologies to follow for obtaining valid daily average $PM_{2.5}$ concentrations for each day of a given year; valid annual 98^{th} percentile values; and valid $PM_{2.5}$ 24-hour metric values.

4.1.1 Calculating the Daily 24hr-$PM_{2.5}$

For continuous monitors, the daily average $PM_{2.5}$ concentration will be calculated from the 1-hour concentrations based on Equation 1:

$$\text{daily 24hr-}PM_{2.5} = \frac{X_1 + X_2 + X_3 + \cdots X_N}{N} \quad \text{(Equation 1)}$$

where,

[10] The report is available at: http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf

daily 24hr-$PM_{2.5}$	is the daily 24-hour average concentration (in µg/m^3) rounded to one decimal place using the procedures specified in Appendix D.
Xi	is the hourly $PM_{2.5}$ concentration (in µg/m^3) for hour i.
N	is the total number of 1-hour $PM_{2.5}$ concentrations available in the given day; N is to be at least 18 (see section 4.1.4).

For manual samplers, the sampler must be operated from midnight to midnight (local time) to obtain the daily 24hr-$PM_{2.5}$ on each day of the given year.

4.1.2 Calculating the Annual 98th Percentile Value

The 98th percentile (98P) value is included in the calculated daily 24hr-$PM_{2.5}$ for the given monitoring station. The 98P value corresponds to the concentration for which 98 percent (%) of all the daily 24hr-$PM_{2.5}$ are less than or equal to it, and 2% are greater than or equal to it. There are several procedures for obtaining a 98P value. For the purpose of the GDAD, the following steps are to be used[11]:

Step 1: Order all the daily 24hr-$PM_{2.5}$ for a given year into an array from highest to lowest concentrations, with equal values repeated as often as they occur. An example is provided in Table 2.

Table 2: An example of an ordered array of daily 24hr-$PM_{2.5}$ from highest to lowest

Rank of the daily 24hr-$PM_{2.5}$	Value of the corresponding daily-24hr-$PM_{2.5}$ (µg/m^3)
1st highest	35
2nd highest	30
3rd highest	27
4th highest	27
5th highest	27
6th highest	24
7th highest	23
8th highest	18
…	…
365 (lowest)	10

[11] It should be noted that these procedures may be different from those presented in statistical text books or derived from statistical software packages. Therefore, before using any given statistical software to calculate the 98P, the user should ensure that the procedures are the same as those presented in this section, otherwise the software cannot be used.

Step 2: Calculate the number *i.d*, defined as follows,

i.d = 0.98*N (0.98 multiplied by N)

where,

i is the integer part of the number.

d is the decimal part of the number.

N is the total number of valid daily-24hr-$PM_{2.5}$ in the given calendar year.

Step 3: The annual 98P value is then the (N – i) highest value in the array established in Step 1. Since the daily 24hr-$PM_{2.5}$ is reported to one decimal place, the 98P value will also be reported to one decimal place.

As an example, if N = 275, 0.98*275 = 269.5, so i = 269. The 98P value then corresponds to the 6^{th} (275-269) highest value in the array of the daily 24hr-$PM_{2.5}$ ordered from highest to lowest values.

Table 3 indicates the highest value to which the 98P value corresponds, depending on the number of available daily 24hr-$PM_{2.5}$ (N).

Table 3: Number of daily 24hr-$PM_{2.5}$ and the corresponding 98P value

Number of daily 24hr-$PM_{2.5}$ (N)	The rank of the daily 24hr-$PM_{2.5}$ to which the 98P value corresponds to
1 - 50	1^{st} highest
51 - 100	2^{nd} highest
101 - 150	3^{rd} highest
151 - 200	4^{th} highest
201 - 250	5^{th} highest
251 - 300	6^{th} highest
301 - 350	7^{th} highest
351 - 366	8^{th} highest

4.1.3 Calculating the $PM_{2.5}$ 24-hour Metric Value

The $PM_{2.5}$ 24-hour metric value is the average of the annual 98P values over three consecutive years, as represented mathematically by equation 2:

$$PM_{2.5} \text{ 24-hour metric value} = \frac{98P_1 + 98P_2 + 98P_3}{3} \quad \text{(Equation 2)}$$

Where,

$98P_1, 98P_2, 98P_3$ are valid annual 98th percentile concentrations (in µg/m^3) for the first, second and third year respectively for the given station.

The metric value will be reported as a whole number (integer) using the rounding procedures specified in Appendix D. Table 4 provides an example of the metric value calculation.

Table 4: Example calculation of the $PM_{2.5}$ 24-hour metric value

Year	98 percentile concentration (µg/m^3)
2009	25.6
2010	33.4
2011	28.7
$PM_{2.5}$ 24-hour metric value	**(25.6 + 33.4 + 28)/3 = 29**

The 3-year average is 29.2 µg/m^3 which when rounded to an integer gives a $PM_{2.5}$ 24-hour metric value of 29 µg/m^3.

4.1.4 Data Completeness Criteria

This section describes the data completeness criteria that have to be satisfied to calculate a valid daily 24hr-$PM_{2.5}$, a valid annual 98P and a valid $PM_{2.5}$ 24-hour metric value.

Criteria for the daily 24hr-$PM_{2.5}$

For continuous monitors, a daily 24hr-$PM_{2.5}$ is to be considered valid if at least 75% (18 hours) of the 1-hour concentrations are available on the given day. If at least 18 hours are available, the denominator in Equation 1 will be the number of hours available. For manual samplers, the sampler must be operated for at least eighteen hours in the day.

Criteria for the 98P

For any given year, the annual 98P will be considered valid if the following two criteria are satisfied:

- **i.** At least 75% valid daily-24hr-$PM_{2.5}$ in the year
- **ii.** At least 60% valid daily-24hr-$PM_{2.5}$ in each calendar quarter

The quarters are defined as follows:

Quarter 1 (Q1): January 1 to March 31
Quarter 2 (Q2): April 1 to June 30
Quarter 3 (Q3): July 1 to September 30
Quarter 4 (Q4): October 1 to December 31

In the event that criteria (ii) is not satisfied but the 98P value based on the available number of daily 24hr-$PM_{2.5}$ exceeds the $PM_{2.5}$ 24-hour standard, the 98P value will be retained for the calculation of the $PM_{2.5}$ 24-hour metric value. In this case, however, the calculated $PM_{2.5}$ 24-hour metric value will be flagged as "*based on incomplete data*".

Criteria for the $PM_{2.5}$ 24-hour metric value

A $PM_{2.5}$ 24-hour metric value will be calculated and considered valid if an annual 98P value is available for at least two of the required three years. For cases where the metric value is based on only two years, the reported metric value for the station will be flagged as being based on only two of the required three years.

4.2 Procedures for the $PM_{2.5}$ Annual Metric

The $PM_{2.5}$ annual metric is the following:

The 3-year average of the annual average concentrations.

The data required to calculate a $PM_{2.5}$ 24-hour metric value for a station therefore includes:

- **i.** The daily average (midnight to midnight local time) $PM_{2.5}$ concentration for each day of a given year; and
- **ii.** The annual average of the daily 24hr-$PM_{2.5}$ for the given year

The following sections describe the procedures and methodologies for obtaining valid daily 24hr-$PM_{2.5}$, valid annual average $PM_{2.5}$ concentrations, and valid $PM_{2.5}$ annual metric values for a given CAAQS reporting station.

4.2.1 Calculation of the Daily 24hr-$PM_{2.5}$

The daily 24hr-$PM_{2.5}$ value will be calculated as described in section 4.1.1.

4.2.2 Calculation of the Annual Average

For each year, the $PM_{2.5}$ annual average concentration will be calculated from the daily-24hr-$PM_{2.5}$ using Equation 3.

$$PM_{2.5} \text{ annual average} = \frac{PM_1 + PM_2 + \cdots + PM_N}{N} \quad \text{(Equation 3)}$$

Where,

PM_i is the valid daily-24hr-$PM_{2.5}$ for day i.

N is the total number of valid daily-24hr-$PM_{2.5}$ in the year.

The annual average is to be rounded to one decimal place based on the procedure specified in Appendix D.

