CCME

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

AMBIENT AIR MONITORING AND QUALITY ASSURANCE/QUALITY CONTROL GUIDELINES

National Air Pollution Surveillance Program

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NOTE TO READERS

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.

This document contains guidance related to air quality monitoring procedures at National Air Pollution Surveillance (NAPS) sites across the country and replaces the *Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone: Canada-wide Standards for Particulate Matter and Ozone* (CCME 2011) and the manual titled *National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines* (EC 2004). It provides recommendations and establishes minimum requirements to ensure that data collected by the NAPS Program are of known quality, defensible, and comparable across Canada.

This document was developed for the Air Management Committee, by staff of the Analysis and Air Quality Section of Environment and Climate Change Canada. CCME would like to thank all individuals that participated in completing this document and more specifically the following working group members representing provincial and territorial governments: Melynda Bitzos and Mike Noble (Ontario), Eric Blanchard (New Brunswick), Fran Di Cesare (Nova Scotia), Chris Gray (Saskatchewan), Jany McKinnon (Québec) and Ryan Wiederick (British Columbia), and Christian Vezina for his contribution as an external reviewer.

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ACRONYMS AND ABBREVIATIONS

$\mu g/m^3$	microgram per cubic metre
µm	micron/micrometre
AADT	annual average daily traffic
AAQS	Analysis and Air Quality Section
AQHI	Air Quality Health Index
AQMS	Air Quality Management System
CA	census agglomeration
CAAQS	Canadian Ambient Air Quality Standards
CAPS	cavity attenuated phase shift
CCME	Canadian Council of Ministers of the Environment
CEPA	*Canadian Environmental Protection Act 1999*
CESI	Canadian Environmental Sustainability Indicators
CFR	Code of Federal Regulations
CO	carbon monoxide
CMA	census metropolitan area
CWAQD	Canada-wide Air Quality Database
DNPH	2,4-dinitrophenylhydrazine
DQA	data quality assessment
DQO	data quality objective
ECCC	Environment and Climate Change Canada
ED-XRF	energy-dispersive X-ray fluorescence
FEM	federal equivalent method (US)
FRM	federal reference method (US)
HEPA	high efficiency particulate air
ICP-MS	inductively coupled plasma mass spectrometry
IR	infrared
MOU	memorandum of understanding
NALC	North American Landscape Characterization
NAPS	National Air Pollution Surveillance Program
NAPS RM	NAPS reference method
NIST	National Institute of Standards and Technology (United States)
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NQAP	Network Quality Assurance Plan

O_3	ozone
OC/EC	organic carbon/elemental carbon
PAH	polycyclic aromatic hydrocarbon
PC	population centre
PM	particulate matter
$PM_{2.5}$	particulate matter ≤2.5 µm (fine)
$PM_{2.5–10}$	particulate matter ≤10 µm and ≥2.5 µm (coarse)
PM_{10}	particulate matter ≤10 µm
ppb	parts per billion
ppm	parts per million
QA/QC	quality assurance/quality control
RM	reference method
RMS	root mean square
Rt	residence time
SCC	sharp cut cyclone
SO_2	sulphur dioxide
SOP	standard operating procedure
SRM	standard reference material
SRP	standard reference photometer
TEOM	tapered element oscillating microbalance
TRAP	traffic-related air pollution
US EPA	United States Environmental Protection Agency
UV	ultraviolet
VOC	volatile organic compound
VSCC	very sharp cut cyclone
VSL	Dutch National Metrology Institute
WHMIS	Workplace Hazardous Materials Information System

GLOSSARY

Accuracy: The comparison of a measurement to a known value. Accuracy can include measures of agreement among repeated measurements (precision) and measurements of positive or negative systematic errors (bias).

Actual conditions: The ambient temperature and pressure of a gas during the time its volume (or volumetric flow rate) is measured.

Buddy sites: Sites that are in close proximity or that would be expected to measure similar concentrations.

Calibration: Adjustment of an instrument or firmware that establishes the relationship between instrument response and expected concentration. It compares values delivered by a device under testing with those of a calibration standard of known accuracy (traceable).

Calibration range: Scale used for multi-point verification and calibration.

Comparability: A qualitative term that expresses the confidence that data sets or methods can be compared with those at other sites for common interpretation and analysis. Data comparability is achieved via uniform procedures and methods.

Completeness: Comparison of the valid data collected versus the total number of data points expected for the measurement frequency (e.g., hourly, daily, seasonally, annually). Completeness confirms whether enough information is being collected to ensure confidence in the conclusion or decisions made with the resulting data.

Continuous Data: Data that is collected using continuous monitoring equipment.

Data flag: Metadata applied to each continuous data record during data collection; can be modified during the validation process.

Datalogger/data acquisition system: Device that collects data and other information from instruments at the monitoring site.

Data qualifier code: Metadata applied to each integrated data record during the validation process.

Data validation: Process of examining objective evidence to confirm that the data are fit for purpose.

Detection limit: The lowest value that a method can report with confidence.

Integrated Data: Data that are integrated from chemical and gravimetric analysis by the NAPS Laboratory on integrated samples.

Multi-point verification: Establishes and subsequently verifies the accuracy and linearity of the instrument at regular intervals to ensure data validity. It must include a pre- and post-zero and at least three upscale points (100%, 60% and 30% of calibration range) in recommended ranges.

Outlier: Data point that is statistically separate from the rest of the data set.

Performance audit: A quantitative evaluation of a measurement system by an independent auditor to determine if criteria are meeting specifications.

Quality assurance (QA): An integrated system that involves determination of monitoring and data quality objectives, network design, site selection, equipment evaluation and training to ensure measurements meet defined standards of quality.

Quality control (QC): Operational procedures and checks used to assess equipment performance relative to desirable or specified criteria. QC is also a check or comparison performed during data validation for the purpose of identifying data that may be invalid, suspect or in need of adjustment.

Reference standard: The standard used by the monitoring organization to which all other gas mixtures or instruments are compared. It can be a standard reference material (SRM) or a transfer standard but not both.

Representativeness: The degree to which data accurately and precisely represent the pollutant concentration of an air parcel surrounding the site for a specific averaging period.

Residence time: The amount of time in seconds that it takes for a sample of air to travel from the sampling inlet to the instrument.

Rise/fall time: The time interval between initial response (the first observable change in analyzer output) and a level of signal output that is 95% of the steady state output after a step increase (rise) or decrease (fall) in input concentration.

Sampling inlet: An opening through which air enters the sampling system before continuing to an analyzer, monitor or sampler.

Span check: The introduction of a known concentration of a gas near the calibration range. The span check point is compared to a reference span value established at the time of multi-point verification or calibration.

Span drift: The percent change in analyzer response to a constant upscale pollutant concentration over a certain number of hours of unadjusted continuous operation.

Standard reference material: A material or gas mixture whose composition is known and is taken as the standard to which all other gas mixtures are compared. In the NAPS Network, this refers to the NIST or VSL materials and the NIST Standard Reference Photometer (SRP).

Suspect data: Data that do not follow expected behaviour (e.g., statistical, historical trend, temporal or spatial). They can also be data that do not have the required documentation or the supporting QC checks.

Tolerance levels: Levels at which calibrations or repair should be initiated to address issues before acceptance criteria are exceeded and data becomes invalid.

Traceability: An unbroken chain of calibrations linked to national/international standards such as NIST, VSL, National Research Council of Canada's Measurement Science and Standards Research Centre (NRC-MSS), and Innovation, Science and Economic Development Canada.

Transfer standard: A gas mixture of known concentration or an instrument of known accuracy verified against a reference standard. It is used in the field for comparison and analytical purposes.

Ultra-fine particles: Particulate matter of size less than 0.1μm (100 nm) in diameter.

Zero air/zero gas: A gas mixture that is free of contaminants to a concentration below the detection limit of the analyzer.

Zero drift: The absolute change in analyzer response to a constant zero air input over a certain number of hours of unadjusted continuous operation.

Zero noise: Measure of the deviations from zero while sampling constant zero air. The noise is measured as the root mean square (RMS) of the deviations from zero.

Zero check: Pollutant-free air introduced to measure responses below the analyzer's detection limit.

1.0 INTRODUCTION

The National Air Pollution Surveillance (NAPS) Program is managed by provincial and territorial governments across Canada in cooperation with Environment and Climate Change Canada (ECCC) (Figure 1.1).

In existence since 1969, NAPS was established to facilitate the collection of air quality data primarily in urban areas (Figure 1-2). Program goals include providing a long-term air quality data record that conforms to quality standards designed to ensure data are reliable, defensible and easily accessible.

The quality of monitoring data is contingent upon the entire air quality monitoring system: station siting, instrumentation selection and performance, and data collection, validation and dissemination. The NAPS *Ambient Air Monitoring and Quality Assurance/Quality Control (QA/QC) Guidelines* (hereafter referred to as the "*Guidance*") are intended to assist air monitoring networks reporting data to the Canada-wide Air Quality Database (hereafter referred to as "*Networks*") to develop and implement quality systems to meet, at a minimum, the NAPS data quality objectives (DQO).

This *Guidance* is designed to be both practical and achievable by the participating *Networks*.

Figure 1-1 NAPS Network

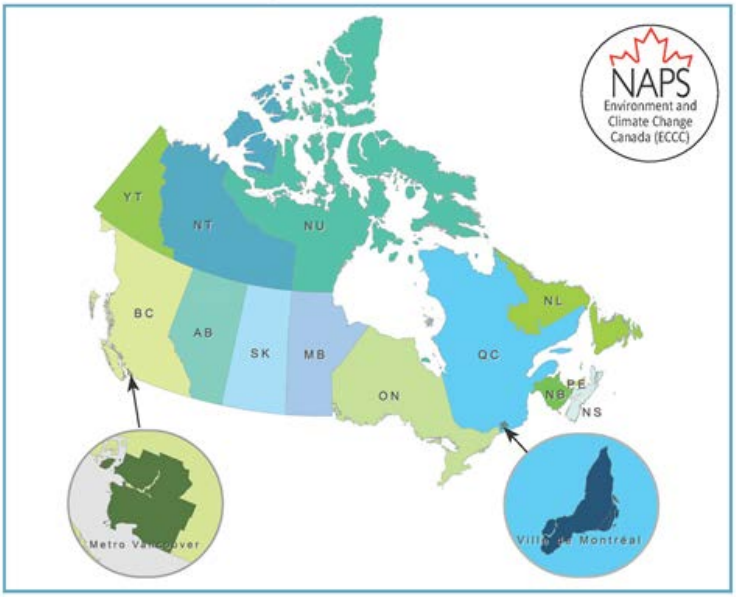


Figure 1-2 Air quality parameters currently measured by NAPS

Air quality data are currently collected from nearly 300 stations Canada-wide, including:

Continuous measurements:

- ground-level ozone (O_3)
- oxides of nitrogen ($NO/NO_2/NO_X$)
- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- $PM_{2.5}$

Integrated measurements:

- particulate matter ($PM_{2.5}/PM_{2.5–10}$)
- volatile organic compounds (VOC) including carbonyls
- polycyclic aromatic hydrocarbons (PAH)

The resulting data support government policies, programs and research studies.

2.0 NAPS PROGRAM AND MONITORING OBJECTIVES

The NAPS Program was established to facilitate and coordinate the collection of ambient air quality data that is representative of populated areas across the country. NAPS is the primary source of air monitoring information in Canada, with nearly 260 stations located in approximately 150 communities reporting to the Canada-wide Air Quality Database (CWAQD). Ambient air quality monitoring is an essential component of Canada's

air pollution management and research program. Air quality data collected by the NAPS Program are used by governments to assess air quality, produce reports, and develop air quality monitoring programs.

The NAPS Program:

- supports the air quality data needs of Air Quality Management System (AQMS); the Canada-United States Air Quality Agreement; the Canadian Air Quality Prediction Program; the Canadian Environmental Sustainability Indicators (CESI) Program; and other regional, Canada-wide and international air quality initiatives that may arise
- provides common guidance on collection, measurement, validation and transmission of data from participating monitoring networks across Canada
- provides centralized laboratory facilities to ensure common analysis techniques that meet or exceed Canadian laboratory standards
- provides a centralized data repository to facilitate access to information
- provides Canada-wide data summary reports that highlight spatial patterns and regional assessments of air quality conditions and long-term trends
- performs technical and scientific research to identify additional potential pollutants of concern and to evaluate appropriate monitoring methods
- shares information and experiences among *Networks* on air quality monitoring.

2.1 NAPS Monitoring Objectives

The most important consideration in designing or implementing any monitoring system is defining its monitoring objectives. Monitoring objectives are statements that clarify the purpose for monitoring and ensure that the data collected are fit for the intended use. The following are the primary and secondary monitoring objectives of the NAPS Program.

Primary objectives:

- track and report on progress for achieving air quality objectives or standards
- measure representative pollutant concentrations in populated areas across Canada and determine long-term trends in air quality
- provide air quality information to the public.

Secondary objectives (not in order of priority):

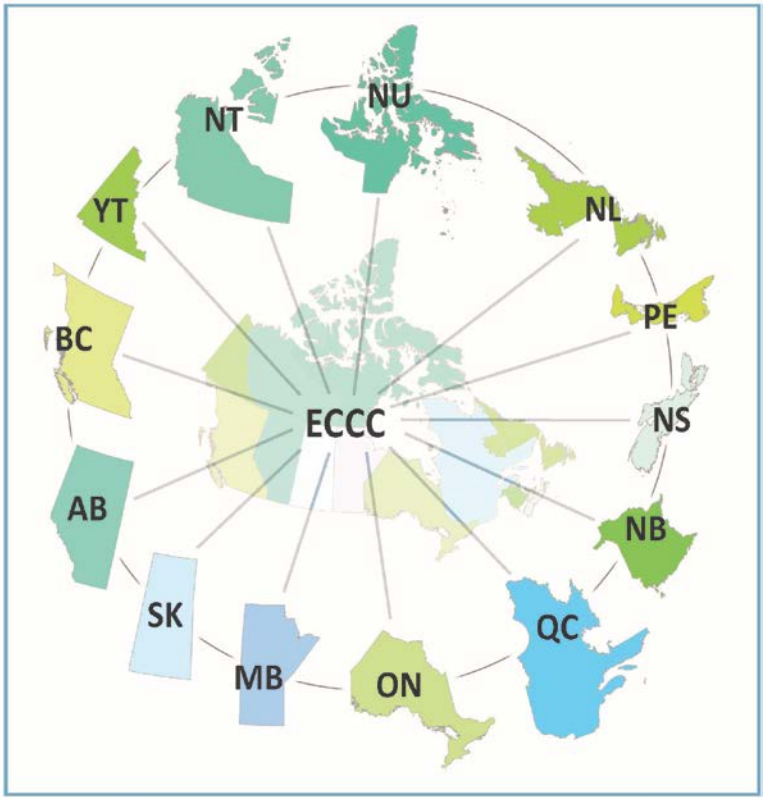
- support the development of air management strategies
- support regional, Canada-wide and international air quality agreements and initiatives
- support research studies to assess air pollution impacts on both health and ecosystems
- verify and validate emissions inventories, models, mapping applications, and support forecast and advisory programs
- support development and evaluation of new monitoring technologies and their application in the NAPS Program
- measure the highest representative pollutant concentrations in populated areas
- measure the upwind and downwind air pollution affecting urban areas
- measure regional background concentrations and transport of pollutants from regional sources (including transboundary sources).

3.0 NAPS PROGRAM ORGANIZATION

Participation in the NAPS Program is formalized through a memorandum of understanding (MOU) between the federal, provincial and territorial governments (Figure 3-1).

All parties and NAPS sites are specified in the MOU, which outlines the general terms and conditions of cooperation among the parties that participate in overall management and support of the NAPS Program.

Figure 3-1 NAPS MOU parties



3.1 NAPS Program Operation

The NAPS Program is operated by ECCC, provincial and territorial governments as well as Metro Vancouver Regional District and Ville de Montréal.

Their respective roles are defined below.

3.1.1 *Environment and Climate Change Canada*

The Analysis and Air Quality Section (AAQS) of the Air Quality Research Division within the Science and Technology Branch of ECCC oversees the NAPS Program.

The roles of NAPS Operations with respect to this *Guidance* are to:

- direct and coordinate a Canada-wide quality assurance/quality control (QA/QC) program (including monitoring performance and system audits, as well as inter-agency testing programs)
- provide laboratory calibration services and field transfer standards
- provide technical training and support to participating *Networks*.

The roles of NAPS Laboratory are to:

- provide sampling media for manual or integrated samplers (including filters, canisters and cartridges) and to receive samples
- analyze integrated samples for particulate matter (PM) components, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC)
- conduct research and special studies in air quality monitoring and coordinate method development with participating *Networks*.

The roles of NAPS Data Management are to:

- maintain the CWAQD and the NAPS Data Products portal
- manage NAPS ambient air quality data and information requests
- report validated NAPS laboratory results to the NAPS Data Products portal
- report validated continuous data received from provinces and territories to the NAPS Data Products portal
- analyze and report on ambient air quality.

3.1.2 *Provincial and Territorial Governments, Metro Vancouver and Montréal*

Provincial and territorial governments as well as Metro Vancouver Regional District and Ville de Montréal contribute to the NAPS Program.

In accordance with this *Guidance*, they should:

- prepare and submit a *Network* Quality Assurance Plan (NQAP)
- select, maintain, calibrate and operate NAPS sites, analyzers, monitors and samplers
- validate and archive continuous data collected at NAPS sites
- inform ECCC of any change or updates to monitoring sites and equipment
- report final validated continuous data to NAPS Data Management.

4.0 DATA QUALITY OBJECTIVES (DQO)

DQO are qualitative and quantitative statements that define the tolerable level of data uncertainty. The DQO of the NAPS Program ensure that the data collected and reported by monitoring sites are of acceptable quality to meet Program objectives (as described in Section 2.0). This *Guidance* has been designed to help ensure that uncertainties associated with the DQO are controlled through appropriate planning, implementation and assessment.

Controlling data quality to achieve the DQO requires identifying both the appropriate criteria and

the methodologies that can be used to achieve DQO.

Important DQO elements for the NAPS Program are:

- **Accuracy:** The comparison of a measurement to a known value. Accuracy can include measures of agreement among repeated measurements (precision) and measures of positive or negative systematic errors (bias).
- **Comparability:** A measure of confidence that one data set or method can be compared with those at other NAPS sites.
- **Completeness:** Comparison of the valid data collected versus the total number of data points expected for the measurement frequency. This assessment confirms whether enough information is being collected to ensure confidence in the conclusion or decisions made with the resulting data.
- **Detection limit:** Detection limit is the lowest value that the method can report with confidence.
- **Representativeness:** The degree to which data accurately and precisely represent the pollutant concentration of an air parcel surrounding the site for a specific averaging period. A monitoring site may also be representative of surrounding environments and other influences (e.g., exposure of the general population or the impacts of emissions from traffic). These sites can be used for grouping, interpreting and extrapolating NAPS data.

The NAPS Program has defined specific criteria for some of the DQO, listed in Table 4-1.

Table 4-1 NAPS Program DQO criteria

Pollutant	Sampling frequency	Averaging period	Accuracy	Completeness[1]
O_3, NO/NO_2/NO_X, SO_2, CO	continuous	1 hour	15%	75%
$PM_{2.5}$	continuous/semi-continuous	24 hours	15%	75%
Speciated particulate compounds	1 per 3 or 6 days[2]	24 hours	see note 3	75%
VOC/carbonyls/PAH	1 per 6 days	24 hours[2]	see note 3	75%

1 *Completeness* refers to the amount of valid data represented for the indicated averaging period (e.g., 45 valid one-minute averages within an hour, or 18 valid one-hour averages in a 24-hour period).
2 Varies by location.
3 Accuracy values are pollutant-specific and compound-specific, as indicated in specific analytical laboratory standard operating procedures (SOP) and methods.

Table 4-2 identifies the DQO elements and their associated determination methodology as provided in this *Guidance*. If methods follow guidelines and meet the quality acceptance criteria described in the *Guidance*, the NAPS DQO should be met. Adherence to this *Guidance* should be verified as described in Assessments and Corrective Action (Section 15.0). If deficiencies are noted, the assessments can help inform either the need for corrective action or a reassessment of DQO (as well as associated methods and measurement objectives for future use).

Table 4-2 NAPS Program DQO and relevant determination methodologies

DQO	Determination methodologies
Accuracy	Accuracy is assessed through comparisons to certified, traceable reference standards or methods. Reference to the relevant sections addressing accuracy are: • Use of analyzers, samplers and methods with appropriate performance specification, including method-detection limits, as described in: – Section 9.0, Monitoring and Sampling Analytical Methods • Calibration and audit checks against certified, traceable reference standards, as described in: – Section 11.0, Verification/Calibration – Section 15.0, Assessments and Corrective Action • The use of QC checks and performance acceptance criteria to invalidate data that do not meet data quality objectives (DQO) related to data accuracy, as described in: – Section 11.0, Verification/Calibration – Section 12.0, Data Collection and Validation – Continuous Data – Section 13.0, Data Collection and Validation – Integrated Data • Collection of collocated and duplicate samples – Section 13.0, Data Collection and Validation – Integrated Data
Comparability	Consistency of measurements throughout the NAPS Program. Reference to the relevant sections addressing comparability are: • consistent site design as described in: – Section 7.0, Network Design and Site Location – Section 8.0, Monitoring Station Design • use of monitoring and analysis methods that meet defined minimum performance specifications, as described in: – Section 9.0, Monitoring, Sampling and Analytical Methods • consistent operation and implementation of monitoring and analysis methods, as described in: – Section 10.0, Routine Operation – Section 11.0, Verification and Calibration • consistent data validation techniques, as described in: – Section 12.0, Data Collection and Validation: Continuous Data – Section 13.0, Data Collection and Validation – Integrated Data
Detection limit	• Use of analyzers, samplers and methods with appropriate performance specification, including method-detection limits, as described in Section 9.0, Monitoring, Sampling and Analytical Methods
Completeness	Meeting this requirement requires that data collection issues that could result in missing or invalid data are minimized. Reference to the relevant sections addressing completeness are: • ensuring adequate education and training for field and data personnel, as described in Section 5.0, Training • ensuring sufficient documentation exists to provide procedure references, track issues and reduce errors, as described in Section 6.0, Documentation and Records • verifying the safe unattended operation of the monitoring station and equipment, and appropriate preventative maintenance to improve system reliability, as described in Section 10.0, Routine Operation.

DQO	Determination methodologies
Representativeness	Representativeness related to the temporal and spatial scale of pollutant concentrations, along with methods that are able to appropriately represent the pollutants measured. Reference to the relevant sections addressing representativeness are: • sufficient sampling frequency, as listed in Table 4-1 • site classification, as defined in Section 6.0 • appropriate site location to represent target populations, as described in Section 7.0, Network Design and Site Location • section 8.0, Monitoring Station Design • selection of appropriate sampling/analytical methods, as described in Section 9.0, Monitoring, Sampling and Analytical Methods

5.0 TRAINING

Relevant education and training are essential for the ability of a monitoring program to achieve network objectives. *Networks* are responsible for ensuring that appropriate training is available to employees supporting the NAPS Program, commensurate with functions and activities listed in this *Guidance*. The *Networks*' NQAP and SOP are important references for training purposes. Often, more experienced staff will provide training to newer staff, but a number of additional training opportunities are available. *Networks* should maintain records of personnel qualifications and training that are accessible for review during audit activities.

NAPS Operations will facilitate training related to instrument operation, maintenance and repair; station set-up; and QA/QC. NAPS Program managers will also facilitate training that may be offered by equipment manufacturers.

Furthermore, a number of courses have been developed for personnel involved with ambient air monitoring. These courses are offered through government and professional organizations such as the Air & Waste Management Association and the United States Environmental Protection Agency (US EPA) Air Pollution Training Institute. Many of these training opportunities are offered online and in person. In addition to training related to air quality monitoring, it is recommended that *Networks* implement a health and safety training program.

Field technicians who work at NAPS sites to install, troubleshoot and repair electrical equipment should have training related to:

- workplace electrical safety (CSA Group)
- Workplace Hazardous Materials Information System (WHMIS)
- working alone
- working at heights and ladder safety
- proper lifting techniques
- safe driving techniques
- first aid.

Transportation of Dangerous Goods training is required for any staff who handle, ship or offer for shipping dangerous goods.

6.0 DOCUMENTATION AND RECORDS

Maintaining appropriate documentation and records is an essential component to ensure that objectives are met and that defensible data are collected and reported. Table 6-1 outlines the recommended documentation for several categories of air quality monitoring activities. Components of NQAP are also described in this section.

All documentation should be easily accessible and retained for a minimum of five years. Most documentation referred to in this section can be in electronic form, enabling ease of accessibility and longer-term storage.

Responsibility for identifying, preparing and supervising quality management documents and records lies with the *Network* that created these documents or records. *Networks* may work with NAPS Operations to incorporate documents into a control system, either as a new document or as part of an existing document (e.g., NQAP, SOP, calibrations). Previous versions of documents should be archived **if no longer in use**. Effective document management includes a system for generating, updating, maintaining and disseminating quality management–related documents and records. Actual, ongoing and completed records are to be maintained as part of the *Network*'s overall record management system and should be available to NAPS Operations upon request.

Table 6-1 Recommended documentation and records

Documentation	Relevant section
NQAP Site information Equipment inventory SOP	Section 6.0, Documentation and Records
Instrument maintenance records Sample handling Records Station logs	Section 10.0, Routine Operation
Calibration documentation	Section 11.0, Verification and Calibration
Raw data Validation logs Validated data	Section 12.0, Data Collection and Management: Continuous Data
Integrated field data sheets Integrated validated data	Section 13.0, Data Collection and Management: Integrated Data
Audit records Audit reports	Section 15.0, Assessments and Corrective Action

6.1 *Network* Quality Assurance Plan (NQAP)

It is important to note that while this *Guidance* provides QA criteria and recommended procedures to meet QA goals, specific procedures to meet these goals should be determined by the *Network* performing the actual monitoring and reporting.

The NAPS Program is initiating a process that requests all participating *Networks* and ECCC develop NQAP. The NQAP will describe how *Networks* are implementing the *Guidance* in order to meet the DQO. These plans should be completed by 2021 and reviewed annually thereafter. An NQAP facilitates communication among data users, staff, *Networks* and external users of the data. An NQAP can relate to a single site or a group of sites operated by the same *Network* using similar methodologies.

NAPS Program managers will submit their respective NQAP and subsequent updates to ECCC prior to the annual management meeting. The NQAP will be available to *Networks* on a document-sharing website with restricted access.

Figure 6-1 Elements of an NQAP

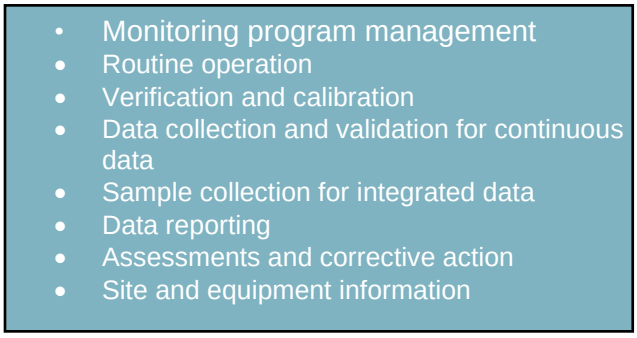


Figure 6-1 and the rest of this section describe proposed elements of the NQAP as related to this *Guidance*. *Networks* should indicate criteria that were not met and what corrective actions will be implemented to address these.

Monitoring Program Management

Provide a revision history of the NQAP, including the following:

- Program organization, including a list of individuals and *Networks* involved with the program identifying their roles and responsibilities
- an organizational chart showing the relationship and lines of communication among project personnel is also helpful
- special training/certifications (Section 5.0)
- DQO (Section 4.0)
- documentation and records, including a list of types of records generated (Table 6-1).

Routine Operation (Section 10.0)

- Provide schedule for routine operations, including site visits and verification/calibration checks
- provide references to any inspection/maintenance requirements in instrument or method-specific SOP
- describe any instrument testing, inspection and maintenance checklists and schedules
- describe corrective action to be taken if issues are noted.

Verification and Calibration (Section 11.0)

- List verification/calibration frequency for each instrument type requiring verification checks and calibrations
- provide references to any calibration procedures in instrument-specific SOP (Note that ECCC has developed a number of NAPS SOP, but these should be modified to accurately reflect the specific methods and procedures used by a monitoring *Network*)
- describe methods for calibration and example forms
- provide references to QC check acceptance criteria used (Section 11.0)
- describe methods for tracking traceability/frequency and certification for calibration standards.

Data Collection and Validation for Continuous Data (Section 12.0)

- Describe any software used and procedures for data collection, handling and storage
- identify data flags used to screen or invalidate data
- identify "on the fly" rules for flagging and correcting data from sites
- identify levels of validation and individuals responsible for each level
- list any criteria used to accept, reject or qualify data (at a minimum, performance-check acceptance criteria listed in Section 10.0 should be used)
- describe analysis methods used for identification and treatment of outliers.

Sample Collection for Integrated Data (Section 13.0)

- Describe handling of integrated samples (see method-specific SOP)
- describe or provide procedures for inspection/acceptance of sample supplies and media
- outline procedures for filling out and submitting field data sheets for sample-tracking purposes
- describe corrective action to be taken if problems arise.

Data Reporting (Section 14.0)

- Describe methods and schedules for data reporting (e.g., how data are submitted, format, hour-ending or hour-beginning)
- describe any *Network*-specific reports
- provide schedule and level of validation for data reporting to the NAPS CWAQD.

Assessments and Corrective Action (Section 15.0)

- Provide an approximate schedule for any internal or external assessments
- include procedures for assessment review and responses.

Site and Equipment Information

Gathering and maintaining accurate site information is a vital part of records management for air monitoring networks. Site information records should include, but are not limited to:

- the unique NAPS ID for each site
- site name and location, including geographical coordinates (lat/long, elevation above sea level), postal code and street address (if available)
- spatial scale of representativeness (Section 7.2).
- monitoring start date (and stop date, if applicable)
- site photographs in each cardinal direction
- site map or satellite image of the area (e.g., Google Earth image)
- sampling inlet placement (Section 8.2.1), including height above ground (metres), distances from local pollutant sources (e.g., roads) and flow obstructions (e.g., trees).
- site diagrams, sketches or photos (e.g., manifold flow diagram, service lines (electrical/communication, equipment configurations)
- instrumentation, sampling and analysis method for each parameter at each site (Section 9.0)
- indicate averaging time for continuous measurements and sampling frequency for integrated samples (see minimum requirements in Section 4.0).

Note that a number of these site details are required metadata when reporting to the CWAQD.

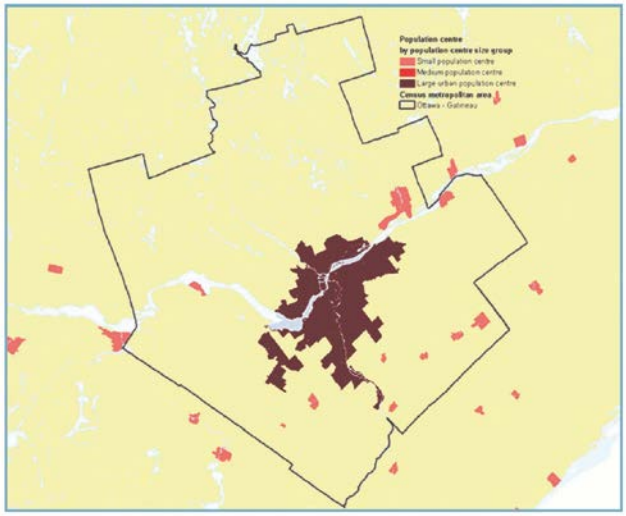
6.2 Site Classification

For site classification, the NAPS Program has adopted a hierarchical classification system (Table 6-2) based on work by University of British Columbia researchers (Brauer *et al.* 2011; Brauer *et al.* 2013; Brauer and Hystad 2012). This classification system includes variables derived in a geographic information system (GIS) and captures urbanization, neighbourhood population, local land use and site type characteristics as described below. This system provides important metadata information that can be used for grouping, interpreting and extrapolating NAPS measurement data.

6.2.1 Class 1: Urbanization

Class 1 identifies the degree of urbanization around the monitoring site (Figure 6-2). The Statistics Canada census population centre (PC) classification (Statistics Canada 2017a, Dictionary) is used to define levels of urbanization. A PC is a populated place or a cluster of interrelated populated places having a population of at least 1,000 people and a density of no fewer than 400 people per km^2, based on the latest census. All areas outside PCs are classified as non-urban (rural) areas. Taken together, PCs and non-urban areas cover all of Canada.

Figure 6-2 Urbanization



A 250 m buffer was used to capture sites that

are adjacent to but not contained within the PC boundaries.

6.2.2 Class 2: Neighbourhood Population

Class 2 summarizes the size of residential populations residing within 4 km of NAPS monitoring sites (Figure 6-3). A distance of 4 km represents the maximum distance associated with a neighbourhood scale of spatial representativeness (Section 7.2). Census "block-face" population (the smallest geographic area for which census information is collected) was used to determine the residential population within 4 km.

Figure 6-3 Neighbourhood Population

Six population size categories have been selected to maximize the differences between sites. They are meant to aid in the grouping of similar sites and provide insights into emission source strengths, such as domestic heating. The neighbourhood population provides further information to inform population exposure assessment.

6.2.3 Class 3: Local Land Use

Class 3 represents the dominant land use category within a 400 m radius around each site (Figure 6-4). A radius of 400 m was selected because this distance represents the middle scale of spatial representativeness (Section 7.2) and corresponds to the US Air Quality System metadata, which summarizes land use within a quarter-mile radius of sites.

Figure 6-4 Local land use

Land use data sets are used to assess this classification. The DMTI Spatial© data set, at a spatial resolution of 30 m, covers exclusively urban areas and includes residential, industrial, commercial, government and institutional, open, parks, and waterbody classifications. The government and institutional classifications are not included in the NAPS classification, as this category captures a diverse mix of land use types.

The forested and agriculture land use classifications come from the 2010 North American Landscape Characterization

(NALC) data set, which covers all areas of Canada, at a spatial resolution of 250 m, since these are not available in the DMTI Spatial© data set. The higher spatial resolution (30 m) 2010 land use data set produced by Agriculture and Agri-Food Canada was also used in conjunction with the NALC for the current version update in 2017. Similar to NALC, this data set covers the entirety of Canada and includes the classifications of forest, cropland, settlement, wetland and waterbody.