4.2.3 Calculation of the $PM_{2.5}$ Annual Metric Value

The $PM_{2.5}$ annual metric value will be calculated using equation 4:

$$PM_{2.5} \text{ annual CAAQS metric value} = \frac{AA_1 + AA_2 + AA_3}{3} \quad \text{(Equation 4)}$$

Where,

AA_1, AA_2, AA_3 are the valid annual average concentrations (in µg/m^3) for the first, second and third year respectively.

The $PM_{2.5}$ annual metric value will be rounded to one decimal place using the procedures specified in Appendix D.

4.2.4 Data Completeness Criteria

This section describes the data completeness criteria that have to be satisfied to calculate a valid daily 24hr-$PM_{2.5}$, a valid annual average and a valid metric value for the $PM_{2.5}$ annual standard.

Criteria for the daily 24hr-$PM_{2.5}$

The criteria for the daily 24hr-$PM_{2.5}$ are the same as those described in section 4.1.4.

Criteria for the Annual Average

For any given year, the annual average $PM_{2.5}$ concentration will be will be considered valid if the following two criteria are satisfied:

- **i.** At least 75% valid daily-24hr-$PM_{2.5}$ in the year
- **ii.** At least 60% valid daily-24hr-$PM_{2.5}$ in each calendar quarter

Criteria for the $PM_{2.5}$ annual metric value

A $PM_{2.5}$ annual metric value will be calculated and considered valid if annual averages are available for at least two of the required three years. For cases where the metric value is based on only two years, the reported metric value for the station will be flagged as being based on only two of the required three years.

4.3 Procedures for the Ozone Metric

The ozone metric is the following:

The 3-year average of the annual 4^th^ highest daily maximum 8-hour average concentration.

The data required to calculate an ozone metric value for a station therefore includes:

- **i.** The daily maximum 8-hour average ozone concentration for each days of the year
- **ii.** The annual 4^{th} highest daily 8hr-O_3-max for a given year

The following sections describe the procedures and methodologies for obtaining valid 8-hour rolling average ozone concentrations, valid daily-maximum 8-hour average ozone concentration (represented by *daily 8hr-O_3-max*), valid annual 4th highest daily 8hr-O_3-max, and valid ozone metric values for a given monitoring station.

4.3.1 Calculating Rolling 8-hour Average Concentrations

An ozone 8-hour average concentration will be calculated for each hour of the day. Eight hour averages calculated for each hour of the day are know as *rolling averages.* A rolling 8-hour average will be calculated from the 1-hour average concentrations using Equation 5:

$$\mathbf{Y_J}\text{-8hr-}O_3 = \frac{Y_J + Y_{J-1} + Y_{J-2} + Y_{J-3} + Y_{J-4} + Y_{J-5} + Y_{J-6} + Y_{J-7}}{8} \qquad \text{(Equation 5)}$$

Where,

Y_J	is the 1-hour average ozone concentration for hour J in a 24 hour clock.
Y_{J-i}	the 1-hour average ozone concentration for hour J-i, with i = 1 to 7.
$\mathbf{Y_J}$-8hr-O_3	is the 8-hour average ozone concentration for hour J.

All 8-hour averages will be reported to one decimal place based on the procedures specified in Appendix D.

Equation 5 assumes that there are eight 1-hour concentrations available in the given 8-hour period. This may not always be the case. A $\mathbf{Y_J}$-8hr-O_3 can be calculated and considered valid if there are at least six 1-hour concentrations; in this case the "8" in equation 5 is replaced by the number of 1-hour average concentrations available (6 or 7, if less than 8), as discussed further in section 4.3.5.

Note that both the 1-hour averages and the 8-hour averages are assigned to the ending hour of the time averaging period. For example, the 1-hour average concentration for the hour 02:00 is the average of the measurements between the hours of 01:00 to 02:00. The 8-hour average for the hour 02:00 is the average of the 1-hour concentrations for the hours from 02:00 of the current day to 19:00 (inclusive) of the previous day.

4.3.2 Calculating the daily 8hr-O_3-max

For any given day, the daily 8hr-O_3-max is the highest of all available 8-hour rolling averages in that day.

4.3.3 Obtaining the Annual 4th highest daily 8hr-O_3-max

In a given year, there can be up to 365 (366 in leap-years) daily 8hr-O_3-max. The annual 4^{th} highest daily 8hr-O_3-max is obtained by first ordering all the daily 8hr-O_3-max in an array from highest to lowest values, with equal values repeated as often as they occur, and each assigned the next rank. The annual 4^{th} highest daily 8hr-O_3-max is then the 4^{th} highest value in the ordered array. Table 5 provides an example.

Table 5: An example of an ordered array of the daily 8hr-O_3-max from highest to lowest values

Rank of the daily 8hr-O_3-max	Value of the corresponding daily 8hr-O_3-max (ppb)
highest	77.8
2nd highest	76.1
3rd highest	70.2
4th highest	70.2
5th highest	65.6
…	…
365 (lowest)	52.5

In this example, the 4th highest daily 8hr-O_3-max is 70.2 ppb

The annual 4th highest daily 8hr-O_3-max are to be reported to one decimal place based on the procedures specified in Appendix D.

4.3.4 Calculating the Ozone Metric Value

The ozone metric value for a given CAAQS reporting station will be calculated using equation 6:

$$\text{Ozone metric value} = \frac{AF_1 + AF_2 + AF_3}{3} \quad \text{(Equation 6)}$$

Where,

AF_1, AF_2, AF_3 are the annual 4th highest daily 8hr-O_3-max for years 1, 2 and 3.

The ozone metric value will be reported as a whole number (integer) using the rounding procedures specified in Appendix D.

4.3.5 Data Completeness Criteria

This section describes the data completeness criteria that have to be satisfied to calculate a valid rolling 8-hour average, a valid daily 8hr-O_3-max, a valid annual 4th highest daily 8hr-O_3-max, and a valid ozone metric value for a given CAAAQS-reporting station.

Criteria for the 8-hour rolling average

A rolling 8-hour average will be calculated and considered valid if there are at least six 1-hour average concentrations in the corresponding 8-hour period. If there are six or seven 1-hour averages, the denominator in equation 5 will be the number of 1-hour averages available (6 or 7) in the corresponding 8-hour period.

Criteria for the daily 8hr-O_3-max

For any given day, the daily 8hr-O_3-max will be considered valid if there are at least 75% (18) valid 8-hour rolling averages in the day. For cases where this criterion is not satisfied and the value of the resulting daily 8hr-O_3-max based on the available number of 8-hour averages exceeds the ozone standard, the resulting daily 8hr-O_3-max will be considered as valid and used to determine the annual 4^{th} highest daily 8hr-O_3-max. In this case, however, the 8hr-O_3-max will be flagged as "*based on incomplete data*".

Criteria for the annual 4th highest daily 8hr-O_3-max

For any given year, the annual 4th highest daily 8hr-O_3-max will be considered valid if there are at least 75% valid daily 8hr-O_3-max in the combined 2nd and 3rd quarters (April 1 to September 30). Where this criterion is not satisfied and the value of the annual 4^{th} highest daily 8hr-O_3-max based on the available daily 8hr-O_3-max exceeds the ozone standard, the resulting annual 4th highest daily 8hr-O_3-max will be considered as valid and used in the calculation of the ozone metric value. In such cases, the annual 4^{th} highest daily 8hr-O_3-max would be flagged as *"based on incomplete data"*.

It should be noted that while the 75% criterion applies to the period April 1 to September 30, the annual 4^{th} highest daily 8hr-O_3-max may occur outside of this period.

Criteria for the Ozone Metric Value

For a given CAAQS reporting station, the ozone metric value will be calculated and considered valid if the annual 4^{th} highest daily 8hr-O_3-max are available in at least two of the required three years. For cases where the metric value is based on only two years, the reported ozone metric value will be flagged as being based on only two of the required three years.

5. ACHIEVEMENT STATUS OF THE CAAQS FOR AIR ZONES

This section describes how to assign a metric value to an air zone for the determination of the achievement status of the CAAQS.

For air zones with a single CAAQS reporting station, the metric value for the air zone will be the metric value for that single CAAQS reporting station.