Aerial imagery is required to classify monitoring sites that meet one of the following criteria:

- have incomplete DMTI Spatial© data within the 400 m buffers
- are under DMTI Spatial©'s government and institutional classification
- are under DMTI Spatial©'s open area category and have a NALC urban classification
- are under DMTI Spatial©'s resource and industrial classification.

Eight categories are used to describe the land use surrounding NAPS sites (Table 6-2).

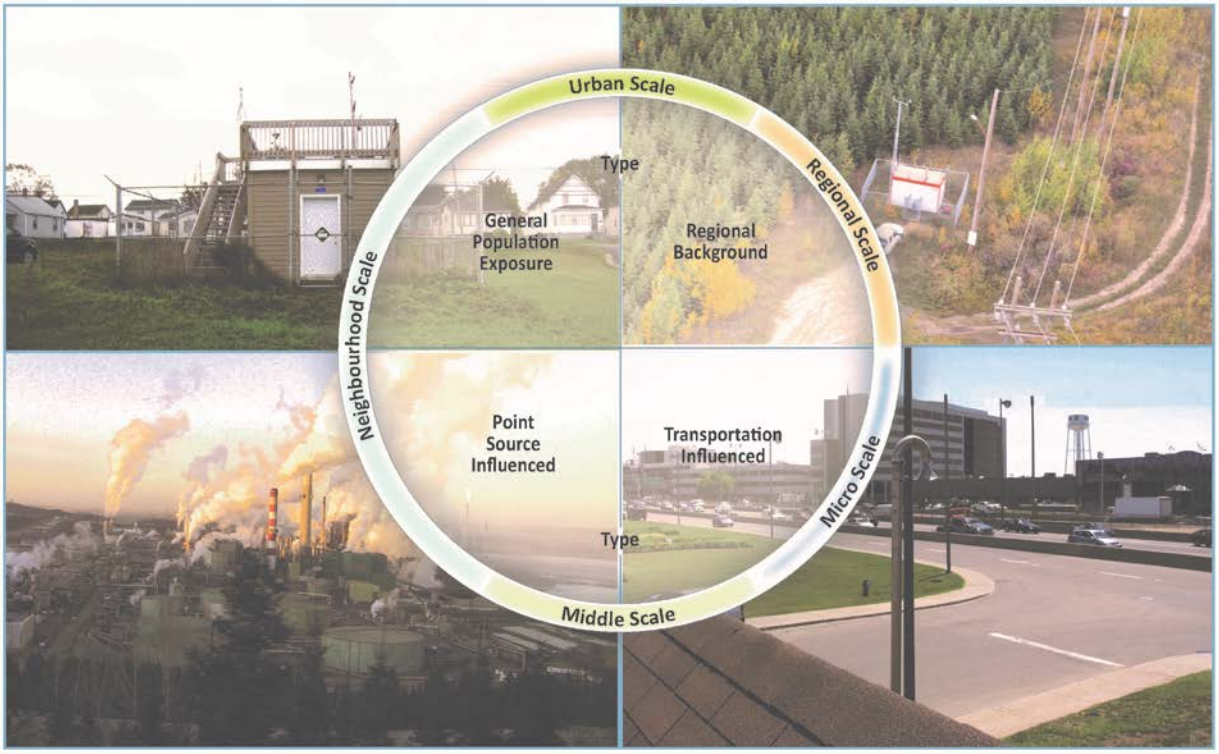
6.2.4 Class 4: Site Type

Class 4 characterizes sites in terms of source influences. These include general population exposure, regional background and local source–influenced (transportation and point source).

General Population Exposure

General population exposure sites measure urban background conditions where concentration gradients are usually small, so measurements tend to be quite representative of larger areas and thus are suitable to assess community-wide or neighbourhood-wide population exposure. This site type is the most common in the NAPS Program (Figure 6-5).

Figure 6-5 Site Types



Regional Background

Regional background sites are sited outside of urban areas to measure:

- air pollutants flowing into an urban area from distant sources, including transboundary sources
- air pollutants flowing out of an urban area
- background concentrations.

These sites are used to determine the contribution of local sources versus distant sources to air pollutant concentrations. They may also be sited to extend the spatial coverage of monitoring for use in air quality forecasting, mapping, modelling and remote sensing applications.

Local Source–Influenced

Local source–influenced sites tend to be pollutant-specific and include both transportation-influenced and point source–influenced sites. They are sited to represent air pollutant exposure to populations residing within the influence of the source(s).

Transportation-influenced sites

These sites are located in areas significantly impacted by transportation emissions (defined as within 100 m of a major roadway). A distance of 100 m was selected based on a review conducted by the Health Effects Institute (2010) on traffic-related air pollution (TRAP) gradients and health

effects. Major roadways are classified as having volumes greater than 15,000 annual average daily traffic (AADT) counts. Only sites within 100 m of major roadways in large urban or medium urban areas are classified as transportation-influenced based on a review of the traffic volumes in urbanization classes.

Other types of transportation-influenced sites (off-road vehicles and engines, rail, marine and aviation) are classified according to their proximity to these sources and based on an analysis of the air quality data.

Point source–influenced sites

These sites are located in populated areas close to a major VOC (typically within 10 km) and SO_2 (~1 kt or greater per year) stationary emissions source. An analysis of point source sites indicated much higher levels of SO_2 or VOC compared with transportation and general population exposure site types, confirming that the point source sites are being significantly influenced by these sources.

Site classification should be documented in the *Networks*' central databases as metadata records and will help end-users and analysts with data interpretation and reporting.

Table 6-2 NAPS site classification system

Site class	Variables	Definition	Code
Urbanization	large urban area	large PC[1] (population ≥100,000)	LU
	medium urban area	medium PC[1] (population between 30,000 and 99,999)	MU
	small urban area	small PC[1] (population between 1,000 and 29,999)	SU
	non-urban (rural) area	non-urban area[1] (population <1,000)	NU
Neighbourhood population	<500	categories of residential population within 4 km of site	P1
	500–9,999		P2
	10,000–49,999		P3
	50,000–99,999		P4
	100,000–149,999		P5
	≥150,000		P6
Local land use	residential	the dominant land use category within a 400 m radius	R
	commercial		C
	industrial		I
	parks		P
	water		W
	agriculture		A
	forested		F
	open		O
Site type	general population exposure	site located in an urban area where populations live, work, shop, play, and that are not classified as transportation or point sources	PE
	regional backgrounds	site outside urban area	RB
	transportation source–influenced	site within 100 m of a major road[2] or influenced by off-road vehicles and engines, rail, marine or aviation sources located in an urban area	T
	point source–influenced	site near (< ~10 km) a major stationary emissions source[3] located in an urban area; classification based on VOC and SO_2[4] ambient measurement data	PS

1 A population centre (PC) is defined as having a minimum population concentration of 1,000 people and a population density of at least 400 people per square km. All areas outside PCs are classified as non-urban (rural areas) (Statistics Canada 2017a).
2 All freeways, highways, and arterial and collector roads with an AADT >15,000 (US EPA 2018).
3 Stationary sources include: industrial facilities, power generation, incinerators and waste-treatment plants.
4 SO_2 emissions greater than ~1,000 tonnes per year (RWDI 2016)

6.3 Equipment Information and Inventory

Along with station documentation, each *Network* should maintain an up-to-date inventory of all monitoring equipment in use. This inventory should include:

- type of equipment used
- ownership information
- purchase price and date of receipt
- equipment description (name and manufacturer)
- equipment identification number (where applicable: e.g., model and serial number)
- equipment location and history (e.g., date of installation).

6.4 Standard Operating Procedures (SOP) for the NAPS Program

SOP are task-specific or method-specific documents that detail the method for an operation, analysis or action with thoroughly prescribed steps. SOP can help ensure consistent performance with organizational practices. They can also serve as training aids, provide ready reference and documentation of proper procedures, reduce error occurrences in data, and improve data comparability, credibility and defensibility. *Networks* should reference relevant SOP in their NQAP and also ensure that applicable SOP and all manufacturer operation and maintenance manuals are accessible for reference on site.

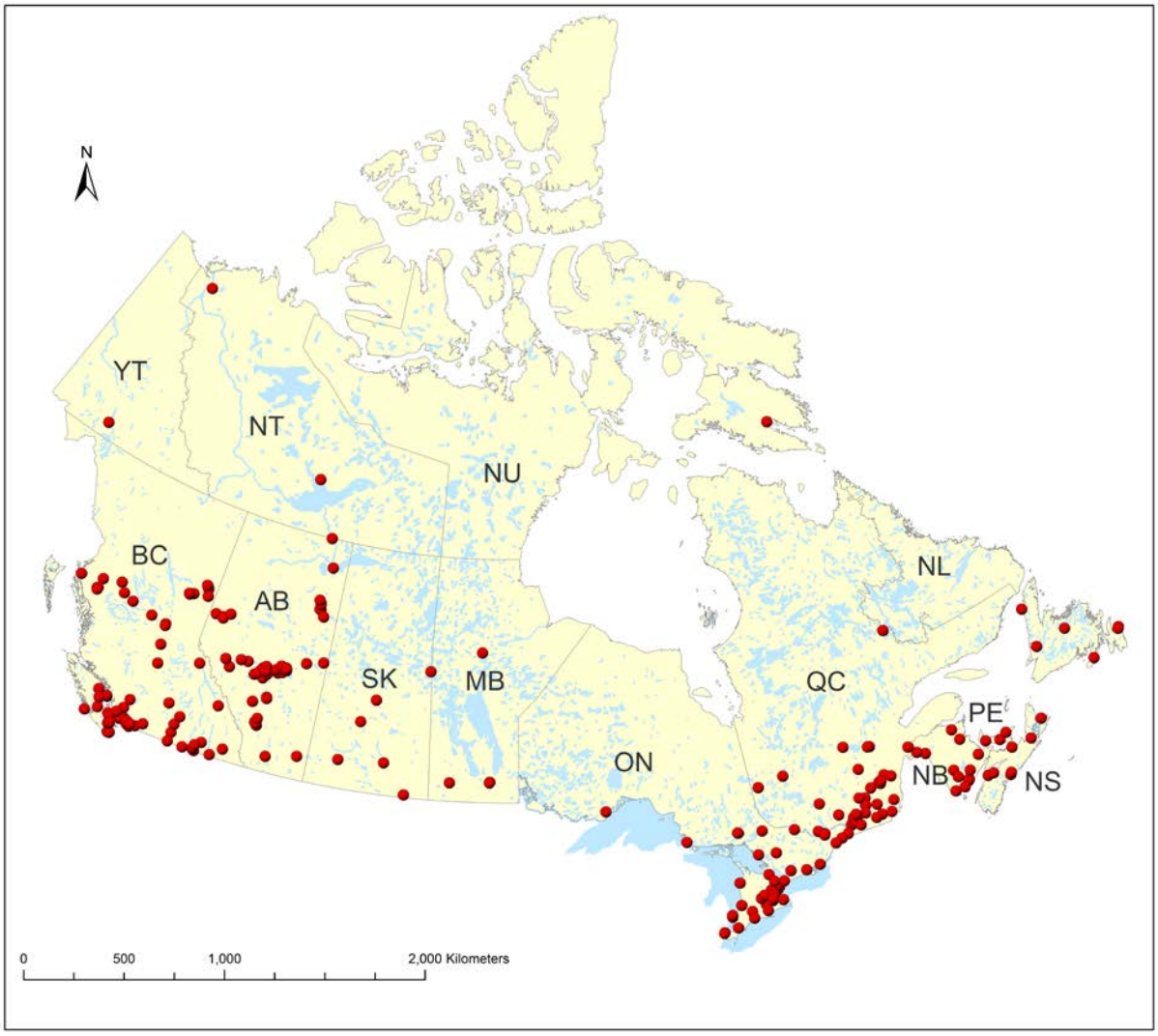
NAPS Operations has developed a number of technical SOP and forms. NAPS SOP related to continuous analyzers and monitors, procedures for collecting integrated samples, data collection, management and reporting processes are referenced in Appendix A.

These SOP contain most of the information needed for a given method or procedure, but users should modify them to accurately reflect the methods and procedures implemented.

7.0 NETWORK DESIGN AND SITE LOCATION

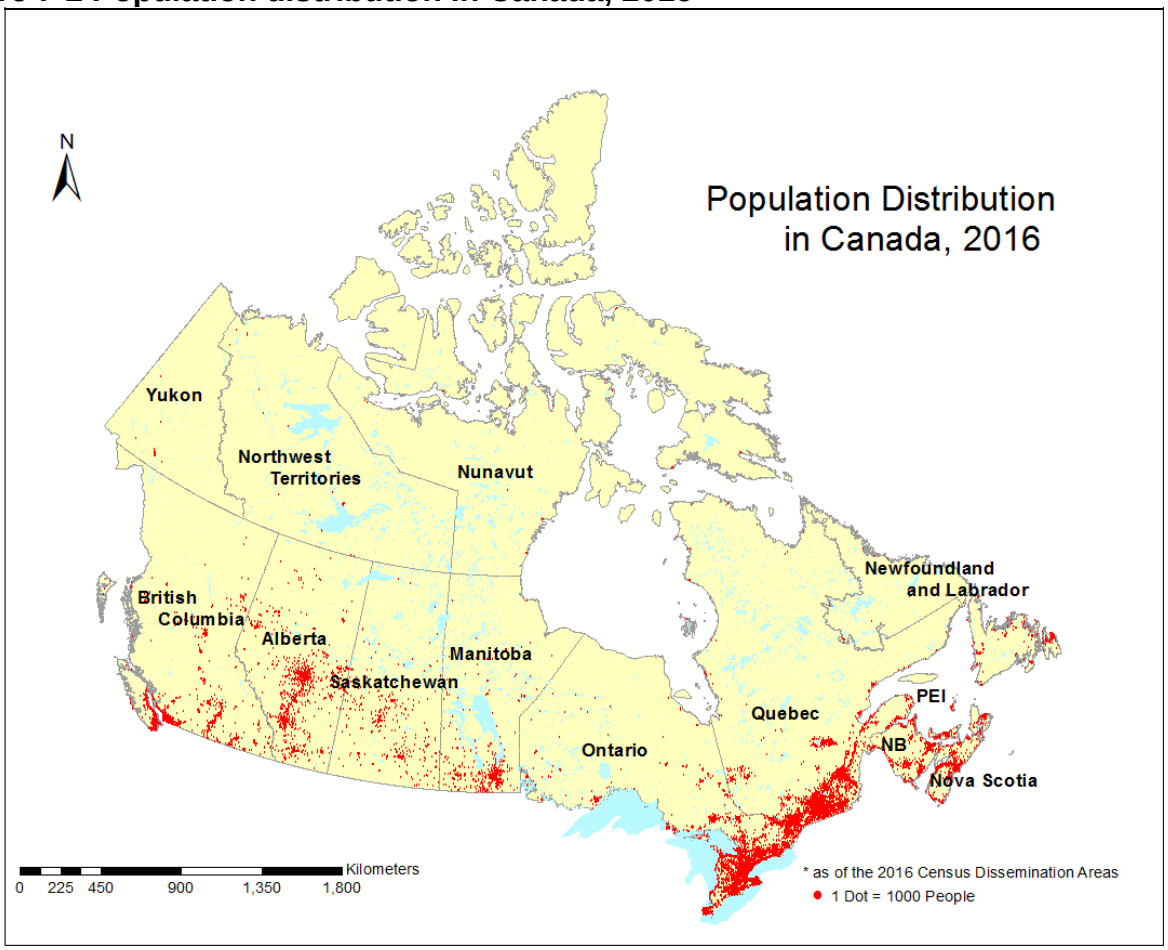
The NAPS Program was established in 1969 to monitor and assess the quality of ambient air in the populated regions of Canada. The primary purpose of the Program was to support the development of Canada-wide air quality objectives for criteria air contaminants and subsequently to track progress towards achieving these objectives. The scope of the Program has evolved to include monitoring the precursors and components of air pollutants, identifying the sources and regions that contribute to air pollutant levels, and providing timely air quality information to the public. However, characterizing air quality for the achievement of Canada-wide ambient standards and objectives continues to be the primary focus of the NAPS Program.

Figure 7-1 NAPS sites



Human health is the key driver for the establishment of the Canadian Ambient Air Quality Standards (CAAQS). As such, locating NAPS sites (Figure 7-1) in populated areas is the highest priority. Canada has a small population living in a large land area, leading to a low population density compared to other countries. The Canadian population, however, is highly concentrated geographically (Figure 7-2). In 2016, two out of three people (66%) lived within 100 km of the southern Canada–United States border, an area that represents about 4% of Canada's territory (Statistics Canada, 2017b).

Figure 7-2 Population distribution in Canada, 2016



The network design will depend on human health effects as well as the magnitude and distribution of pollutant concentrations within a defined area or region. Monitoring of air pollutants for which there is no safe level for health effects (e.g., NO_2, O_3, $PM_{2.5}$) should focus on sites located within densely populated areas.

All census metropolitan areas (CMA) and census agglomerations (CA) with a population greater than 100,000 should have at least one monitoring site. There are 41 CMA and CA in Canada with a population greater than 100,000 (2016 Census; see Statistics Canada 2017a). These account for 73% of the total population. However, regionally important urban areas and communities with air quality concerns should also be considered as a priority for air quality monitoring sites.

Within urban areas, *Networks* must determine the number of sites to be deployed and their distribution (for many communities there will only be one site). The typical approach to monitoring in urban areas involves placing sites at carefully selected representative locations, chosen to meet the desired monitoring objectives and considering the emission and dispersion patterns of the pollutants being monitored. The representativeness of a site will depend on the spatial variability of air pollutant concentrations across a defined area. These variations occur as a result of several factors, including emission characteristics, atmospheric conditions, topography, urban effects, chemical transformations, and natural removal processes. Modelling and other assessment

techniques may be used to assess how representative a monitoring site is of a community or neighbourhood.

Sites for monitoring pollutants associated with local sources (e.g., CO, PAH, SO_2, VOC) should be optimally sited for measurement data to be useful. Data from these sites may also be used to identify sources or regions (as tracers for certain emission types) that contribute to poor air quality and to assess long-term trends in air quality.

Another consideration for network design is the extent of the air pollution coverage. If the air pollutant is mostly of local origin, then sites will be focused in urban areas. If there is a substantial regional contribution to the pollutant concentrations, additional sites may be located outside of urban areas to measure the portion that comes from regional transport or background sources (e.g., O_3, $PM_{2.5}$, VOC).

There has been and continues to be a very large monetary investment in air quality monitoring in Canada. This investment and the importance of air quality data demand strategic planning and design to ensure that the network provides adequate coverage to characterize air quality conditions that address NAPS monitoring objectives. Selecting sites that satisfy multiple objectives will reduce costs and maximize the efficiency of the network. Wherever feasible, air pollutants that share similar characteristics (e.g., spatial variability, common sources, health or environmental impacts) should be monitored at the same site.

Networks should recognize that air monitoring networks are dynamic and should adapt to changes in air pollution patterns, as well as address new and emerging air quality issues. Each monitoring network should be evaluated periodically to assess whether its objectives are being met. *Networks* may relocate sites to meet changes in requirements, as warranted. However, sites with long trend record should not be moved unless continued operation is no longer possible. In such a case, every effort should be made to ensure that the new location measures comparable data. This will allow for analysis of long-term air quality trends.

7.1 Network Design

The NAPS Network has, as its foundation, a subset of “core” monitoring sites that measure a comprehensive set of air pollutant parameters. These sites satisfy many monitoring objectives and provide the basis for multi-pollutant characterizations across a range of site types. The core sites operate in addition to the other NAPS sites, which are designed specifically to meet various program and pollutant-specific requirements (Figure 7-3 and Figure 7-4).

7.1.1 Core Sites

Core sites include a comprehensive set of measurements at a select number of representative locations across Canada that addresses multiple monitoring objectives.

The integrated NAPS $PM_{2.5}$ reference method (RM) sampling sites form the basis of the core sites. In addition, continuous $PM_{2.5}$, O_3 and NO_2 parameters should be included, as a minimum. Additional parameters (e.g., CO, PAH, integrated $PM_{10-2.5}$, SO_2, VOC) are measured at a subset of core sites.

Factors that are to be considered for locating core sites include:

- Population (including regional population centres)
- geographical and spatial representativeness
- areas with known or suspected high pollutant concentrations
- areas influenced by local emission sources.

It is not feasible or necessary to measure all pollutants at core sites and as such, two levels or tiers of core monitoring sites are identified as Tier 1 (T1) and Tier 2 (T2).

Table 7-1 Parameters monitored at core sites

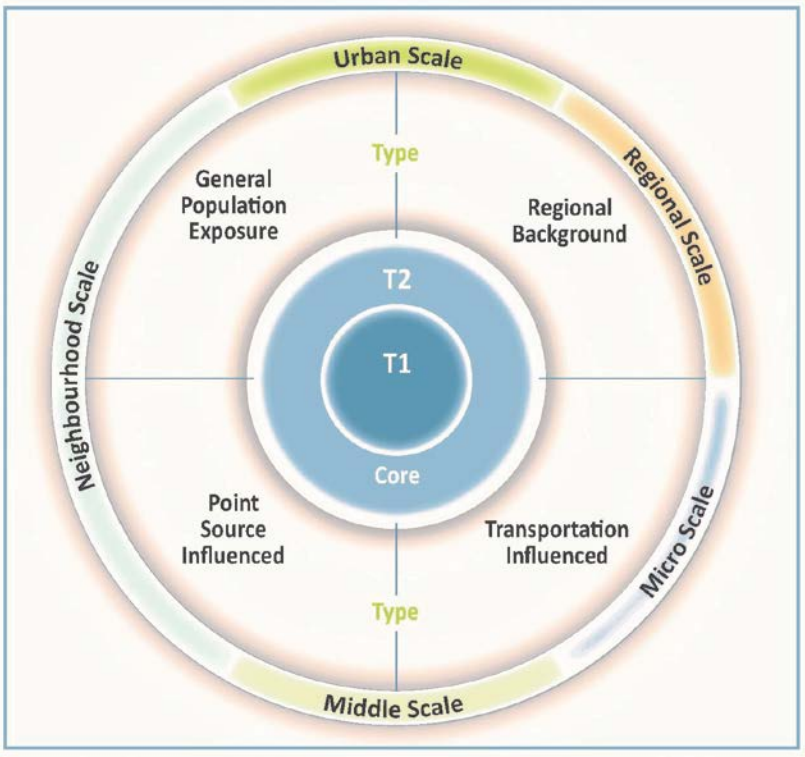
Parameter	T1	T2
$PM_{2.5}$ RM	x	x
Continuous $PM_{2.5}$	x	x
O_3	x	x
NO_2	x	x
$PM_{2.5}$ speciation	x	
SO_2	x	o
CO	x	o
VOC	x	o
Integrated $PM_{2.5-10}$	x	o
Carbonyl	o	o
PAH	o	
Meteorology	R	

x = monitored
o = optional
R = recommended

This tiered approach specifies the parameters measured at core sites, and T1 features the most comprehensive set of parameters (Table 7-1).

Figure 7-3 Graphical concept of core sites

Core stations are located so as to support different site types at various spatial scales.



Tier 2 Sites

The NAPS $PM_{2.5}$ reference method (NAPS $PM_{2.5}$ RM) forms the basis of the T2 core monitoring sites. In each province or territory, the recommended number of sites increase with population (in million) as follows:

Population	Number of sites
<1 million	at least one
≥1 million to <2 million	at least two
≥2 million to <4 million	at least three
≥4 million to <6 million	at least four
≥6 million to <8 million	at least five
≥8 million to <10 million	at least six
≥10 million to <12 million	at least seven
≥12 million	at least eight

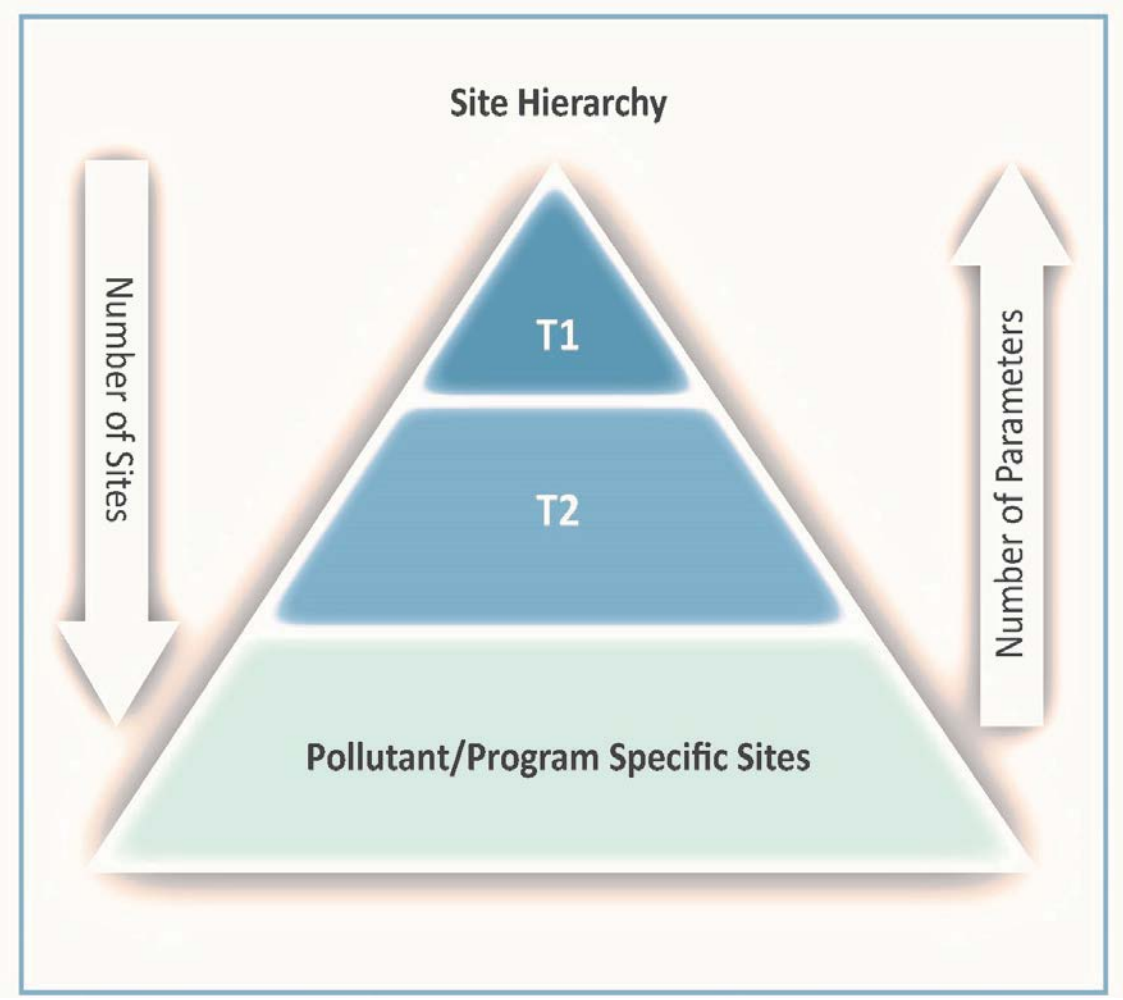
In Canada, the NAPS $PM_{2.5}$ RM uses a time-integrated filter-based method for determining $PM_{2.5}$ mass. Although the US EPA's testing procedures for $PM_{2.5}$ automated federal equivalent methods (FEM) approval (US EPA 2006) covers a diverse range of conditions, side-by-side comparisons

of different FEMs and the NAPS RM has shown that instruments do not always agree with one another over varying timescales and meteorological conditions. It is recommended that each *Network* operate at least one co-located NAPS $PM_{2.5}$ RM with the FEM instrument models deployed in their network. Larger *Networks* should deploy additional co-located NAPS $PM_{2.5}$ RM sites to compare with their FEMs (Table 7-2).

Tier 1 Sites

T1 core sites are based on the $PM_{2.5}$ speciation sampling sites. T1 sites can also serve as platforms to support the introduction of monitoring technologies to the NAPS Program by testing and evaluating new instruments and parameters (e.g., ultra-fine particles and continuous black carbon).

Figure 7-4 NAPS site hierarchy



7.1.2 Program-specific Sites

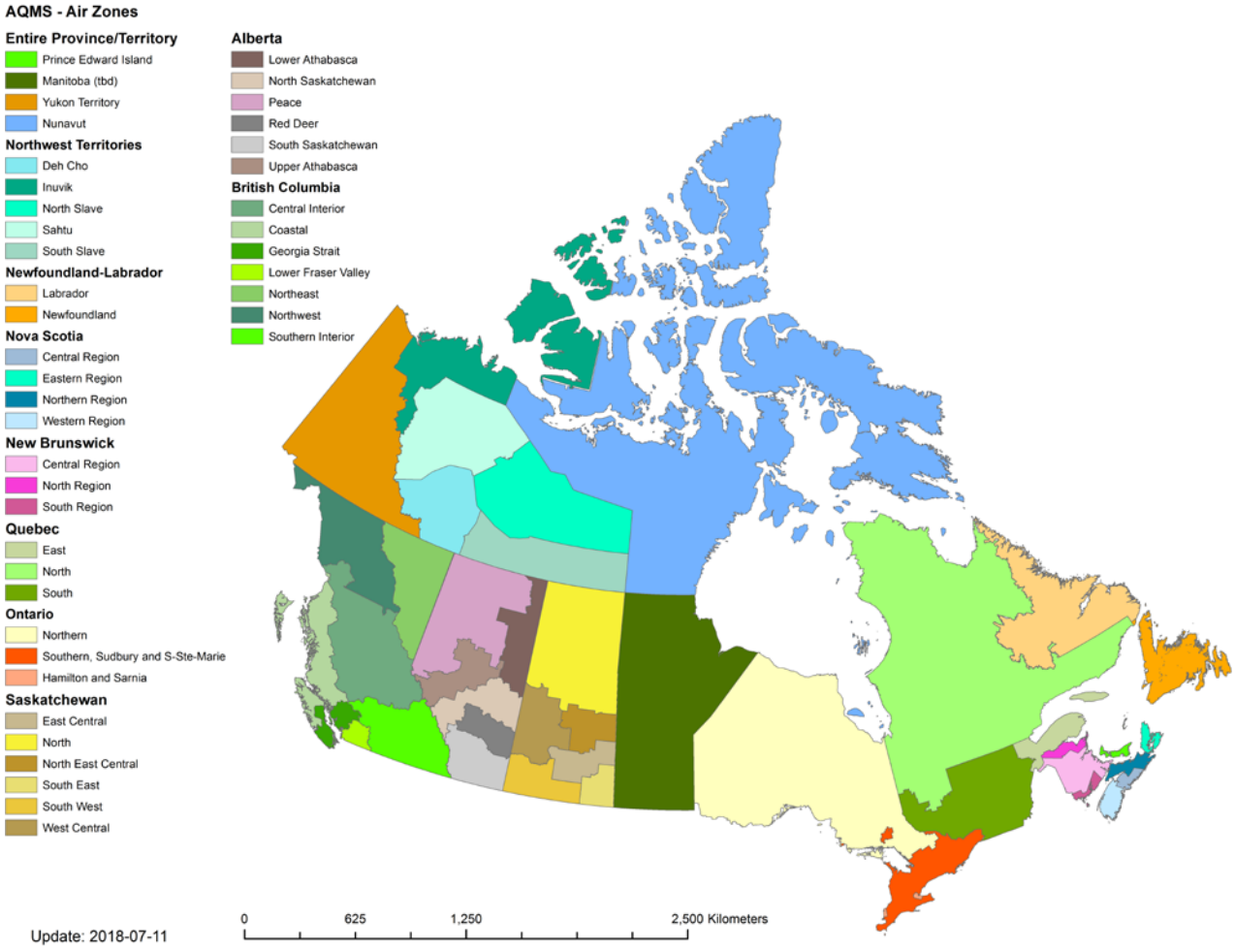
Most sites in the NAPS Program support the following policy initiatives:

Air Quality Management System and Canadian Ambient Air Quality Standards

CAAQS have been developed for $PM_{2.5}$, O_3, NO_2 and SO_2. They are established as objectives under the *Canadian Environmental Protection Act 1999* (CEPA).
The following site distribution is recommended for reporting on achievement of CAAQS:

- In communities with a population greater than 100,000, at least one site measuring continuous $PM_{2.5}$, O_3 and NO_2.
- In each provincial or territorial air zone (Figure 7-5), at least one site measuring continuous $PM_{2.5}$, O_3 and NO_2.
- The highest priority for measuring SO_2 should be in communities where populations are (or may be) exposed to levels within the health effects range (>40 ppb, one-hour average). Other priorities include core sites (T1 and possibly T2) and trend sites (CESI)
- Based on considerations such as regional population density, proximity to point sources, local air quality and public concern, sites measuring NO_2, O_3, continuous $PM_{2.5}$ or SO_2 could also be located in communities with populations of less than 100,000.
- Regionally representative background sites measuring, as a minimum, $PM_{2.5}$ and O_3.

Figure 7-5 AQMS air zones



Air Quality Health Index (AQHI)

The Air Quality Health Index (AQHI) is delivered in partnership with Health Canada and the provincial and territorial governments. This index provides a current hourly value and a two-day air quality forecast for communities across Canada. Warnings and alerts are also issued when conditions warrant. In addition, the AQHI includes messaging on how to reduce personal health risks and air pollutant emissions from individual activities.

To deliver the AQHI to Canadians, consistent and reliable data are required from at least one site measuring continuous $PM_{2.5}$, O_3 and NO_2 for a community or a determined forecast region.

7.1.3 Pollutant-specific Sites

Other than the previously mentioned program-specific and core sites, the NAPS Program supports additional sites that are mainly targeted to specific secondary monitoring objectives (Section 2.0).

VOC Sites

The NAPS Program includes measurements of VOC. In addition to being an important precursor to the formation of ground-level O_3 and PM (secondary organic aerosol), individual VOC species have been declared "toxic" under CEPA.

A program of systematic year-round measurements of VOC began in 1989 at a large number of urban sites across the country. Several non-urban sites were added to the Program in 1993. Measurements of VOC are important in both characterizing emission changes in O_3 precursors and in characterizing human health effects from toxic species. Consistent methodology applied in the NAPS Program provides accurate trend determinations. Speciated VOC measurements can also be used to infer emission contributions and validate emission inventories.

Near-road Sites

Living near major roadways has been identified as a risk factor for various health outcomes. Statistics Canada estimates that 4 million Canadians, about 13% of the total population, live within 100 m of a major road (Evans *et al.* 2011). Information from these sites is used to characterize air quality near roadways and the spatial extent to which Canadians are exposed to TRAP.