For air zones that have two or more CAAQS reporting stations, a metric value for each standard will first be calculated for each station based on the procedures in section 4. The air zone metric value for a given standard will then be the highest metric value of all stations for the given standard. However, stations with metric values based on only two years of data will be excluded for consideration of the *air zone* metric value. In the event that *all* station metric values are based on two years of data, the air zone metric value will then be the highest metric value of all the stations. For such cases, the reported air zone metric value will be flagged as being based on only two years.

An air zone achieves a given standard if the air zone metric value for that standard is equal to or less than the standard and in non-achievement if the air zone metric value is above the standard. To better define the spatial variability in levels across an air zone, the air zone report to be produced by a province or territory can also report the metric-values on a station-basis.

Tables 6 and 7 provide examples for assigning the air zone metric value in the case of three CAAQS reporting stations.

Table 6: Assigning the air zone $PM_{2.5}$ 24-hour metric value (example 1)

	Values of the 98P (µg/m³)				
Station ID number	**2008**	**2009**	**2010**	**Station metric value** (µg/m³)	**Air zone metric value** (µg/m³)
1	NA	24.9	26.7	26	25
2	25.1	24.8	24.2	25	
3	24.2	23.4	23.8	24	

In Table 6, since station 1 has only 2 of the required 3 annual 98P, its metric value is not considered for determining the air zone metric value (even though it is the highest station metric value). Stations 2 and 3 have a 98P value in each of the 3-year, and as such they are both considered in assigning the air zone metric value. The metric values are 25 µg/m³ for station 2 and 24 µg/m³ for station 3. The highest of these two is 25 µg/m³, and this is the metric value assigned to the air zone.

In the example of Table 7, all three CAAQS reporting stations in the air zone have one missing annual 98P value. In this case, since all stations have one missing annual 98P, the station metric values are all considered in assigning the air zone metric value. The highest of the metric values of the three stations is 27 µg/m³, and this becomes the air zone metric value.

Table 7: Assigning the air zone $PM_{2.5}$ 24-hour metric value (example 2)

	Values of the 98P (µg/m^3)				
Station ID number	**2008**	**2009**	**2010**	**Station metric value** (µg/m^3)	**Air zone metric value** (µg/m^3)
1	NA	25.9	22.7	24	27
2	25.1	28.8	NA	27	
3	NA	26.4	24.8	26	

6. CAAQS METRIC VALUES FOR COMMUNITIES

As mentioned in section 3, all communities with a population of 100,000 or more are to have at least one CAAQS reporting station. Metric values will also be reported for these communities since reporting at the community level provides the public with better information regarding the $PM_{2.5}$ and ozone concentrations in their respective communities. If a community has more than one CAAQS reporting station, the metric value to report for the community will be the highest of all stations in that community based on the procedures defined in section 5 for air zones. To better define the spatial variability in levels across a community, the metric values for a given standard can also be reported for each station in the community.

As also mentioned in section 3, provinces and territories have flexibility in reporting CAAQS metric values for smaller communities and for rural areas, even if the monitoring stations in these smaller communities and rural areas are not classified as being CAAQS reporting stations. Provinces and territories can identify in their air zone report which communities are above a standard, and which are below or equal to the standard.

7. ACCOUNTING FOR TRANSBOUNDARY FLOWS AND EXCEPTIONAL EVENTS

The ambient $PM_{2.5}$ and ozone concentrations measured at a monitoring station may be the sum total of $PM_{2.5}$ and ozone from local anthropogenic sources and from various other origins. Two broad origins are *transboundary flows* and *exceptional events* (defined in section 7.1). In some cases, it is possible that a given standard is not achieved in an air zone because of influences from TF/EE. In these cases, the province/territory in which the air zone is located has the option to consider these influences when implementing management actions within the air zone, and it can also convey to the public that a given standard was not achieved as a result of these influences.

From a management perspective, it is important for provinces and territories to know the sources that contributed to the measured levels of $PM_{2.5}$ and ozone in an air zone. While jurisdictions may not be able to directly manage contributions from TF/EE, they can, and should, attempt to manage the emissions within their boundaries to improve air quality and prevent the further deterioration of air quality.

The main purpose of this section is to provide guidance on the procedures to be used to demonstrate that a given standard would have been achieved in an air zone if not for the influence from TF/EE for provinces and territories that opt to make this demonstration.

Making this demonstration is a two step process. The first step is the demonstration that TF/EE did indeed influence[12] the measured levels of $PM_{2.5}$ or ozone. The second step is the demonstration that in the absence of data influenced by TF/EE, the air zone would have achieved the given standard. Step 1 and 2 are discussed in detail in sections 7.2 and 7.3 respectively.

7.1 Defining Transboundary Flows and Exceptional Events

Transboundary flows and exceptional events are two broad categories for the origins of $PM_{2.5}$, ozone and their precursors for which jurisdictions have little or no direct control. The definitions of transboundary flows and exceptional events are as follows:

Transboundary flows (TF) are defined as the transport of air pollution across provincial and territorial boundaries, and between Canada and the United States.

Exceptional events[13] ***(EE)*** are events that contribute to air pollution levels in an air zone and satisfy at least one of the following criteria:

- **i.** The event is not reasonably controllable or preventable;
- **ii.** The event is caused by human activities which are ***unlikely to recur***; or
- **iii.** The event is a natural source; "*natural*" means an event in which human activities plays little or no direct causal role to the event in question.

The following is a non-exhaustive list of examples of exceptional events:

- Air pollution originating from biogenic emissions and other natural sources from within North America

[12] It should be noted that the "influence" is evaluated from a qualitative perspective; that is, no attempts are made to quantify the TF/EE contribution and the local contribution. For TF/EE purposes, this approach implicitly assumes that the measured concentrations are fully attributable to TF/EE, although this may not necessarily be the case in reality.

[13] Adapted from the EPA

- Downward transport to the surface of ozone present in the free troposphere (i.e. above the mixing layer/boundary layer), or from the stratosphere[14] (e.g. stratospheric intrusions)
- Intercontinental transport of air pollution
- High wind dust events within North America, excluding the re-suspension of road dust
- Forest and grass fires caused by lighting, arson or other non-controllable causes from within North America
- Prescribed forest and grass fires from within North America conducted for security reasons or for enhancement of forests and wildlife purposes (excludes the prescribed burning of land-clearing debris and prescribed agricultural burns)
- Structural fires, which include any accidental (including arson) fire involving a human-made structure
- Volcanic and seismic events
- Chemical spills, industrial accidents and the releases of air pollutants for safety reasons, and which are not recurring events[15]
- Air pollutants generated by human activities for safety or life-threatening situations

Under the CWS for PM and Ozone, *background concentrations* were included as one of the possible pollution origins that could contribute to the non achievement of the CWS. The CWS GDAD provided a definition of background concentrations which is similar to the *EPA policy-relevant background* concentration definition: *"Background concentrations are the ambient levels resulting from anthropogenic and natural emissions outside North America and natural sources within North America"*. There is also a scientific definition of "background concentrations", where the levels originate from natural sources only.

Because of the challenge in defining and quantifying background contributions, the CAAQS GDAD does not explicitly mention background concentrations as a possible cause for the non-achievement of a given standard. However, some of the given examples for EE implicitly capture any "background" contribution.

7.2 Demonstrating the Influence of TF/EE – the Weight of Evidence Approach

The CWS GDAD provided a prescriptive process for demonstrating the influence of TF and EE. However, application of the process through a number of pilot projects (in Ontario, Alberta,

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[14] The *troposphere* is the layer of air closest to the earth surface; it typically ranges from the surface up to 8-12 km above the surface. The *stratosphere* is the layer of air which comes immediately after the troposphere. The troposphere and stratosphere have distinct chemical and thermal characteristics. The *free troposphere* begins after the mixing layer (also called boundary layer); the mixing layer is the height above ground in which pollutants emitted at the surface can disperse up to.

[15] It should be noted that criteria (ii) of the EE definition explicitly mentions that an EE is one that is unlikely to *recur.* This means, for example, that "regular" or "frequent" releases of air pollutants for safety reasons do not qualify as exceptional events.