The recommended criteria for near-road sites should include:

- at least one site for CMA with a population greater than 1 million
- the following parameters: black carbon, CO, NO_2, O_3, $PM_{2.5}$, SO_2, ultra-fine particles and traffic counting
- if resources allow, a second near-road site for CMA with a population greater than 2.5 million
- locating the stations within 30 m of the outside edge of the nearest traffic lane.

Note: A major roadway with an AADT greater than 30,000 is recommended for near-road sites. AADT is defined as "the total volume of vehicle traffic of a road for a year, divided by 365 days" (U.S. Department of Transportation, Federal Highway Administration 2014).

Regional background sites

Regional background sites are located outside of urban areas to measure:

- air pollutants flowing into an urban area from distant sources, including transboundary sources
- air pollutants flowing out of an urban area
- background concentrations.

These sites are used to determine the contribution of local sources versus distant sources to air pollutant concentrations. They may also be sited to extend the spatial coverage of monitoring for use in air quality forecasting, mapping, modelling and remote sensing applications.

7.2 Site Location Selection Process

Multiple steps are required for designing and implementing a monitoring network and selecting site locations (Figure 7-6):

- identify the program or purpose for monitoring (e.g., CAAQS)
- determine the monitoring objective(s)
- siting stations
- identify the number and location of sites (e.g., communities with a population > 100,000)
- select the pollutants to be monitored by determining:
    - the site type
    - the most appropriate spatial scale (Table 7-2 and Figure 7-7)
- investigate information on land use, including transportation and point sources that may impact air quality
- identify possible locations that would meet monitoring objectives and the populations living in the surrounding area.

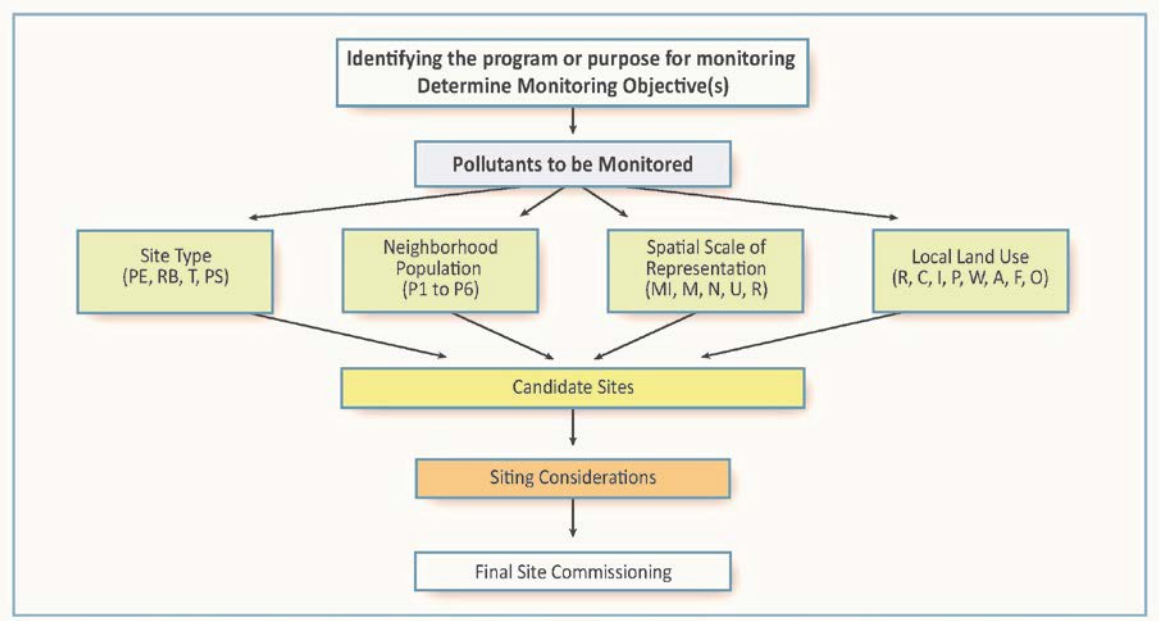
A number of practical considerations should be accounted for prior to final site selection:

- sampling inlet spacing criteria (Section 8.0)
- station design within existing structures (e.g., inlet or exhaust holes, access to roof)
- site suitability in terms of terrain
- security against unauthorized access and vandalism
- site safety
- availability of power
- soil conditions
- underground utilities
- availability of communication systems (e.g., cellular reception, land line or satellite)
- year-round accessibility
- property ownership
- long-term viability of the site

- acquiring a lease or agreement from the property owner to install a monitoring station
- obtaining permit(s) to install and operate the monitoring station.

Note: Ideal siting may not be possible for practical, logistical or other reasons. *Networks* may consult with NAPS Operations in cases where proposed new locations do not meet all recommended criteria.

Figure 7-6 Design requirements of the monitoring network and the selection of sites



7.2.1 Prioritizing Monitoring Objectives

Section 2.1 identifies the monitoring objectives for the NAPS Program. However, these objectives do not apply to all the pollutants monitored under NAPS, nor do they indicate their relative importance. Table 7-2 provides a qualitative priority ranking (low, medium, high) of these objectives for each of the pollutants monitored. This ranking is based on factors such as data usage, pollutant levels, air quality programs or policies, and network reviews. The relative priority of a particular monitoring objective may vary according to the data user.

7.2.2 Spatial Scales of Representativeness

Representativeness is one of the DQO for the NAPS Program. The spatial representativeness of a particular monitoring site is dependent on a number of factors, such as topography, meteorological conditions, proximity to sources, and the chemical and physical properties of the pollutant being measured. The goal when siting stations is to correctly match the spatial scale represented by the air sample with the scale most appropriate for the monitoring objective at the site. To satisfy the

Program's primary monitoring objectives, NAPS sites are generally spatially categorized as neighbourhood or urban scales. Table 7-3 and Table 7-4 show the relationship between spatial scale of representativeness and the pollutants measured and site types respectively.

Figure 7-7 Spatial scales

This document defines five categories of spatial scales of representativeness, these are:

- MI (micro) = concentrations in air typical of areas ranging from several metres up to approximately 100 m
- M (middle) = concentrations in air typical of areas up to several city blocks ranging from about 100 m to 0.5 km
- N (neighbourhood) = concentrations in air typical of some extended area of the city that has relatively uniform land use on the order of 0.5–4 km
- U (urban) = concentrations in air typical of the overall city-wide area on the order of 4–50 km
- R (regional) = usually a non-urban area of reasonably homogeneous geography that may extend from tens to hundreds of kilometres (U.S. EPA 1997).

Table 7-2 Monitoring objective priorities by pollutant and spatial scales of representativeness

Monitoring objectives	CO	NO_2	O_3	SO_2	$PM_{2.5}$ Cont.	$PM_{2.5}$ Int.	$PM_{2.5–10}$ Int.	PAH	VOC	Appropriate spatial scales
Track and report progress on achievement of air quality objectives or standards	low	high	high	high	high					N,U
Measure representative pollutant concentrations in populated areas and enable the determination of long-term trends in air pollutant concentrations	low	med	med	low	med	low	low	low	med	M,N,U
Provide air pollution information to the public		high	high	med	high					M,N,U
Support development of air management strategies	low	low		med	low	med	low	low	med	M,N,U
Support research studies to assess air pollution impacts on health and ecosystems		low	low	low	low	med	low	med	med	M,N,U
Verify and validate emissions inventories, models, mapping, and support forecast and advisory programs		med	med	low	med	low			low	U,R
Measure highest representative pollutant concentrations in populated areas	med	med	med	med	med				low	MI,M,N
Measure regional background concentrations and transport of pollutants from regional sources (including transboundary)		low	med	low	med	low		low	low	U,R
Measure air pollution upwind and downwind of urban areas			low		low	low		low	low	U,R
Support regional, Canada-wide and international air quality agreements and initiatives		low	low	low	low	low		med	low	U,R
Support development and evaluation of new monitoring technologies		low		low	med	med			low	MI,M,N

Cont. = continuous
Int. = integrated

Table 7-3 Pollutants and relevant spatial scale of representativeness

	CO	NO_2	O_3	SO_2	$PM_{2.5}$ Cont.	$PM_{2.5}$ Int.	$PM_{2.5–10}$ Int.	PAH	VOC
Micro	*	*			*	*	*		*
Middle	*	*		*	*	*	*		*
Neighbourhood	*	*	*	*	*	*	*		*
Urban			*		*	*		*	*
Regional			*		*	*		*	*

7.2.3 Site Types

There are three monitoring site types (Section 6.0):

- general population exposure
- regional background
- local-source influenced (transportation and point source).

Table 7-4 Site types and spatial scale of representativeness

	Micro	Middle	Neighbourhood	Urban	Regional
General population exposure			*	*	
Regional background					*
Local source–influenced: transportation	*	*			
Local source–influenced: point source		*	*		

<u>General Population Exposure Sites</u>

Population or community-oriented monitoring sites are used to determine the area-wide exposure to air pollutants. These sites should be located within the urban boundary (urbanization classification) in residential, commercial or other areas where people spend significant amounts of time, and the levels measured should not be unduly influenced by individual sources. Local land use and neighbourhood population classifications can be useful in determining optimal site locations.

Existing sites should be assessed periodically to ensure that they measure representative concentrations in densely populated areas (i.e., >P1), in contrast to sites located in less populated areas that may not necessarily represent the entire area under consideration.

Regional Background Sites

Regional background sites are located in non-urban (rural) areas upwind or downwind of communities to measure air pollution from regional sources or background levels.

These sites should be located in sparsely populated areas (i.e., P1 or P2) away from significant air pollution sources (i.e., >250 m from major roadways and >15,000 AADT; > ~10 km from point sources emitting > ~1 kt/year). It is also desirable to site these stations in an open area, away from tree canopies and preferably on high ground.

Regional background sites may also be deployed to extend the geographical coverage required for air quality forecasting, mapping, modelling and remote sensing.

Local Source-Influenced Sites

Transportation-influenced sites

Sites located in populated areas influenced by traffic located within 100 m of a major road (defined as all freeways, highways, and arterial and collector roads), or by other forms of transportation such as off-road vehicles and engines, rail, marine or aviation sources.

Traffic-influenced sites are located in large urban (LU) and medium urban (MU) PCs near major roadways (AADT >15,000).

Point source-influenced sites

Sites located in populated areas close (typically within 10 km) to a major stationary emissions source. These sites are primarily located near large VOC or SO_2 (~1 kt/year or greater) sources, which are the pollutants most influenced by stationary source emissions.

Note: Fence-line monitoring sites are not reported to the NAPS CWAQD. They are defined as "sites that are located within or on the property line of a facility or those sites that are very near to a facility and in areas not used or accessed by the public or with no nearby population of appreciable size" (RWDI 2016).

7.2.4 *Population Density*

An important consideration in the selection of a NAPS monitoring site is the population living nearby. For urban monitoring, sites should be located in densely populated areas. Conversely, sites that are intended to capture regional background concentrations should be located in sparsely populated areas. There are six categories of neighbourhood population (Table 6-2).

7.2.5 Local Land Use

The dominant land use assigned within a 400 m radius of each site, which corresponds to the middle scale of representativeness, must conform to the monitoring objectives and site type (Section 6.2.1). General population exposure and local source–influenced sites should be located in residential, commercial or industrial land use categories. Regional background sites are located in agricultural, forested, water or open land use categories. Park category sites may be located in either urban or non-urban areas.

8.0 MONITORING STATION DESIGN

8.1 Station Design

The proper design of a monitoring station is crucial and takes into consideration air sample integrity, instrument requirements, functionality and operator safety. Requirements and considerations for station design include the following:

- Stations must be secure, with restricted access to the public.
- All electrical circuits should adhere to provincial and territorial electrical codes. Electrical circuits located outdoors should use ground-fault circuit interrupters and be able to support load demands.
- The station and monitoring system must adhere to provincial and territorial safety codes, be equipped with an ABC-class fire extinguisher and a first aid kit and have a mobile telephone or land line available.
- The station should be designed with sufficient lighting, access to instrumentation and a workspace for the station operator.
- The station should be designed with reliable power and communications systems. For sites with transient power, a line and power conditioning system should be added.
- The shelter must be ventilated, heated and cooled to maintain a stable temperature in the desirable range of 20-30°C throughout the year.
- Instrument racks inside a station should be properly secured, and instruments should be installed to allow air to circulate freely to avoid overheating.
- The station should be designed to ensure safe access to the roof, including appropriate guardrails (as required by local safety codes) to prevent falls.
- Gas cylinders should be properly mounted.

8.2 Sampling Inlet System Design

Components of a sampling inlet system vary by method and can include a PM-sized selective inlet, an inlet line or probe, a manifold (and bypass pump), filters, and sample lines to the instruments. The sampling inlet system should be designed to prevent water from entering the air stream (using a rain cover such as a funnel) and should follow the manufacturer’s installation requirements, NAPS methods, SOP and guidelines.

One important consideration for the sampling inlet system is that **all components** in contact (or

close contact) with the air sample prior to analysis (including the tubing and manifold) must be **non-reactive** (Table 8-1) with the pollutants measured. Also, **to reduce** residence time (Rt) within the system, all sample lines should be kept as short as possible.

Table 8-1 lists acceptable sampling inlet system material and required sample Rt. Section 8.3.1 provides Rt definition and calculations.

Table 8-1 Sampling inlet material and Residence Time (Rt)

Pollutant	Inlet system components	Lines to manifold	Sample Rt
CO	borosilicate glass (e.g., Pyrex), quartz or Teflon	clear Teflon ¼ -inch (FEP, PFA, PTFE)	<20 seconds[4]
NO_X			
O_3			
SO_2			
PM	borosilicate glass (e.g., Pyrex), quartz or conductive material, such as stainless steel or anodized aluminum[1,2]	N/A	
PAH	conductive material, such as stainless steel or anodized aluminum[1,2]	N/A	
VOC	borosilicate glass (e.g., Pyrex), quartz or stainless steel[2]	clear Teflon ¼ -inch[3]	

1 For PM instruments, anodized aluminum inlet system components are often provided by the manufacturer.
2 Teflon or other plastics are not acceptable materials for PM and PAH monitoring, because these materials can become statically charged and attract particles.
3 Sampler lines to the Summa canister must be stainless steel or nickel.
4 Although <20 seconds is required, ~10 seconds is preferable to allow for variability in flow rates.

A manifold system with a water trap to collect condensation is preferable for a monitoring station with multiple gas analyzers, rather than separate sample lines for individual instruments.

For continuous and integrated PM monitoring, manifold systems are not recommended. These instruments should use individual inlets, and the sampling tube from inlet to instrument should be as vertical as possible to avoid particle loss due to impaction.

8.2.1 Sampling Inlet Placement

The sampling inlet is an opening through which an air sample enters the sampling inlet system before being routed to an analyzer, monitor or sampler. These inlets are either provided by the instrument manufacturer or custom designed.

To obtain a representative air sample, placement of the sampling inlet should meet the following recommended spacing criteria for height, obstructions, roadways and distance between inlets.

Specifications for spacing of sampling inlets relative to roadways at neighbourhood and urban scales are listed in Table 8-2, and spacing requirements relative to obstructions that can alter air flow are listed in Table 8-3.

Table 8-2 Minimum separation distance between roadways and sampling inlets[1] for neighbourhood and urban scale sites

Annual average daily traffic (vehicles per day)	≤10,000	≤15,000	≤20,000	≤40,000	≤70,000	≥110,000
Minimum distance between roadway and inlet (metres)[2]	≥10	20	30	50	100	≥250

1 For traffic-influenced sites (where AADT value exceeds 15,000), the inlet must be located within 100 m (*maximum*) of the roadway.
2 Distance to the nearest traffic lane. The distance for intermediate traffic counts should be interpolated.

Table 8-3 Specifications for sampling inlet siting

Pollutant	Height from ground to inlet (metres)[1]	Horizontal and vertical distance from supporting structures to inlet[2] (metres)	Distance from inlet to any air flow obstacle[3] (e.g., buildings, trees) (metres)
CO	2–15	>1	>2 × height of obstacle above inlet[2]
NO_X	2–15	>1	
O_3	2–15	>1	
SO_2	2–15	>1	
PM	2–15	>2	
PAH	2–15	>2	
VOC	2–15	>1	

1 For micro up to neighbourhood scales, the maximum height should be as low as feasible.
2 When inlet is located on a rooftop, this separation distance is in reference to roof, walls, parapets or other structures located on the roof.
3 Must have unobstructed air flow 270° surrounding the inlet (180° if located on the side of a building).

For flow rates less than 20 litres per minute (L/min), sampling inlets must be at least 1 m apart and at least 2 m apart for flow rates greater than 20 L/min (distance measured from centre of inlets). Sampling inlets for co-located instruments should be no greater than 4 m from each other.

In addition to the requirements listed in the tables above, sampling inlet placement should consider the following:

- If an inlet is located on the side of a building, ideally it should be located on the side of prevailing winds.
- Inlets should not be placed in close proximity to air outlets (e.g., exhaust fans).
- To avoid undue local influences, inlets should be located away from minor sources such as fugitive emissions, exhausts or stacks.
- Inlets should be located away from dirty or dusty areas (such as dirt roads).
- Areas subject to possible heavy snow accumulation should be avoided.

8.3 Manifold Design

For a monitoring station with multiple gas analyzers, an air sampling manifold can reduce excess moisture, pressure drops and dust entrainment.

Manifold designs commonly used for NAPS monitoring include either a conventional borosilicate glass (Pyrex) or quartz manifold with a blower motor (Figure 8-1), or an octopus-style manifold system (Figure 8-2).

Important considerations and requirements for manifold design include the following:

- Check that air flow is unrestricted, with minimal bends.
- Install a water trap at the manifold.
- For gas analyzers, install Teflon filters between the manifold and the analyzer's sample inlet port, unless the analyzer is configured with an existing internal filter. Note that **filters located before the manifold inlet are not recommended**, as the flow restriction created by a filter may limit the ability of a fan or blower to provide a sufficient flow rate. More importantly, the filter will create a vacuum in the manifold.
- Ensure air flow through the manifold does not cause the pressure inside the manifold to be more than **1 inch** of water below the ambient pressure. The methodology for determining pressure drops is described in Section 8.3.2.
- Use individual sampling lines and inlets for VOC or carbonyl instruments. However, they may be connected to a manifold **only** if a conventional 4-inch, 2-inch or 1-inch manifold is used.
- Take care to ensure that the inlet system does not have any leaks. Calibration checks through the entire sampling inlet system will indicate possible dilution due to leaks.
- Check that placement of the calibration gas lines be designed to challenge the entire measurement system, including the **sampling line and manifold system**.
- Vent exhaust from analyzers and the manifold outside and away from the sample inlet using an exhaust manifold or individual lines. If using individual lines, ensure that they are of minimal length to avoid back-pressure to the analyzer. If venting to the outside is not possible, the exhaust should be scrubbed before venting into the station.

Figure 8-1 Example of a conventional 1-, 2- and 4-inch manifold system (which can be configured horizontally or vertically)

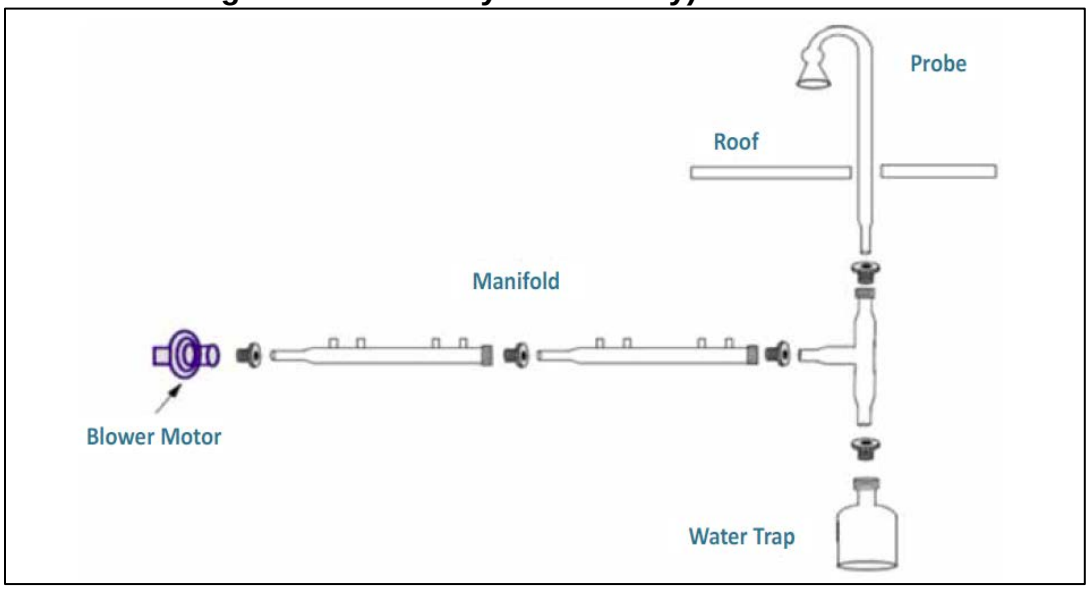
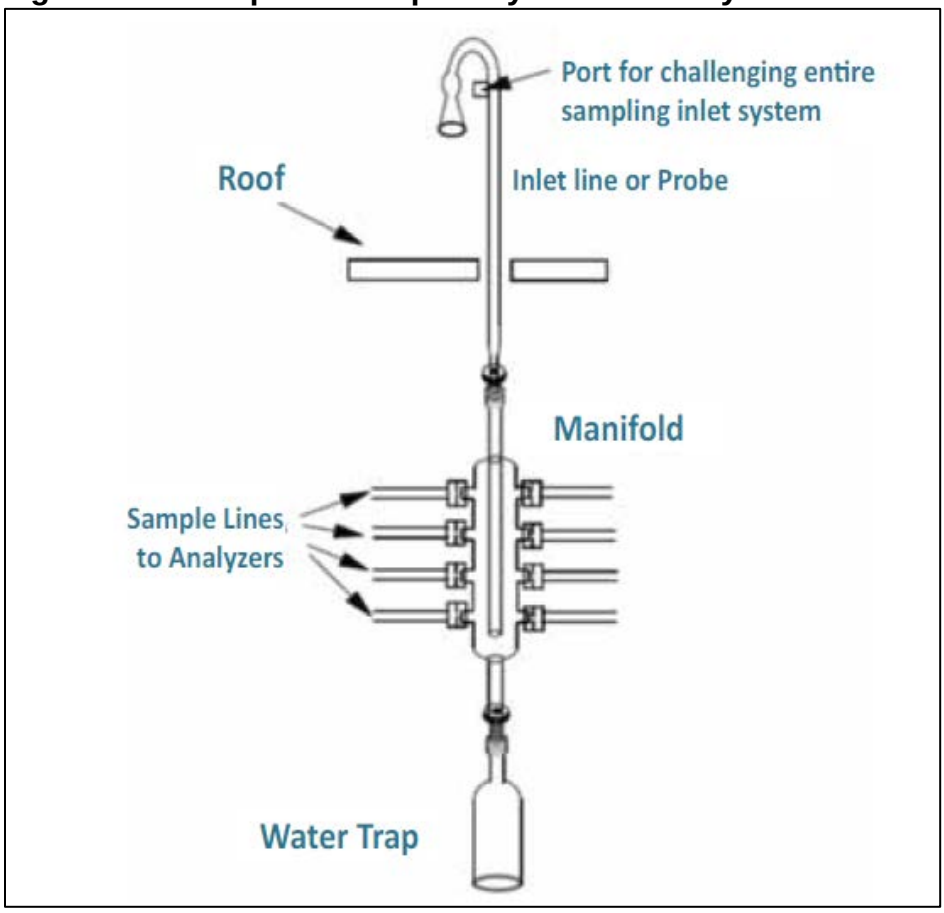


Figure 8-2 Example of octopus-style manifold system



8.3.1 Residence Time (Rt) Calculations

Rt is defined as the amount of time that it takes for a sample of air to travel from the sampling inlet to the instrument. Although a 20-second Rt is the maximum allowed, it is recommended that the Rt within the sampling inlet system be approximately 10 seconds to allow for variability in flow rates.

The Rt is determined as follows. First, calculate the total volume using the following equation:

$$\text{Total volume} = C_V + M_V + L_V$$

Where:

C_V = volume of the sample probe and extensions
M_V = volume of the sample manifold and trap
L_V = volume of the sampling line to the instrument

Once the total volume is calculated, divide the sum of the flow rates of all instruments to obtain the Rt. **If the Rt is greater than 20 seconds**, attach a blower or metered pump to increase the flow rate and decrease the Rt to the acceptable level.

8.3.2 Pressure Drop Measurements

If a manifold system is used, the air flow through the sample system must not create a pressure drop greater than approximately 1 inch of water below the ambient pressure. The pressure drop should be assessed as follows:

- measure the ambient pressure near the manifold
- measure the pressure inside the manifold by attaching a manometer to a spare sampling port on the manifold
- calculate the pressure drop
- adjust the flow rate to ensure that the pressure drop is less than 1 inch and the Rt requirements are met.

If these requirements cannot be met, the manifold volume is too small, and an appropriately sized manifold must be used.

9.0 MONITORING, SAMPLING AND ANALYTICAL METHODS

To achieve the NAPS DQO for accuracy and comparability, monitoring, sampling and analytical methods must meet defined minimum performance specifications for the following pollutants:

Continuous (hourly) parameters:

- CO
- NO, NO_2, NO_X
- O_3
- SO_2
- $PM_{2.5}$

Integrated sampling:

- $PM_{2.5}$ and $PM_{2.5–10}$
  - mass concentration
- $PM_{2.5}$ components
  - major elements
  - trace elements
  - ions
  - inorganic PM precursors: ammonia, nitric acid, SO_2
  - organic carbon/elemental carbon (OC/EC)
  - levoglucosan and other biomass burning markers
- $PM_{2.5–10}$ components
  - major elements and ions
- VOC
  - non-polar hydrocarbons
  - non-polar halogenated
  - polar, including carbonyls (e.g., ketones, aldehydes)
- PAH

9.1 Continuous Methods

Analyzers that satisfy the requirements of the US EPA as federal reference methods (FRM) or FEM for ambient air monitoring are selected for use in the network (US EPA 2018).
Modifications to reference or equivalent methods may be permitted for use within the NAPS Program if it can be demonstrated that they meet the NAPS performance specifications. The operating characteristics of these modified instruments will be documented, and their performance will be evaluated in the laboratory and field for environmental conditions encountered across the country.

For example, the $PM_{2.5}$ FEM requires a very sharp cut cyclone (VSCC), but the use of a sharp cut cyclone (SCC) is allowed under NAPS because field testing has demonstrated that the SCC performs as well as the VSCC.

A current list of US EPA reference and equivalent methods is maintained online (US EPA 2018) and includes approved methods for O_3, NO_2, CO, SO_2 and $PM_{2.5}$. Acceptance of the US EPA FRM and FEM for use in the NAPS Program assures the comparable performance of air quality measurements.

Non-FRMs/FEMs could be used for the initial assessment of an area prior to selecting an air monitoring site location.

Table 9-1 lists NAPS minimum acceptable performance specifications for continuous methods. Table 9-2 lists principles of operation for methods currently used by the NAPS Program for continuous ambient air monitoring.

Table 9-1 NAPS minimum performance specifications and operating ranges for continuous methods

Pollutant	Instrument range[1]	Operating range[2]	Lower detection limit[3]	Zero noise[4]	Zero drift (24 hours)[5]	Span drift (24 hours)[6]	Rise/fall time[7] (max.)
CO	0–10 ppm	0–5 or 0–10 ppm	0.04 ppm	0.02 ppm RMS	<0.1 ppm	<1% of full scale	60 sec
$NO/NO_2/NO_X$	0–500 ppb	0–500 ppb	0.4 ppb	0.2 ppb RMS	<0.5 ppb	<1% of full scale	80 sec
O_3	0–500 ppb	0–500 ppb	1 ppb	0.3 ppb RMS	<1 ppb	<1% of full scale	20 sec
SO_2	0–500 ppb	0–200 or 0–500 ppb	0.1 ppb	<0.06 ppb RMS	<0.2 ppb	<0.5 % of full scale	140 sec
$PM_{2.5}$[8]	0–200 µg/m^3	0–200 µg/m^3 to 0–1000 µg/m^3	2 µg/m^3 (daily)	N/A	N/A	N/A	N/A

ppm = parts per million; ppb = parts per billion; µg/m3 = microgram per cubic metre; RMS = root mean square

1 Instrument range represents the minimum full-scale output that must be available from an analyzer/monitor to be used.
2 Based on the US EPA–approved specified range for the instrument.
3 *Lower detection limit* refers to the lowest detectable quantity of pollutant that can be distinguished from the absence of the pollutant (i.e., zero air for gas analyzers).
4 *Zero noise* is a measure of the deviations from zero while sampling constant zero air. The noise is measured as the RMS of the deviations from zero.
5 *Zero drift (24-hour)* is the absolute change in analyzer response to a constant zero air input over 24 hours of unadjusted continuous operation.
6 *Span drift (24-hour)* is the percent change in analyzer response to a constant upscale pollutant concentration over 24 hours of unadjusted continuous operation.
7 *Rise/fall time* is the time interval between initial response (the first observable change in analyzer output) and a level of signal output that is 95% of the steady state output after a step increase (rise) or decrease (fall) in input concentration.
8 Range of 0–200 µg/m^3 applicable only if using analog output, 0–1,000 µg/m^3 if using digital output (but not exceeding 2,000 µg/m^3).

Relying solely on the performance specifications provided by a manufacturer does not necessarily guarantee that a method will perform as expected in the field during routine operations. To ensure that NAPS minimum performance specifications are met, appropriate maintenance, operating conditions and performance evaluations should be followed (as detailed in this *Guidance*).

The US EPA has approved a number of continuous methods as FRMs or FEMs, including those found in Table 9-2.

Table 9-2 Principles of operation for NAPS continuous methods

Parameter	Principle of operation
CO	Non-dispersive infrared (FRM): This is the most commonly used continuous CO measurement method. These analyzers operate on the principle that the CO molecule has a sufficiently characteristic infrared (IR) absorption spectrum for detection. Sample air passes through a chamber in front of an IR source. Optical bandpass filters focus the wavelength of the IR energy to the CO absorption range. The detector produces a signal proportional to the amount of IR absorbed, enabling the concentration of CO to be calculated.
$NO/NO_2/NO_X$	Chemiluminescence (FEM): NO concentrations are determined photometrically by measuring the light intensity from the chemiluminescent reaction of NO mixed with excess O_3. The chemiluminescence method detects only NO, so NO_2 **must first be converted to NO** for measurement purposes. Sample flow either is directed through a converter to reduce NO_2 to NO, or it bypasses the converter to allow detection of only NO. The sample stream with reduced NO_2 is a measurement of NO plus NO_2, expressed as NO_X. The difference between NO_X and NO detection is calculated as the NO_2 concentration. Cavity attenuated phase shift (CAPS) (NO_2 only; FEM): Direct measurements of NO_2 using CAPS technology are approved as an EPA-equivalent method and are acceptable for NAPS. CAPS instruments use low-power LEDs, where NO_2 light absorption is directly correlated to NO_2 concentration. CAPS analyzers measure only NO_2, not NO or NO_X.
O_3	Ultraviolet (UV) photometry (FEM): This is the most commonly used continuous O_3 measurement method. An air sample passes through a beam of light from a UV lamp, which is absorbed by O_3. The amount of UV light absorbed is proportional to the amount of O_3 in the sample. These instruments are favoured due to ease of operation and low maintenance and because they do not require reagent gases or solutions.
SO_2	UV fluorescence (FEM): This is the most commonly used continuous SO_2 measurement method. This method is based on the principle that SO_2 molecules absorb UV light at one wavelength and emit UV light at a different wavelength. The intensity of the emitted light is proportional to the number of SO_2 molecules in the sample gas. These instruments are favoured because of their inherent linearity, sensitivity and the absence of consumable reagent gases.
$PM_{2.5}$	Beta attenuation (FEM): Particle sizes (e.g., ≤2.5 µm) are aerodynamically separated before analysis. For these measurements, filter tape is exposed to ambient sample flow, and PM is deposited on the filter. Beta rays are emitted from a source and attenuated when they pass through the deposits on the filter. The beta attenuation through the deposit is blank corrected using beta attenuation through a clean filter. The blank-corrected attenuation readings are converted to mass concentrations. Light scattering (FEM): This method relates light-scattering measurements to mass measurements, where particle light scattering is determined by illuminating particles and measuring the scattered intensity at different orientations from the incident light. The scattering measurement is often highly correlated with mass concentrations, but the relationship can depend on particle properties like size, shape and composition. Tapered element oscillating microbalance (TEOM): Particle sizes are aerodynamically separated before analysis. A TEOM consists of a hollow glass element that oscillates at a known frequency. The air sample passes through a filter attached to the tapered element. As particles are deposited on the filter, the oscillating frequency changes in proportion to the amount of mass deposited. This change in frequency is used to determine PM concentration. For US EPA equivalency, TEOMs measuring $PM_{2.5}$ must be operated with a Filter Dynamics Measurement System, which corrects for volatilization and other filter mass loading issues.

9.2 Integrated Methods

For the NAPS Program, ECCC conducts chemical and gravimetric analysis of samples at its ISO17025-accredited laboratories in Ottawa. ECCC also provides sampling media for integrated samplers, including filters, VOC canisters, cartridge assemblies and filter packs. Accredited procedures to ensure sample integrity are followed throughout the process from sample preparation to shipping, collection and analysis.

NAPS $PM_{2.5}$ Reference Method (RM)

Atmospheric particulate matter (PM) is a complex mixture of solid and liquid particles including the vapour-phase semi-volatile compounds that are adsorbed or absorbed to the particle. True measurement of the aerosol is rarely, if ever done, and therefore, $PM_{2.5}$ can only be defined operationally according to the sampling and mass determination method utilized.

An integrated, 24-hour interval, gravimetric method has been adopted as the NAPS Reference Method (RM) for $PM_{2.5}$ mass concentration measurements. Although constituent mass loss or gain artifacts can occur during filter sampling, reference methods provide a benchmark for comparing measurement techniques.

The NAPS $PM_{2.5}$ RM collects fine particulate matter of aerodynamic diameter 2.5 μm and smaller ($PM_{2.5}$) on a pre-weighed Teflon filter using a particle size selective inlet, located on the inlet tube, by drawing a known volume of ambient air over a 24-hour interval. Once the sampling period is completed, the filter is removed and transported to the NAPS Laboratory where it undergoes conditioning and gravimetric weight determination. The average $PM_{2.5}$ concentration (in units of $\mu g/m^3$) is calculated from the mass difference of the filter divided by the actual volume calculated from the flow meter and the sampling time interval (24 hours).