Québec, and the Maritime provinces) suggested that a more flexible and simpler approach would achieve the same objectives. For the CAAQS, a *Weight of Evidence* (WOE) approach will be used to demonstrate the influence of TF/EE.

Consistent with the air zone metric value, the WOE approach will be applied to the data from the CAAQS reporting-stations in the air zone with the highest $PM_{2.5}$ 24-hour metric value, and to the CAAQS reporting station with the highest ozone metric value in the air zone. For CAAQS non-achievement, the WOE approach will be applied to a limited number of daily 24hr-$PM_{2.5}$ and daily 8hr-O_3-max that exceed their corresponding standard. The WOE analyses will stop once pre-specified conditions are satisfied; this is discussed further in section 7.3.

The ***weight of evidence*** **(WOE)** approach consists of performing, evaluating and documenting a series of technical analyses that collectively support the conclusion that exceedances of the $PM_{2.5}$ 24-hour standard or exceedances of the ozone standard on a given day were influenced by transboundary flows and/or exceptional events[16].

In using the WOE approach, a jurisdiction will conduct a series of analyses and will have the flexibility to select the types of analyses most appropriate to demonstrate the influence of the event. The number and the complexity of the analyses will vary on a case-by-case basis depending on the nature of the TF/EE event. At the very least, however, a detailed description of the prevailing meteorological conditions for the period covering the occurrence of the influence of TF/EE should be provided.

Appendix E provides selected examples of some of the WOE analyses that can be conducted as part of the WOE approach.

The WOE approach requires substantial expert judgment in the selection and interpretation of analyses to support the demonstration of the influence of TF/EE on the exceedance of a standard. Provincial and territorial air quality experts, in consultation with the federal government as needed, would use the evidence from the analyses, along with their expert judgment, to ascertain the most probable cause(s) of the measured ambient levels of $PM_{2.5}$ and ozone.

Agreement among multiple lines of evidence (i.e. different analyses) would be sufficient to support the influence[17] of TF/EE. However, if the lines of evidence are contradictive or do not support each other, the conclusion of the influence of TF/EE would be questioned.

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[16] Adapted from the USEPA www.epa.gov/scram001/guidance/guide/owt_guidance_07-13-05.pdf. Retrieved June 25, 2011.

[17] The number of "lines of evidence" would vary according to the degree of intensity of transboundary flows and/or exceptional event. For many forest fire smoke examples, the scale of the $PM_{2.5}$ and ozone incursion would often be so large, obvious and lengthy that only one line of evidence, e.g. automatic camera images, might be required.

7.2.1 Transparency and Accountability of the WOE Analyses

For transparency and accountability, it is recommended that the WOE analyses conducted to demonstrate the influence of TF/EE be documented in detail in an appendix to the air zone report to be produced by provinces and territories. This appendix should include the following information:

- **i.** Identification of the days where the daily 24hr-PM2.5 or the daily 8hr-O3-max are believed to be influenced by TF/EE.
- **ii.** Identification of the TF/EE event(s) that influenced the daily 24hr-PM2.5 or daily 8hr-O_3-max.
- **iii.** Weight of evidence analysis that supports a causal relationship between the measured ambient levels of pollutants and the TF/EE events; or, concurrently, analysis demonstrating that emissions from the air zone, or from within the province or territory in which the air zone is located, could not have been a major contributor to the measured ambient levels under the prevailing meteorological conditions.
- **iv.** Discussion regarding why TF/EE are the most likely contributor to the non-achievement of a standard.

Provinces or territories reporting the influence of TF/EE may initiate or lead the WOE analyses. The federal government may provide technical expertise in support of these analyses when requested by provinces and territories.

7.3 Demonstrating the Achievement of a Standard if not for TF/EE

To demonstrate that a given standard would have been achieved in an air zone if not for the influence of TF/EE, provinces and territories will recalculate the air zone metric value for the standard with the TF/EE data removed. If the recalculated air zone metric value is less than or equal to the standard, the province or territory has demonstrated that the non-achievement of the standard was influenced by TF/EE. If the recalculated metric value remains above the standard, it implies that even in the absence of TF/EE the standard would still not have been achieved in the air zone. In this case, although there may indeed have been a significant influence of TF/EE, the province or territory cannot report that the standard would have been achieved if not for TF/EE.

Sections 7.3.1 to 7.3.3 describe the procedures to follow to identify TF/EE influence days for the $PM_{2.5}$ 24-hour metric value, the $PM_{2.5}$ annual metric value and the ozone metric value respectively. Examples of the recalculation procedures of the metric values with TF/EE influenced data removed are provided for the $PM_{2.5}$ 24-hour metric value and the ozone metric value. It should be noted that for the *recalculation* of the metric values, the data completeness criteria specified in section 4 do not apply.

7.3.1 Procedures for the $PM_{2.5}$ 24-hour Standard

Demonstrating the achievement of a standard if not for the influence of TF/EE will be done using the data from the CAAQS reporting-station with the highest $PM_{2.5}$ 24-hour metric value in the air zone. WOE analyses will then be conducted on the data from this station only for the years of the 3-year period where the 98P value exceeds the value of standard. The procedures are then as follows:

For each year where the 98P values exceeds the applicable[18] standard, the daily 24hr-$PM_{2.5}$ will first be ordered in an array from highest to lowest values, with equal values repeated as often as they occur. Starting from the highest daily 24hr-$PM_{2.5}$ and moving downward sequentially to the next highest value, WOE analyses will be conducted to evaluate if a given daily 24hr-$PM_{2.5}$ was TF/EE influenced. If yes, the value is identified as being TF/EE influenced. This process stops when either:

- **i.** A 98P value that is not TF/EE influenced has been identified; this is an iterative process where a 98P is obtained after each removal of the daily 24hr-$PM_{2.5}$ found to be TF/EE influenced; or

- **ii.** The next highest value of the daily 24hr-$PM_{2.5}$ for TF/EE evaluation is less than or equal to the standard.

For clarity, the following should be noted:

- **i.** *A 98P value that is not TF/EE influenced has been identified* means that all daily 24hr-$PM_{2.5}$ preceding the value of the 98P are not TF/EE influenced.
- **ii.** It may not be necessary to conduct WOE analyses on all three years. A new metric value can be recalculated after each removal of the TF/EE data in a given year. For example, if the removal of TF/EE influenced data in the first year leads to a metric value that is already less than the standard, it is then not necessary to evaluate if the levels in the other two years were TF/EE influenced.

Tables 8 and 9 provide an example of these procedures. For this example, it is assumed that the $PM_{2.5}$ 24-hour standard is 30 $\mu g/m^3$ and the values shown for the daily 24hr-$PM_{2.5}$ are those from the station with the highest metric values.

In Table 8, the values in bold are the actual annual 98P values: 25.4 $\mu g/m^3$ in 2008, 35.4 $\mu g/m^3$ in 2009 and 38.0 $\mu g/m^3$ in 2010. Calculating their average gives an air zone metric value of 33 $\mu g/m^3$ (after rounding). WOE analyses can be conducted for the years 2009 and 2010; for 2008 no WOE analyses are required since the annual 98P value (25.4 $\mu g/m^3$) is less than the standard. In Table 8, the numbers flagged with a double asterisk have been identified, through the WOE analyses, as being TF/EE influenced.

[18] By "applicable" standard it is meant the 2015 standard for years 2015 and before, and the 2020 standard for years between 2016 and 2020 inclusive.

In 2009, WOE analyses were no longer conducted beginning with the 10th highest value and also with the 10th highest value in 2010 since these values were less than the standard.

Table 8: An example of an ordered array of all daily 24hr-$PM_{2.5}$ from highest to lowest values

	Daily 24hr-$PM_{2.5}$ ($\mu g/m^3$)		
Rank	**2008**	**2009**	**2010**
Highest	32.3	48.9**	45.1**
2nd highest	32.4	45.5**	41.8**
3rd highest	30.2	39.5**	40.7
4th highest	28.9	39.8	39.9**
5th highest	28.0	38.1**	38.1**
6th highest	27.5	36.3	**38.0****
7th highest	**25.4**	36.1**	34.3
8th highest	23.1	**35.4**	31.4
9th highest	22.3	31.3	30.3
10th highest	21.5	29.3	29.3
11th highest	21.2	28.4	28.7
	21.0	28.2	28.6
	…	26.5	28.3
		24.9	27.2
Actual # of valid daily 24hr-$PM_{2.5}$	350	352	295
Actual 98P value corresponds to	7th Highest	8th Highest	6th Highest

Table 9 presents the daily 24hr-$PM_{2.5}$ after the removal of the flagged data. Notice that after the removal of the TF/EE data, the rank to which the 98P value corresponds differs in some years compared to Table 8 which has all daily 24hr-$PM_{2.5}$.

Table 9: Ordered array of the daily 24hr-$PM_{2.5}$ after the removal of the TF/EE influenced data

	Daily 24hr-$PM_{2.5}$ ($\mu g/m^3$)		
	2008	**2009**	**2010**
Highest	32.3	39.8	40.7
2nd highest	32.4	36.3	34.3
3rd highest	30.2	35.4	31.4
4th highest	28.9	31.3	30.3
5th highest	28.0	29.3	29.3
6th highest	27.5	28.4	**28.7**
7th highest	**25.4**	**28.2**	28.6
8th highest	23.1	26.5	28.3
9th highest	22.3	24.9	27.2
10th highest	21.5		
11th highest	21.2		
12th highest	21.0		
Revised # of valid days after the removal of TF/EE days	350	347	290
Revised 98P corresponds to	7^{th} Highest	7^{th} Highest	6^{th} Highest

The bold values in Table 9 are the revised 98P values after the removal of the TF/EE influenced data. The 98P values are 25.4 $\mu g/m^3$ for 2008, 28.2 $\mu g/m^3$ for 2009 and 28.7 $\mu g/m^3$ for 2010. These values give a recalculated metric value of 27 $\mu g/m^3$ (after rounding).

Since the recalculated metric value (27 $\mu g/m^3$) is less than the standard, the jurisdiction has demonstrated that the $PM_{2.5}$ 24-hour standard would have been achieved if not for the influence of TF/EE.

7.3.2 Procedures for the $PM_{2.5}$ Annual Standard

Demonstrating that the $PM_{2.5}$ annual standard would have been achieved if not for the influence of TF/EE will be conducted using the data from the CAAQS reporting-station with the highest annual metric value. The process for the demonstration is similar to the $PM_{2.5}$ 24-hour standard. The procedures for determining the TF influence, however, differ from the procedures for EE.

For transboundary flows, it is proposed that an interim approach (explained below) be applied for identifying the days to be removed for the recalculation of the $PM_{2.5}$ annual metric value, with a recommendation to develop a more comprehensive approach for the proposed review of the $PM_{2.5}$ standards in 2015. The interim approach is recommended since in some parts of Canada TF influences may occur during a large number of individual days or groups of consecutive days in a given year. In this case, making the demonstration for every TF influenced day can be challenging. Conversely, some exceptional events such as wild forest fires typically have well defined beginning and end dates, which allows for a straightforward analysis of such episodes.

The recommended approaches for identifying the TF/EE influenced days to be removed for the recalculation of the $PM_{2.5}$ annual metric value are described below.

Interim Approach for Transboundary Flows

For transboundary flows, only days when the daily 24hr-$PM_{2.5}$ concentration is higher than the applicable *24-hour standard* will be considered for TF influences for the $PM_{2.5}$ annual standard. Those days with levels higher than the 24-hour standard and found to be TF influenced will then be removed for the recalculation of the *annual* metric value.

Approach for Exceptional Events

For exceptional events, all days where the daily 24hr-$PM_{2.5}$ concentration is higher than the applicable *annual standard* can be evaluated for an EE influence. If such days are all part of the same event, it may not be necessary to conduct WOE analyses for each day, as long as the WOE analyses support the conclusion that the daily 24hr-$PM_{2.5}$ were all influenced by the same EE with well defined beginning and end dates. For EE, it is also recommended that the type of EE be clearly specified (e.g. a “high wind dust event”, a “wild forest fire” event).

7.3.3 Procedures for the Ozone Standard

Demonstrating the achievement of the ozone standard if not for the influence of TF/EE will be done using the data from the CAAQS reporting-station with the highest ozone metric value. WOE analyses will only be required for those years in the 3-year period where the annual 4^{th} highest daily 8hr-O_3-max value exceeds the applicable standard.

To demonstrate that the $PM_{2.5}$ 24-hour standard would have been achieved if not for contributions from TF/EE, provinces and territories will need to recalculate the $PM_{2.5}$ 24-hour metric value with the TF/EE data removed. If the recalculated metric value is less than or equal to the standard, the province or territory has successfully demonstrated that the non-achievement of the standard was influenced by TF/EE. If the recalculated metric value remains above the standard, the demonstration has not been made.

The procedures are then as follows:

For each year in which the annual 4th highest daily 8hr-O_3-max exceeds the standard, the daily 8hr-O_3-max will first be ordered in an array from highest to lowest values, with equal values repeated as often as they occur. Starting from the highest daily 8hr-O_3-max and moving downward sequentially to the next highest value, WOE analyses will be conducted to evaluate if a given daily 8hr-O_3-max was TF/EE influenced. If yes, the value is identified as being TF/EE influenced. The process stops when either:

i. The 4th highest value after the removal of the TF/EE data is less than or equal to the standard; or

ii. Four highest daily 8hr-O_3-max which are not TF/EE influenced have been identified.

As discussed for $PM_{2.5}$ in section 7.3.1, it may not be necessary to conduct WOE analyses on all three years. A new metric can be recalculated after each removal of the TF/EE data in a given year. For example, if the removal of TF/EE influenced data in the first year leads to a metric value that is less than the standard, it is not necessary to evaluate if the levels in the other two years were TF/EE influenced.

Tables 10 and 11 provide an example of the procedures for ozone. For this example, it is assumed that the ozone standard is 65 ppb.

The required annual 4th highest daily 8hr-O_3-max and annual 98th percentile of the daily 24hr-$PM_{2.5}$ will be obtained based on the data remaining after the removal of the TF/EE influenced data.

Table 10: An example of an ordered array of all daily 8hr-O_3-max from highest to lowest values

daily 8hr-O_3-max (ppb)				
	2008	**2009**	**2010**	**3-year Average**
Highest	92.1	80.3	79.4	
2nd	80.3	76.5**	72.3	
3rd	79.5**	76.2**	66.5	
4th	78.1**	72.1	64.9	72
5th	76.0**	70.6	60.4	
6th	75.8	69.8**	57.5	
7th	72.4**	63.3	54.1	
8th	70.4	63.0	54.0	
9th	67.4	62.3	53.6	
10th	64.5	62.1	53.6	
…				
365th	20.	22.6	21.1	

In Table 10, the annual 4^{th} highest daily 8hr-O_3-max are 78.1 ppb for 2008, 72.1 ppb for 2009, and 64.9 ppb for 2010. Their average gives an air zone metric value of 72 ppb, which is above the standard.

WOE analyses can be conducted for the years 2008 and 2009; for 2010 no WOE analyses are required since the annual 4^{th} (64.9 ppb) is less than the standard. In Table 8, the numbers flagged with a double asterisk have been identified, through the WOE analyses, as being TF/EE influenced. For 2008, the WOE analyses stopped after the 8^{th} highest daily 8hr-O_3-max since four non-TF/EE were identified; in 2009 WOE analyses were no longer required after the 6^{th} highest value since the 7^{th} highest value is less than the standard. Table 11 provides the daily 8hr-O_3-max with the TF/EE data removed.

Table 11: Ordered array of the daily 8hr-O_3-max in Table 10 after the removal of the TF/EE influenced data

Daily 8hr-O_3-max (ppb)				
	2008	**2009**	**2010**	**3-year Average**
Highest	92.1	80.3	79.4	
2nd	80.3	72.1	72.3	
3rd	75.8	70.6	66.5	
4th	70.4	63.3	64.9	66
5th	67.4	63.0	60.4	
6th	64.5	62.3	57.5	
.				