Brief descriptions of sampling and analysis methods are listed in Table 9-3.

Table 9-3 Principles of sampling and analysis for NAPS integrated methods

Parameter	Principle of operation
$PM_{2.5}$ mass concentration (NAPS $PM_{2.5}$ RM)	Samples are collected on Teflon filters using the NAPS $PM_{2.5}$ RM. Mass concentrations are calculated from the difference between pre- and post-sampling weights using sampled volumes. Gravimetric analysis is performed under controlled environmental conditions.
$PM_{2.5–10}$ mass concentration	Samples are collected on pre-weighed Teflon filters. Mass concentrations are calculated from the difference between pre- and post-sampling weights using sampled volumes. Gravimetric analysis is performed under controlled environmental conditions.
Chemical Characterization of $PM_{2.5}$	To characterize $PM_{2.5}$ and $PM_{2.5–10}$ species, samples undergo laboratory analysis using a variety of techniques such as ion chromatography (precursor gases, ions), energy-dispersive x-ray fluorescence (ED-XRF) for elements, and inductively coupled plasma mass spectrometry (ICP-MS) for both near-total and water soluble metals.
Chemical characterization of $PM_{2.5-10}$	$PM_{2.5–10}$ samples are analysed for elements by energy-dispersive x-ray fluorescence (ED-XRF), and for PM precursor gases and ions by ion chromatography.
$PM_{2.5}$ Speciation	Samples are collected using a combination of denuders and Teflon, nylon and quartz filters at $PM_{2.5}$ Speciation sites. In addition to the chemical characterization described above, samples undergo laboratory analysis using a variety of techniques such as ion chromatography (precursor gases, ions, biomass burning markers), total optical reflectance for carbon (OC/EC), energy-dispersive x-ray fluorescence (ED-XRF) for elements, and inductively coupled plasma mass spectrometry (ICP-MS) for both near-total and water soluble metals.
VOC	VOC are collected using stainless steel Summa canisters. Ambient air is drawn into an evacuated canister at a constant flow rate. A combined gas chromatography/flame ionization detector system is used for quantification of C2 hydrocarbons, while a combined gas chromatography/mass selective detector system is used for quantification of C3 to C12 hydrocarbons and chlorinated hydrocarbons.
Carbonyls	Samples are collected by drawing ambient air at a constant flow rate through a 2,4-dinitrophenylhydrazine (DNPH)–coated silica-gel cartridge. Samples undergo analysis using high-pressure liquid chromatography.
PAH	Samples are collected using a NAPS-modified high-volume particulate sampler. Ambient air is drawn at a constant flow rate through a Teflon-coated borosilicate glass filter to capture the particle components, in combination with a cartridge that contains polyurethane foams to trap the gaseous PAH. Samples undergo analysis using gas chromatography/mass spectrometry.

9.3 New Instrument Pre-deployment Testing and Inspection

Testing and inspecting instruments in a controlled environment such as a laboratory or workshop prior to deployment in the field ensures that they are performing within a manufacturer's specifications. This baseline testing may also help identify problems associated with instrument siting.

9.3.1 Continuous Gas Analyzers

To identify potential issues, several multi-point verifications and zero/span checks should be performed for at least one week. This testing should also include monitoring of instrument diagnostics to ensure that the various internal electromechanical, temperature and pneumatic sensors are performing as expected. Manufacturer operation manuals may include such testing procedures.

9.3.2 PM Instruments

The most important operating parameter of PM instruments is the flow rate. A calibration should be performed and all sensors verified (pressure, temperature, flow, etc.). Testing should include monitoring of instrument diagnostics. To determine instrument stability, the instrument should be operated with a zero filter (high efficiency particulate air [HEPA]) for at least three days. Manufacturers' operation manuals may include such testing procedures.

10.0 ROUTINE OPERATION

Routine operation and maintenance at monitoring sites is the responsibility of the *Network*, and includes site- and equipment-preventative maintenance, repairs, instrument checks and calibrations, as well as sample collection for laboratory analysis. Although routine site visits are discussed in this section, additional guidelines and schedules for verification and calibration activities are also discussed in Section 11.0.

10.1 Routine Inspection and Maintenance Checks

Routine visits are necessary to verify the continued operation of the unattended monitoring station and equipment. Preventive maintenance increases data capture, ensures system reliability, and helps to identify any potential problems and corrections before failures occur. Station operators should visit sites weekly for routine checks, but actual schedules may vary according to the *Networks* due to unique circumstances or constraints.

Remote diagnostic testing of various monitoring equipment and station parameters can complement station visits. Such routine checks or diagnostic tests may indicate that corrective action on-site is necessary; a trained field technician visiting the site would be able to troubleshoot

and address these issues. Additionally, instrument manufacturers or NAPS Operations may also be able to provide troubleshooting and repair assistance.

Due to the many types of equipment in use, only general inspection and maintenance guidance is provided here. In most cases, US EPA reference or equivalent method requirements, instrument-specific SOP, and manufacturer information will provide detailed preventative maintenance schedules and specific requirements or recommendations. Consequently, it is important that instrument SOP and manufacturers' manuals are readily available on site for reference during maintenance or repair.

Furthermore, an up-to-date preventative maintenance checklist should be available at each site (either electronically or as a paper log) to help ensure that maintenance performed is documented in an appropriate and consistent manner.
General site and monitoring system inspection and maintenance items include the following:

- check shelter integrity and security, including any wear, corrosion or weathering
- inspect inlet, manifold and sample lines to the instruments for dirt buildup; clean the manifold and replace sample lines as necessary
- inspect PM size selective inlets for dirt or damage; clean/replace inlets and empty water-trap jars as necessary
- inspect continuous PM sample tape for pinholes or damage
- inspect the gas analyzer inlet filters (replace as necessary)
- inspect drying agents such as silica gel (replace as necessary)
- confirm adequate supply of consumables (e.g., desiccant, filters, gloves)
- if station temperature is not logged, verify that the temperature has remained within the correct range (20-30°C) since the last visit; adjust the thermostat if necessary
- review any instrument alarms, instrument issues and data issues that have been identified since the last visit
- update site and station logs (Section 10.3) and instrument maintenance records (Section 10.4).

10.1.1 Integrated Samples: Specific Requirements

Routine site visits are required to install and remove sampling media (e.g., filters, canisters, cartridges and filter packs). Appropriate sample handling procedures must also be in place to prevent contamination or sample loss during handling, sampling, and transport to and from the laboratory. During these visits, routine checks should be performed.

Each instrument has detailed field SOP describing sample collection procedures, as listed in Appendix B.

Requirements for handling samples include:

- wearing disposable, powder-free gloves while handling carbonyl cartridges and PAH sampling media
- inspecting individual filters prior to use to ensure their integrity (i.e., no pinholes, tears, creases or other flaws)

- purging the VOC sampling system **before** sampling
- ensuring that the sampler is set to the specified flow rate, start/end time, date and duration
- fully completing the field data sheets; a copy of each must be sent to the lab, and a copy should be retained by the operating *Network*.

NAPS Operations provides troubleshooting and repair services for all integrated samplers and should be contacted if issues occur.

10.2 Quarterly and Semi-annual Station Visits

In addition to routine inspection and maintenance checks, scheduled site visits are recommended, either quarterly or semi-annually, by trained field technicians. During these visits, multi-point verification checks are performed. If instrumentation is outside of recommended criteria, calibration adjustments should be conducted.

The following activities should be performed during scheduled quarterly or semi-annual station visits:

- verify or update inventory for all equipment at the site
- perform any scheduled maintenance, such as leak checks, sample inlet and manifold cleaning, and sample line replacement
- verify zero-air supply system for each analyzer and change and correct if necessary
- perform multi-point verification checks for gas analyzers (Section 11.1)
- perform flow verification and calibration checks for PM instruments (Section 11.2)
- verify time-stamps against correct time for all instrumentation, including datalogger
- update site and station logs (Section 10.3) and instrument maintenance records (Section 10.4).

10.3 Site and Station Logs

Field data records for ambient air monitoring provide valuable reference information for the data validation process and help ensure data defensibility. A checklist is used for routine site visits: it should be maintained along with site documentation and detailed field logs. Paper copies of log notes can be maintained on site. However, electronic or web-based logging systems ensure that information is better organized and readily available to any personnel involved in station operation and in data-validation processes. All on-site activities should include documentation of both “as-found” and “as-left” site and instrument conditions. Documented information for each log entry should include, **at a minimum**, the following:

- site name and ID number
- date and time, instruments and systems assessed, and name of the operator or technician conducting all routine and non-routine maintenance activities
- a record of damage, malfunction, modification, repair or other corrective action to station systems and equipment
- information relevant to site-specific operational checks (e.g., air conditioning, fencing,

shelter leaks)
- date and time of most recent verification checks and calibrations, including associated calibration records (see Section 10.4 for calibration documentation requirements)
- anything unusual that may have affected results (e.g., burning nearby, construction activities, loose connections to the instrument).

10.4 Instrument Maintenance Records

Each instrument and associated equipment should have its own maintenance log containing the repair and calibration history. Repairs can occur on site, in *Network* laboratories or at NAPS Operations, or equipment can be returned to the manufacturer.

Minimum information that should be documented includes:
- the manufacturer's name, equipment model and serial number, or other unique identification
- a record of any instrument-specific damage, malfunction, modification, repair or other corrective action
- information relevant to instrument-specific operational checks and maintenance (e.g., leak checks, flow checks)
- date and time of most recent verification checks and calibrations, including reference to associated calibration records (see Section 11.3 for calibration documentation requirements).

11.0 VERIFICATION AND CALIBRATION

DQO (Section 4.0) help to ensure that data collected are of acceptable accuracy, completeness, comparability and representativeness. An important part of meeting DQO is *defining acceptance criteria*.

The calibration of an instrument establishes the quantitative relationship between the value of a known traceable standard and the instrument's response. The term *calibration* is associated with an adjustment of an instrument or software, while *verification* does not involve any adjustment. Once an instrument's calibration relationship is established, the instrument should be verified at frequencies recommended in this *Guidance*. Results from this multi-point verification should be used to determine if an instrument calibration (adjustment) is necessary or whether data should be further assessed.

The NAPS Program has defined acceptance criteria for QC checks, multi-point verification, and calibration of continuous analyzers and integrated PM samplers. Along with the general guidance provided here, specific analyzer and sampler verification and calibration procedures should follow instrument SOP and manufacturer operation manuals.

11.1 Gas Analyzers

For gas analyzers, multi-point verification occurs upon initial installation, in response to exceedances of tolerance levels of QC checks and at specified frequencies. QC checks can be accomplished on an automated schedule, initiated remotely or performed on-site by a trained technician.

- Table 11-1 lists recommended activity frequencies for QC checks, as well as multi-point verification and calibration.
- Table 11-2 lists verification and calibration ranges.
- Table 11-3 lists tolerance levels for QC checks.
- Table 11-4a and Table 11-4b list tolerance levels and acceptance criteria for multi-point verification.

11.1.1 QC Checks for Gas Analyzers

Zero check: For a zero check, pollutant-free air is introduced to measure the analyzer's response to concentrations below its detection limit. The zero check is compared to the zero reference value established at the time of multi-point verification or calibration. If the zero is outside of tolerance levels, a zero adjustment should be performed using either a scrubber or zero-air source with a dilution calibrator.

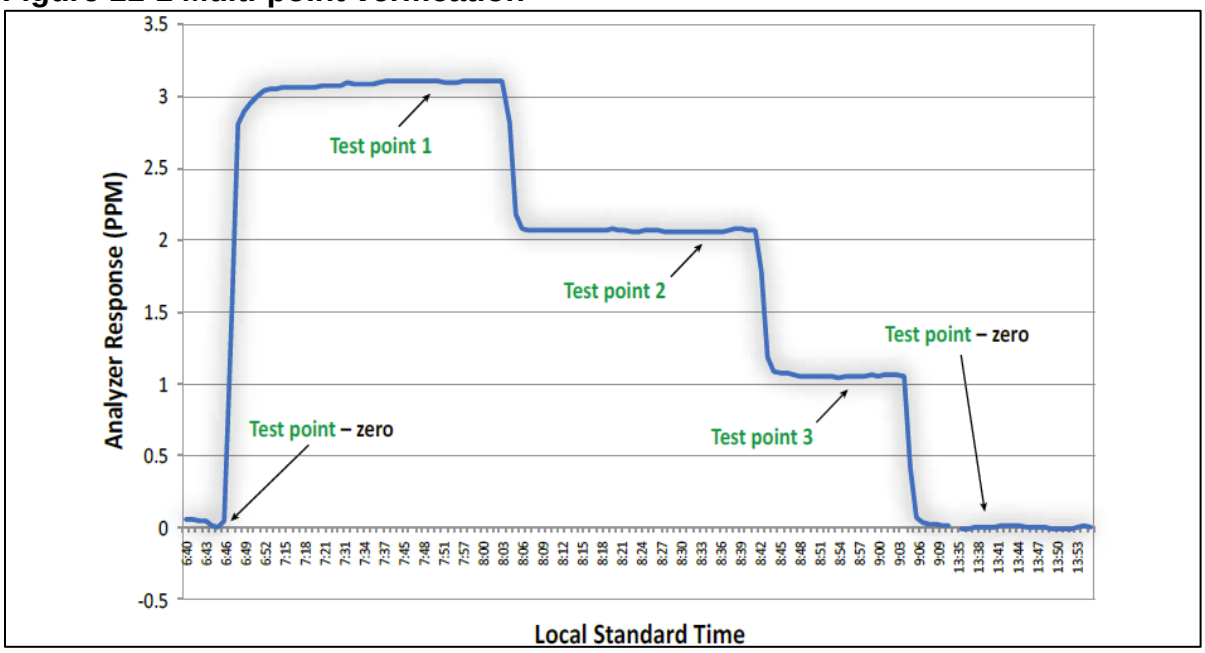
If the value from the zero check immediately following multi-point verification or calibration is not essentially zero, then either the scrubber or the zero-air system scrubbing media may need to be replaced.

Span check: A span check involves introducing a known concentration of a pollutant gas at a concentration higher than values expected at the site during routine operations, and *near the calibration range*. Table 11-2 shows the recommended calibration ranges by parameter. The span check point is compared to a reference span value established at the time of multi-point verification or calibration. If the span is found to be outside of the tolerance level, an "as-found" multi-point verification should be conducted, and a subsequent corrective action should be initiated. A span check can be performed using permeation devices, span gases or high-concentration gases with a dilution calibrator (recommended method).

11.1.2 Verification and Calibration

Multi-point verification: A multi-point verification (using traceable standards and materials) initially establishes and subsequently verifies the accuracy and linearity of the instrument at regular intervals to ensure data validity. This verification must be performed before any instrument calibration and includes a pre- or post-zero and at least three upscale points (100%, 60% and 30% of calibration range) in the recommended ranges (Figure 11-1 and Table 11-2).

Figure 11-1 Multi-point verification



These recommended ranges have been set from NAPS data assessed over a three-year period (2012–2015) and are meant to encompass at least 150% of the air quality objectives and standards. These ranges are both realistic and achievable using existing calibration equipment and reference materials.

Calibration: A calibration is an instrument adjustment that establishes the relationship between instrument response and expected concentration. If a multi-point verification indicates the instrument is operating outside defined tolerance levels or acceptance criteria, a calibration should be performed according to the manufacturer's operating manual. Analyzer calibration must include a zero adjustment and an upscale adjustment at the recommended calibration ranges as indicated in Table 11-2. After completing the adjustments, allow the analyzer to stabilize; then perform an additional verification on the zero and **at least one upscale point**, recording "as-left" information, to confirm that any adjustments made were applied correctly.

Table 11-1 Gas analyzer QC, verification and calibration activity frequencies

Activity	Minimum frequency
Analyzer QC checks (zero and span) (CO, NO_X, O_3, SO_2)	Weekly[1]
Analyzer multi-point verification (CO, NO_X, O_3, SO_2)	Upon installation or relocation Before and after any repairs that may affect calibration[2] Before instrument calibration Every 6 months (semi-annually) if zero/span checks are performed daily Every 3 months (quarterly) if zero/span checks are performed on any schedule other than daily Before instrument shutdown When span check exceeds tolerance levels
Analyzer calibration (CO, NO_X, O_3, SO_2)	In response to exceedance of the multi-point verification tolerance levels and acceptance criteria[3]

1 Zero and span checks can be automated to be performed daily.

2 Verification prior to repair may not be possible.

3 Additional verification checks of the zero and at least one upscale point after a calibration are recommended to ensure the instrument was appropriately calibrated.

Table 11-2 Multi-point verification and calibration ranges

Level	Pollutants			
	CO	**NO_X**	**O_3**	**SO_2**
Calibration range	0 – 3 ppm	0 – 300 ppb	0 – 200 ppb	0 – 200 ppb

11.1.3 Tolerance Levels and Acceptance Criteria

Tolerance levels for zero and span checks: Levels at which analyzer multi-point verification, calibration adjustment or repair should be initiated to **address issues before acceptance criteria are exceeded** and data become invalid. To avoid potential data loss, these levels are more restrictive than the acceptance criteria.