With the TF/EE days removed, the annual 4th highest are 70.4, 63.3 and 64.9 ppb respectively for 2008, 2009 and 2010. Their average gives a recalculated CAAQS metric value of 66 ppb. Since the recalculated CAAQS metric value remained higher than the standard, the jurisdiction cannot report that the standard was not achieved because of the influence of TF/EE.

8.0 REPORTING OF METRIC VALUES FOR AIR ZONES AND COMMUNITIES

When provinces and territories produce air zones reports, it is recommended that a section be included which provides the air zone metric values and the achievements status for each CAAQS. All air zone metric values will be reported based on the actual $PM_{2.5}$ and ozone concentrations, that is, without the removal of the TF/EE influenced data. As applicable, provinces and territories can indicate that a given standard would have been achieved if not for the influence of TF/EE. The report would then also include an appendix with the WOE analyses to demonstrate that the standard would have been achieved if not for the occurrence of TF/EE.

Provinces and territories are also to report the actual metric values for communities with a population of at least 100,000, and for smaller communities and rural areas as applicable. Metric values can also be reported on a CAAQS reporting station basis.

Provinces and territories also have the flexibility of conducting the WOE analyses for communities and, as applicable, could mention that the metric value for a community would have been *below* or equal to a given standard if not for the occurrence of TF/EE (if the WOE analyses support the conclusion).

APPENDIX A – REPRESENTATIVE MONITORING SPATIAL SCALES

The monitoring of ambient $PM_{2.5}$ and ozone levels can be conducted for various purposes and, depending of the location of a given monitoring station, the concentrations of air pollutants measured at a given station *may* be representative of the levels that prevail across a given area. For example, some monitoring stations may be located to capture the worst case concentrations near an industrial complex, or at the intersections of busy roads to capture the highest levels from traffic emissions. Measurements from such stations are typically representative of micro scale conditions within 100 m of the station.

The U.S. Environmental Protection Agency (EPA) defines five categories of spatial scales in its guidelines for siting State and Local Air Monitoring Stations and National Air Monitoring Stations[19]:

Micro Scale

Localized areas such as downtown street canyons, traffic corridors or a major stationary source such as a power plant where the general public would be exposed to maximum concentrations.

Middle Scale

Downtown areas that people typically pass through, areas near major roadways, areas such as parking lots, and feeder streets generally with dimensions of a few hundred metres.

Neighbourhood Scale

Reasonably homogeneous urban sub-regions with dimensions of a few kilometres and of generally more regular shape than the middle scale.

Urban Scale.

Entire metropolitan or rural area ranging in size from 4 to 50 kilometres.

Regional Scale

Dimensions of as much as 100s of kilometres with some degree of homogeneity.

These typical scales can be used as guidelines for where to locate CAAQS monitoring stations in air zones and communities.

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[19] *Guideline for Ozone Monitoring Site Selection. Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Report No. EPA-454/R-98-002, August 1998.*

Environmental Protection Agency (1996), Air Quality Criteria for Particulate Matter, Research Triangle Park, NC: National Centre for Environmental Assessment – RTP Office; report nos. EPA/600/P-95/001aF-cF.3v.

APPENDIX B – CANADIAN CENSUS METROPOLITAN AREAS AND CENSUS AGGLOMERATIONS

The information in this Appendix can be used by jurisdictions to establish the communities for which they will report metric values.

Most of Canada's vast land area is sparsely populated. Canada is one of the most urbanized nations, according to the Organization for Economic Cooperation and Development (OECD), with most Canadians living in communities with a population of 10,000 and more.

Urban-focused economies tend to expand beyond official municipal or even county boundaries in terms of shopping trips and commuter travel. As a result, Statistics Canada has created groupings of municipalities, or **census subdivisions (CSD)**, to encompass the area under the influence of a major urban centre. Specific guidelines are used to group municipalities that are closely interconnected due to people working in one municipality and living in another. The resulting geographic units are called **census metropolitan areas (CMA)** for larger urban centres (100,000 or more in their urban core in the previous census) and **census agglomerations (CA)** for smaller urban centres (with an urban core of at least 10,000 but less than 100,000 in the previous census). Based on the 2006 Census, there are 31 CMA and 113 CA in Canada. Table 1 provides population information regarding CMA and CA, where it can be

Table 1: Total population of Canadians living in CMA and CA compared to the total population of Canada

Total number of CMA and CA	144
Total population in CMA and CA	25,631,557
Total population of Canada	31,612,897
Percentage of population living in CMA and CA	81%

While the criteria for CMAs and CAs have changed slightly over time, the key element has always been the notion of the commuter shed. The internal structure of the CMA has also reflected the relative differences between urban and rural areas; the three major distinctions within the CMA are the urbanized core, the urbanized fringe and the rural fringe. The urban core is a large urban area around which a CMA or CA is delineated. The urban fringe is the urban area within a CMA or CA that is not contiguous to the urban core. The rural fringe encompasses all remaining territory. Adjacent CSD are used as building blocks if they meet certain criteria.

Census subdivision is the general term applied to municipalities (as determined by provincial legislation) or their equivalent (e.g. Indian reserves, Indian settlements and unorganized territories). In Newfoundland, Nova Scotia and British Columbia, the term also describes geographic areas that have been created by Statistics Canada in cooperation with the provinces as equivalents for municipalities for the dissemination of statistical data.

Users often need data for areas that are smaller than a municipality. As a result, Statistics Canada created **census tracts (CT)** to equal neighbourhood-like areas of 2,500 to 8,000 people (preferably close to 4,000) within all CMAs and CAs that contain an urban core with a population of 50,000 or more in the previous census. The CT boundaries generally follow permanent physical features such as major streets and railway tracks and attempt to approximate cohesive socio-economic areas. CT are generally held constant from one census to the next, so that they are comparable over time. CT do not necessarily follow CSD or CD boundaries. In practice, however, there are few cases of CTs not nesting perfectly within CSD and CD.

The definitions of geographic terms and census concepts are presented here in summary form only. Users should refer to the *2001 Census Dictionary* (Catalogue No. 92-378-XIE01000, ISBN 0-662-31155-8) for the full definitions and additional remarks related to these concepts and definitions.

Table 2: CMAs and CAs in Atlantic Canada based on the 2006 Census

CMA/CAs with population over 100,000 are in italics.

	CMA/CA	Population	Total population for the considered CMA/CA	Total Provincial or Territorial Population
Newfoundland and Labrador			**231,801**	**505,469**
St. John's	*CMA*	*181,113*		
Bay Roberts	CA	10,507		
Grand Falls-Windsor	CA	13,558		
Corner Brook	CA	26,623		
Prince Edward Island			**74,778**	**135,851**
Charlottetown	CA	58,625		
Summerside	CA	16,153		
Nova Scotia			**586,120**	**913,462**
Halifax	*CMA*	*372,858*		
Kentville	CA	25,969		
Truro	CA	45,077		
New Glasgow	CA	36,288		
Cape Breton	*CA*	*105,928*		
New Brunswick			**429,992**	**729,997**
Moncton	*CMA*	*126,424*		
Saint John	*CMA*	*122,389*		
Fredericton	CA	85,688		
Bathurst	CA	31,424		
Miramichi	CA	24,737		
Campbellton	CA	17,888		
Edmundston	CA	21,442		

Table 3: CMA and CA for Québec based on the 2006 Census

CMA/CAs with population over 100,000 are in italics.
CMAs with population over 500,000 are in bold.

	CMA/CA	Population	Total population for the considered CMA/CA	Total Provincial or Territorial Population
Québec			**6,021,824**	**7,546,131**
Matane	CA	16,438		
Rimouski	CA	46,807		
Rivière-du-Loup	CA	24,570		
Baie-Comeau	CA	29,808		
Saguenay	*CMA*	*151,643*		
Alma	CA	32,603		
Dolbeau-Mistassini	CA	14,546		
Sept-Îles	CA	27,827		
Quebec	***CMA***	***715,515***		
Saint-Georges	CA	31,364		
Thedford Mines	CA	26,107		
Sherbrooke	*CMA*	*186,952*		
Cowansville	CA	12,666		
Victoriaville	CA	48,893		
Trois-Rivières	*CMA*	*141,529*		
Shawinigan	CA	56,434		
La Tuque	CA	15,293		
Drummondville	CA	78,108		
Granby	CA	68,352		
Saint-Hyacinthe	CA	55,823		
Sorel-Tracy	CA	48,295		
Joliette	CA	43,595		
Saint-Jean-sur-Richelieu	CA	87,492		
Montreal	***CMA***	***3,635,571***		
Salaberry-de-Valleyfield	CA	39,672		
Lachute	CA	11,832		
Val-d'Or	CA	32,288		
Amos	CA	17,918		
Rouyn-Noranda	CA	39,924		
Ottawa - Gatineau (part of Que.)	*CMA*	*283,959*		

Table 4: CMA and CA for Ontario based on the 2006 Census

CMA/CAs with population over 100,000 are in italics.
CMAs with population over 500,000 are in bold.

	CMA/CA	Population	Total population for the considered CMA/CA	Total Provincial or Territorial Population
Ontario			**9,866,873**	**12,160,282**
Ottawa - Gatineau (Part of Ont.)	**CMA**	**846,802**		
Cornwall	CA	58,485		
Hawkesbury	CA	12,267		
Brockville	CA	39,668		
Pembroke	CA	23,195		
Petawawa	CA	14,651		
Kingston	*CMA*	*152,358*		
Belleville	CA	91,518		
Cobourg	CA	18,210		
Port Hope	CA	16,390		
Peterborough	*CMA*	*116,570*		
Kawartha Lakes	CA	74,561		
Centre Wellington	CA	26,049		
Oshawa	CMA	330,594		
Ingersoll	CA	11,760		
Toronto	***CMA***	***5,113,149***		
Hamilton	***CMA***	***692,911***		
St. Catharines - Niagara	*CMA*	*390,317*		
Kitchener	*CMA*	*451,235*		
Brantford	*CMA*	*124,607*		
Woodstock	CA	35,480		
Tillsonburg	CA	14,822		
Norfolk	CA	62,563		
Guelph	*CMA*	*127,009*		
Stratford	CA	30,461		
London	*CMA*	*457,720*		
Chatham-Kent	*CA*	*108,589*		
Leamington	CA	49,741		
Windsor	*CMA*	*323,342*		
Sarnia	CA	88,793		
Owen Sound	CA	32,259		
Collingwood	CA	17,290		
Barrie	*CMA*	*177,061*		
Orillia	CA	40,532		
Midland	CA	35,402		
North Bay	CA	63,424		
Greater Sudbury	*CMA*	*158,258*		
Elliot Lake	CA	11,549		
Temiskaming Shores	CA	12,904		
Timmins	CA	42,997		
Sault Ste. Marie	CA	80,098		
Thunder Bay	*CMA*	*122,907*		
Kenora	CA	15,177		

Table 5: CMA and CA for Manitoba, Saskatchewan and Alberta based on the 2006 Census

CMA/CAs with population over 100,000 are in italics.
CMAs with population over 500,000 are in bold italics.

	CMA/CA	Population	Total population for the considered CMA/CA	Total Provincial or Territorial Population
Manitoba			**777,011**	**1,148,401**
Winnipeg	***CMA***	***694,668***		
Portage la Prairie	CA	20,494		
Brandon	CA	48,256		
Thompson	CA	13,593		
Saskatchewan			**574,009**	**976,275**
Regina	*CMA*	*194,971*		
Yorkton	CA	17,438		
Moose Jaw	CA	33,360		
Swift Current	CA	16,533		
Saskatoon	*CMA*	*233,923*		
The Battlefords	CA	17,765		
Prince Albert	CA	40,766		
Estevan	CA	11,135		
Lloydminster-Saskatchewan Portion	CA	8,118		
Alberta			**2,603,499**	**3,290,350**
Medicine Hat	CA	68,822		
Brooks	CA	22,452		
Lethbridge	CA	95,196		
Okotoks	CA	17,145		
Calgary	***CMA***	***1,079,310***		
Canmore	CA	12,039		
Red Deer	CA	82,772		
Camrose	CA	15,620		
Edmonton	***CMA***	***1,034,945***		
Lloydminster-Alberta Portion	CA	18,905		
Cold Lake	CA	11,991		
Grande Prairie	CA	71,868		
Wood Buffalo	CA	52,643		
Wetaskiwin	CA	11,673		

Table 6: CMA and CA for British Columbia, Yukon, Northwest Territories and Nunavut based on the 2006 Census

CMA/CAs with population over 100,000 are in italics.
CMAs with population over 500,000 are in bold italics.

	CMA/CA	Population	Total population for the considered CMA/CA	Total Provincial or Territorial Population
British Columbia			**3,585,368**	**4,113,487**
Cranbrook	CA	24,138		
Penticton	CA	43,313		
Kelowna	*CMA*	*162,276*		
Vernon	CA	55,418		
Salmon Arm	CA	16,205		
Kamloops	CA	92,882		
Chilliwack	CA	80,892		
Abbotsford	*CMA*	*159,020*		
Vancouver	***CMA***	***2,116,581***		
Squamish	CA	15,256		
Victoria	*CMA*	*330,088*		
Duncan	CA	41,387		
Nanaimo	CA	92,361		
Parksville	CA	26,518		
Port Alberni	CA	25,297		
Courtenay	CA	49,214		
Campbell River	CA	36,461		
Powell River	CA	16,537		
Williams Lake	CA	18,760		
Quesnel	CA	22,449		
Prince Rupert	CA	13,392		
Kitimat	CA	8,987		
Terrace	CA	18,581		
Prince George	CA	83,225		
Dawson Creek	CA	10,994		
Fort St. John	CA	25,136		
Yukon			**22,898**	**30,372**
Whitehorse	CA	22,898		
Northwest Territories			**18,700**	**18,700**
Yellowknife	CA	18,700		
				52,238
Nunavut				

APPENDIX C – QUALITATIVE TOOLS TO ESTIMATE AIR QUALITY LEVELS

The following list presents some of the qualitative methods and tools that are available to obtain a preliminary estimate of air quality levels in air zones.

Chemical Transport Models and Dispersion Models

Chemical transport models (CTM) and dispersion models are tools that can be used to estimate the air quality in a given area. CTM are typically used for regional scale modelling and they require detailed emission inventories and meteorological data throughout the modelling domain. Dispersion models are less resource-intensive, however, they are not as comprehensive as CTM. Dispersion models are primarily used for modelling the impact of directly emitted air pollutants. Some dispersion models are also equipped to model non-directly emitted air pollutants based on simplified chemistry principles. Many jurisdictions across Canada already use dispersion models as part of their regulatory process for industrial facilities, most of which were developed and used by the U.S. EPA as part of its regulatory process. Environment Canada (EC) could provide technical expertise to jurisdictions with the use of the AURAMS (*A Unified Regional Air quality Modelling System*) model to estimate air quality levels in air zones.

Passive monitors

Passive monitors rely on the diffusion of gaseous components through a membrane onto an adsorbent material. There are no moving parts and power is not required. They can be left in the field for long periods of time (generally one month) and provide an integrated concentration for the time deployed. Networks of passive monitors can be used to provide overall spatial patterns and temporal trends of selected air pollutants as a preliminary indication of air quality.

Portable monitors

Portable monitors are self-contained continuous monitors for single or multiple pollutants. They do not need the physical infrastructure of a permanent station but do require power which can be supplied by battery or solar panels. Portable monitors can be used for short or long-term air quality surveys, but have their limitations due to the lack of infrastructure support.

Satellite imagery

Satellite imagery is an emerging technology which can be used to augment fixed site monitoring and special surveys and it is currently most reliable for PM and nitrogen dioxide. EC could provide this information on request. Other agencies in the U.S. also provide this information, often through a web site.

Data interpolation techniques

Data interpolation techniques work best for regional pollutants like ozone, or over areas where the number of monitors for a given air pollutant is relatively large and relatively uniform in spatial distribution. Data interpolation techniques may be less reliable for $PM_{2.5}$ since ambient levels of $PM_{2.5}$ are strongly affected by local emissions. The basic concept behind data interpolation can be demonstrated by an example of an air zone with two ozone monitors. The ozone concentration at the location in the middle of the two stations can be estimated (or *interpolated*) by the average of the concentrations at the two stations. More advanced interpolation techniques apply different weights to the monitored concentrations.

***Land-use regression models*.**

Land-use regression models are basically an advanced form of statistical regression. They are typically used to obtain an estimation of the impact of traffic-related air pollutant emissions in urban areas by using actual monitored data and other predictor variables like traffic volume and meteorology. They are a useful tool in estimating urban air quality in parts of the urban areas where there are no monitors.

APPENDIX D – NUMBER ROUNDING CONVENTIONS

1. Rounding to Whole Numbers (Integers)

The following procedures are to be used to round fractions to whole numbers.

a) Numbers with first decimal ≥ .5 will be rounded upward

b) Numbers with first decimal < .5 will be rounded downward

Examples of rounding convention:

Applying the above procedures, the number 10.557 rounded to a whole number becomes 11, and 10.459 becomes 10.

2. Rounding to the First Decimal Place

The following procedures are to be used to round numbers to the first decimal place:

a) Numbers with second decimal ≥ .05 will be rounded upward

b) Numbers with second decimal < .05 will be rounded downward

Examples of rounding convention:

Applying the above procedures, the number 10.557 rounded to the first decimal place becomes 10.6, and 10.449 becomes 10.4.

APPENDIX E – EXAMPLES OF WEIGHT OF EVIDENCE ANALYSES

In conducting the weight of evidence (WOE) approach, a jurisdiction would undertake a series of analyses to support the report of the occurrence of transboundary flows (TF) or exceptional events (EE). Below is a non-exhaustive list of analyses and tools that could be used on a case-by-case basis. Provinces or territories reporting the influence of TF/EE may initiate or lead the WOE analyses. The federal government may provide technical expertise in support of these analyses when requested by provinces and territories.

Most meteorological information discussed below, including back trajectories, can be obtained from Environment Canada (EC). As needed, EC may also assist in conducting chemical transport modelling of high pollution episodes.

1. Meteorological Data

The photochemical production of ozone from both anthropogenic and natural precursors typically requires sunny conditions and light winds; the production is favored further if these conditions occur concurrently with high temperatures. If high ozone levels are measured in the absence of such meteorological conditions, it may indicate ozone of other origins.

For $PM_{2.5}$, local direct emissions of $PM_{2.5}$ can accumulate over time under persisting light or calm wind conditions, and very low mixing layer. These types of conditions are typically associated with high pressure systems or ridges. The occurrence of high $PM_{2.5}$ levels and the lack of high pressure systems may indicate $PM_{2.5}$ of non-local origin, especially if high $PM_{2.5}$ levels are observed over a large geographic area. Other analysis would then need to be conducted to evaluate what these other origins could be.

2. Wind Direction and Speed

Provinces and territories can produce pollution wind roses that combine wind speed and wind direction with observed ozone and $PM_{2.5}$ concentrations as part of their demonstration of transboundary influences. Pollution wind roses indicate the concentrations of $PM_{2.5}$ and ozone associated with given wind direction sectors; if high pollutant levels occur only with specific wind sectors, it provides a preliminary indication of where the sources of the high levels may be located.

3. Air Parcel Back-trajectories

Air parcel back trajectories (or simply back-trajectories) are more robust analyses than wind direction pollution roses to evaluate the source region of high $PM_{2.5}$ and ozone levels. The back-trajectories indicate the location over which the air passed before arriving at a given location within an air zone. If a given location experiences high levels of $PM_{2.5}$ or ozone, back trajectories can indicate if the air arriving at the location traveled over high emission source regions, thereby indicating the possibility of transboundary influence.

Back-trajectories can also be used to determine if inter-continental transport is a plausible reason for the observed high levels. For example, if high $PM_{2.5}$ levels are measured in the west coast of Canada, and back-trajectories indicate that during the time of the high levels the air was coming from Asia, it would then need to be explored if unusual events had occurred in Asia. For example, the occurrence of very high winds may have caused dust particles from deserts in Asia to move upward above the mixing layer, followed by horizontal transport across the Pacific Ocean into Canada's west coast.

4. Spatial Extent

The spatial extent of elevated levels of ozone and $PM_{2.5}$ can also be used to evaluate the origins of the measured $PM_{2.5}$ and ozone levels in an air zone. For example, seldom does TF affect only a monitor within a given air zone or province/territory. Typically TF, and ozone transported downward, affect large areas of a jurisdiction.

Mapping levels of $PM_{2.5}$ and ozone across an airzone or jurisdiction on the same days can help identify whether the high levels were restricted to a single station, or whether they occurred over a large area. Mapping tools such as the EPA's animated *AIRNow* and *AirNow-Tech* websites (http://www.airnow.gov/; http://www.airnowtech.org/) can be used to evaluate the spatial extent of high $PM_{2.5}$ and ozone levels. If only a single station recorded high levels, it may signal that it was unlikely that it was caused by TF/EE.

5. Correlation with Other Contaminants and Diurnal Variations

Some air pollutants emitted from the same sources may display the same diurnal or seasonal patterns. For example, in urban areas concentrations of $PM_{2.5}$, carbon monoxide (CO) and nitric oxide (NO) all increase in the morning due to elevated vehicle emissions. If $PM_{2.5}$ concentrations were high without corresponding increases in concentrations of CO and NO, it may signal the influence of other sources.

In the summer, ozone concentrations generated from local precursor emissions are typically the highest in early evening and then gradually decrease as production stops (due to the lack of sunshine). This locally generated ozone also displays a relationship with nitrogen dioxide (NO_2) since ozone formation ultimately results from NO_2. Particularly in urban areas, NO_2 levels peak in the morning and decrease as ozone levels increase throughout the day. A departure from these typical patterns and diurnal variations might signal the influence of other sources of ozone.

Jurisdictions can choose to graph the hourly data of $PM_{2.5}$ and ozone precursor concentrations (e.g. NO, NO_2, NOx, SO_2 and VOCs) and compare their daily cycle as it may provide an indication of the origins of the measured levels of $PM_{2.5}$ and ozone.

6. Air Quality Modelling

For episodes that are more complex, jurisdictions may choose to conduct air quality modelling, using approved models, to determine the relative contributions from various origins. A number of modelling scenarios may be run depending on whether the event under consideration is TF or EE. Typically, however, the modelling must be conducted for the event in question, using the meteorology and emissions (as possible) that prevailed during the event.

7. Documentation of Forest Fires

Evidence to support the occurrence of forest and grass fires in or near a community can include photographs of smoke from automatic cameras that compare rapid changes in visibility caused by the arrival of smoke. Personal observations by federal or provincial government staff, air zone staff and other environmental professionals of large smoke plumes, and smoke odor in the community can be used as evidence. Media (written and visual) coverage of fires can also be used as evidence.

Satellite imagery can confirm that forest fire smoke passed over the affected community and possibly contributed to an exceedance of a standard. The satellite image can be provided by the Satellite Services Division of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) which provides access to fire and smoke products using archived data, analysis and forecast products. While satellite imagery can indicate the presence of smoke above a community, the surface smoke concentrations in the community may or may not be elevated. However, communities in deep valleys that appear on satellite imagery to be full of smoke are likely to experience elevated smoke concentrations.

Satellite data and analysis files are generally only archived for six to twelve months. All jurisdictions should promptly download files that may be needed in future CAAQS analysis. (See Appendix E for sources of satellite information)

8. Time of year for exceedance of the CAAQS

Time of year helps identify potential factors that may have contributed to the exceedance of a given standard on a given day. For example, high ozone levels produced by local anthropogenic precursor emissions occur in the warm season from April through September. If ozone CAAQS exceedance days occur outside of this period, it could signal the influence from other sources. Analysis would then be conducted to determine the cause(s) of the high ozone levels. For $PM_{2.5}$, time of year may not be as relevant since high PM levels can occur throughout the year.

9. Vertical Ozone Profiles

Ozone profiles show how ozone levels vary with height above ground, from the surface to about 50 km, and can help identify potential episodes of downward ozone transport from higher elevations. Vertical ozone profiles typically take into account surface pressure and albedo, cloud data such as cloud top pressure, cloud fraction and cloud albedo. Vertical profiles of ozone are archived for some locations in Canada.