Acceptance criteria for multi-point verification: When multi-point verification exceeds these limits, data should be invalidated to the most recent time when such measurements were **known to be valid**, unless data correction can be justified.

Table 11-3 QC checks tolerance levels for gas analyzers

Instrument	QC checks	Tolerance levels
CO	Zero check span check	± 0.1 ppm[1] 10% of reference value[2]
NO_X	Zero check span check	± 2.0 ppb[1] 10% of reference value[2]
O_3	Zero check span check	± 2.0 ppb[1] 10% of reference value[2]
SO_2	Zero check span check	± 1.0 ppb[1] 10% of reference value[2]

1 When the zero check is exceeded, an adjustment of the zero may be required; a trend analysis of the zero results will determine if a baseline-drift correction is needed.
2 When the span check is exceeded, a multi-point verification is required.
Note: Frequent adjustment of the instrument should not be necessary and can lead to increased data uncertainty. Furthermore, frequent adjustment usually indicates that instrument issues need to be addressed.

Table 11-4a Multi-point verification: Zero-point tolerance levels for gas analyzers

Activity	Instrument	Tolerance level[1]
Zero point	CO	+/- 0.08 ppm
	NO_X	+/- 1.0 ppb
	O_3	+/- 1.0 ppb
	SO_2	+/- 0.5 ppb

1 When exceeded, instrument zero adjustment is required.
Note: Frequent adjustment of the instrument should not be necessary and can lead to increased data uncertainty, which usually indicates instrument issues that need to be addressed.

Table 11-5b Multi-point verification: Upscale points acceptance criteria for gas analyzers

Activity	Instrument	Tolerance level[1]	Acceptance criteria
Upscale points maximum % difference[2]	CO, NO_X, O_3, SO_2	4%	15%
Molybdenum converter efficiency (NO_2 coefficient)	NO/NO_2/ NO_X	96 – 104%	15%

1 The accuracy of multi-point verification and calibration is considered to be within these levels when using traceable standards. When exceeded, a calibration is required.
2 This is the maximum difference between each measured upscale point and the transfer standard value.

11.1.4 Multi-Point Verification and Calibration Considerations

Calibration adjustments should be performed according to the operation manual. Procedures may also be described in analyzer-specific SOP.

Additional considerations for gas analyzer multi-point verification and calibration adjustments are as follows:

- The analyzer, dilution and ozone calibrator, gas cylinders and zero air system should be equilibrated to operating temperature prior to verification or calibration.
- All calibration and verification transfer standards must be traceable to a NAPS reference standard and the certification cannot have expired.
- The certified gas should pass through as much of the sampling inlet system as possible, including all filters and other components used during normal sampling. Injecting gas through the manifold is recommended and could identify issues with the manifold and sample lines. However, it is acceptable to inject gas directly to an analyzer that has an internal filter or to an external sample filter if the analyzer does not have an internal filter.
- The instrument response should be allowed to stabilize at each point before results are recorded or adjustments made. For the upscale point, two consecutive five-minute averages should be compared. These two five-minute averages should be within 1 ppb of each other for O_3, NOx and SO_2 and 0.02 ppm for CO.
- All verification and calibration should include documentation of both “as-found” and “as-left” conditions (even if no changes were made).
- After a multi-point verification or calibration:
    - verify linearity to confirm that the instrument is operating within the manufacturer’s specifications
    - update the new reference zero and span check values in the datalogger
    - restore the sampling inlet system and analyzer to normal operation.
- Station documentation for calibration events should be maintained (Section 10.4).

11.1.5 Automatic Zero or Span Adjustments

Several analyzers can perform automatic zero or span adjustments based on zero and span check results. Automatic zero adjustments may be desirable because zero drift is common in many analyzers.

If automated zero adjustments are made, it is important that they be reviewed during the data validation process, as zero-check results could become unreliable due to equipment failure or other issues. Automatic span adjustments are not permitted, unless they are performed using traceable standards and materials.

11.2 PM Instruments

Unlike the reference (gas) standards available for verifying and calibrating gas analyzers, no such

standards are available for calibrating PM instruments. As a result, the only parameters that can be verified and calibrated are flow, temperature, pressure and other instrument-specific parameters. These are critical to proper instrument operation and collection of appropriately sized particles.

Recommended PM instruments checks frequencies are listed in Table 11-5 and NAPS acceptance criteria are listed in Table 11-6.

QC checks for PM instruments**:**

- **Flow rate:** Verification of the flow rate set-point against a certified flowmeter. A specific flow rate is required at the inlet to properly separate particles in the air (e.g., 16.67 L/min for $PM_{2.5}$ particle size selection).
- **Temperature, pressure and relative humidity:** One-point verification of these parameters against traceable standards. This is important for PM instruments, as ambient conditions affect the sampled volume used for concentration calculations.
- **Zero:** Verification of the instrument zero by removing all particulates in the sample air using a HEPA filter. The zero check should be performed according to the instrument operating manual.
- **Leak:** Verification of the pressure in the inlet system according to manufacturer-recommended procedures. The PM inlet is replaced with a leak-check adapter, and the pressure or flow rate is measured and compared with manufacturer specifications.
- **Calibration:** Instrument adjustment that establishes the relationship between instrument response and expected value. If QC checks indicate that the instrument is operating outside of defined tolerance levels or acceptance criteria (Table 11-6), a calibration should be performed according to the manufacturer's operating manual. To confirm that all adjustments were applied correctly, perform an additional verification to record "as-left" information.

Table 11-5 PM instruments QC activity frequencies

Activity	Minimum frequency
PM instrument QC Checks (one-point flow, temperature, pressure and leak check)	Upon installation or relocation Before and after any repairs that may affect instrument calibration[1] Before instrument calibration Every 3 months for continuous monitors Every 6 months for integrated samplers Before instrument shutdown

1 Verification prior to repair may not be possible.

11.2.1 PM Instrument Tolerance Levels and Acceptance Criteria

Tolerance levels: These are levels at which calibrations or repair should be initiated to address issues **before acceptance criteria are exceeded** and data become invalid. To avoid potential data loss, these levels are more restrictive than the acceptance criteria.

Acceptance criteria: When one-point verification exceeds these limits, data should be invalidated to the most recent time when such measurements were **known to be valid**, unless data correction can be justified.

Table 11-6 QC check tolerance and acceptance criteria for PM instruments

Instrument	Frequency	One-point verification	Tolerance level[1]	Acceptance criteria
Continuous $PM_{2.5}$	every 3 months	flow rate (set point vs. standard)	4%	7%
		temperature (reading vs. standard)	± 2 °C	N/A
		barometric pressure (reading vs. standard)	± 10 mmHg	N/A
		relative humidity (reading vs. standard)	10%	N/A
		leak check	as per instrument manual	as per instrument manual
Integrated PM	every 6 months or every 30 samples (whichever comes first)	flow rate (set point vs. standard)	4%	7%
		temperature (reading vs. standard)	± 2°C	N/A
		barometric pressure (reading vs. standard)	± 10 mmHg	N/A
		leak check	as per instrument manual	as per instrument manual

1 When tolerance level is exceeded, a calibration is required.

11.2.2 PM Instrument Verification and Calibration Considerations

Calibration adjustments should be performed according to the operation manual. Procedures may also be described in instrument-specific SOP.

Additional considerations for PM instrument verification and calibration adjustments are as follows:

- Traceable standard materials and devices should be equilibrated to operating temperature prior to verification or calibration.
- All calibration and verification standards must be traceable to a NAPS reference standard, and the certification cannot have expired.
- A leak check should be performed **before** all other QC checks, as this will affect instrument flow rate and resulting volume. Leaks in the sampling inlet system exceeding manufacturer specifications invalidate data up to the date of the previous acceptable leak check. During calibration, if the inlet system has been disassembled, a post-leak check must be performed.
- Flow rate is dependent on ambient temperature and pressure, so these checks and calibrations must be made before flow calibrations.

- An “as-found” flow verification should be performed before any instrument maintenance or adjustments (if possible).
- After flow calibration, an “as-left” one-point flow verification should be performed.
- For continuous PM monitors, comparison to a NAPS RM sampler can be used to assess PM concentration data accuracy.
- Station documentation for calibration events should be maintained (Section 11.3).

11.3 Verification and Calibration Documentation

Calibration documentation should be maintained and updated as required. Results should readily be available for review by data validators and auditors.

Documentation should include:

- date of calibration
- instrument location (site ID)
- name of technician performing activity
- instrument serial number or other identification
- verification and calibration data, including both “as-found” and “as-left” conditions
- if the span gas is from a cylinder, cylinder ID, installation date and cylinder pressure should be recorded
- calibration standards traceability and certification documentation (Section 11.5)
- any comments regarding calibration issues or instrument or system servicing that may affect calibration results.

11.4 Integrated VOC, Carbonyls and PAH Samplers

An accurate sample volume and elapsed time is necessary to determine sample concentration. For VOC, carbonyl and PAH samplers, all flow meters and control devices (such as mass flow meters and roots meters) are verified and calibrated in a laboratory that applies NAPS metrology prior to field deployment, and they should be returned for repair or re-calibration as required.

11.5 Traceability of Calibration and Standards

Traceability promotes measurement quality across the NAPS Program and across time. NAPS data should be traceable to one or more of these fundamental units through an unbroken chain of calibrations, each associated with an estimated uncertainty of measurement and therefore contributing to total measurement uncertainty.

Base units of measurement in the International System of Units include:

- mass (kilogram)
- amount of substance (mole)
- length (metre)
- temperature (kelvin)

- current (ampere)
- time (second).

11.5.1 Traceability

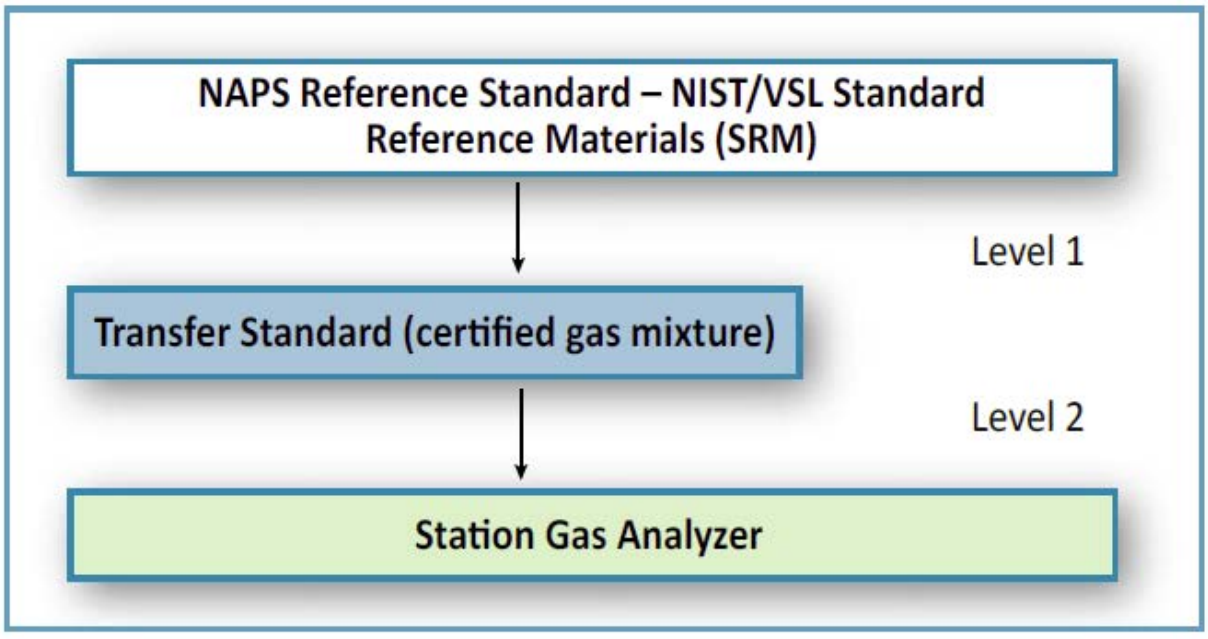
Materials and devices used for calibrating NAPS equipment must be certified for accuracy against NAPS reference standards, which can be recognized primary standards or traceable to one. The following are recognized sources of primary standards:

- The US National Institute of Standards and Technology (NIST): standard reference material (SRM), ozone standard reference photometer (SRP), relative humidity devices.
- The Dutch National Metrology Institute (VSL): SRM.
- The National Research Council Canada's Measurement Science and Standards Research Centre (NRC-MSS): low-flow measurement devices.
- Innovation, Science and Economic Development Canada: high-flow measurement devices.

The NAPS Applied Metrology Laboratory maintains the NAPS Program reference standards. *Networks* may choose to maintain their own SRM.

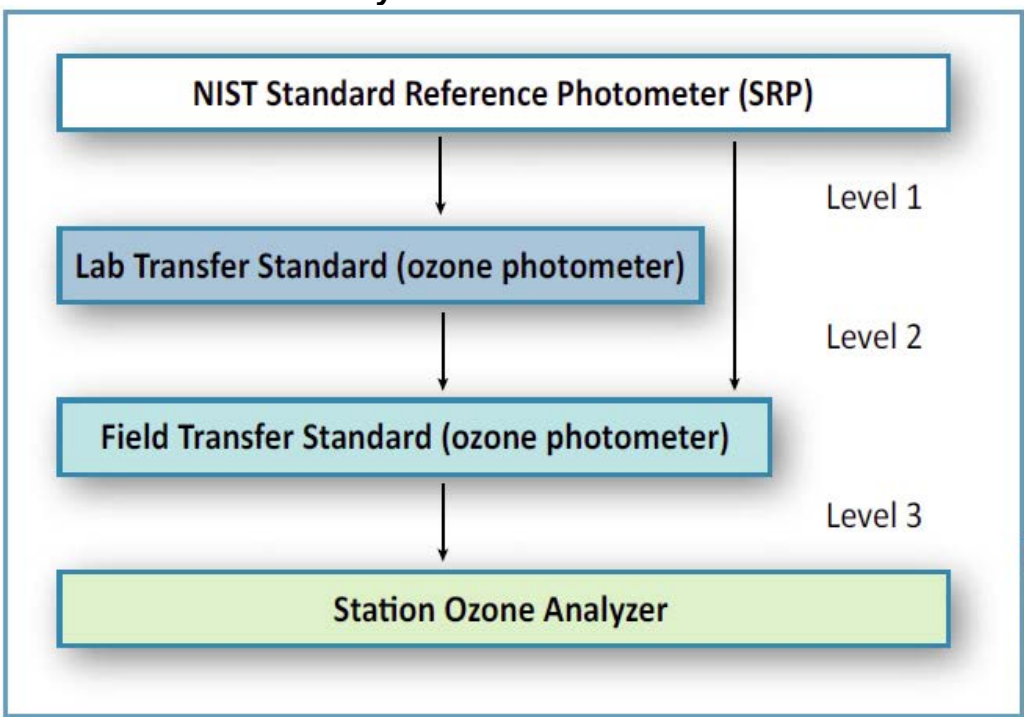
For the calibration of gas analyzers (excluding ozone), a maximum of two levels of traceability from the reference standard is allowed, to ensure an acceptable degree of uncertainty. This is because each level of traceability must account for the dilution of a high-concentration gas, which includes uncertainties associated with the zero air and gas flow measurements plus gas concentration (Figure 11-2).

Figure 11-2 Allowable levels of traceability from reference standard to station gas analyzers (excluding ozone)



For the calibration of ozone analyzers only, three levels of calibrations are allowed to maintain uncertainty to an acceptable degree (Figure 11-3). An additional level is allowed, as only one uncertainty is transferred between levels.

Figure 11-3 Allowable levels between calibrations from the reference standard to station ozone analyzers



11.5.2 Reference and Transfer Standards

Periodic re-certifications of transfer standards against reference standards are required for traceability. Transfer standards and certification services may be provided by the NAPS Applied Metrology Laboratory. The *Network* is responsible for ensuring that equipment certifications have not expired, re-certifications are obtained as necessary and copies of certification documents are maintained (Table 11-7).

Re-certification of gas dilution calibrators and ozone transfer standards is required following any maintenance or repair.

Table 11-7 Transfer standards certification frequency

Transfer standards	Certification frequency
Gas mixtures	obtain as needed, based on cylinder pressure or certification expiry (two years)
Ozone photometers	annually or upon request
Flow measurement devices (dilution mass flow controller, low- and high-volume transfer devices)	annually or upon request
Temperature and pressure measurement devices	upon request
Relative humidity measurement devices	annually or upon request

12.0 DATA COLLECTION AND VALIDATION: CONTINUOUS DATA

Data collection is the process of acquiring data from instruments, while data verification and validation includes techniques used to accept, reject, modify and qualify data. *Networks* participating in the NAPS Program are responsible for collecting and validating continuous data according to the guidelines presented in this section. They should identify the details of the validation and the level achieved in their NQAP.

The data collection and validation requirements listed in this section are intended to ensure that final reported data meet the NAPS Program DQO.

12.1 Data Collection

Data acquisition systems, referred to as *dataloggers*, collect data and other information from the instruments. The central data management system manages communications and data gathering with the station dataloggers, which are stored in a database (Figure12-1). The data management system also offers a set of tools to assess and validate data against defined quality requirements and to analyze, display and report the data. The reporting features of the central system allow for the calculation of air quality indices and the transfer of data to various external clients and to NAPS Data Management.

Dataloggers and software packages are commercially available for collecting, verifying, validating and reporting air quality data.

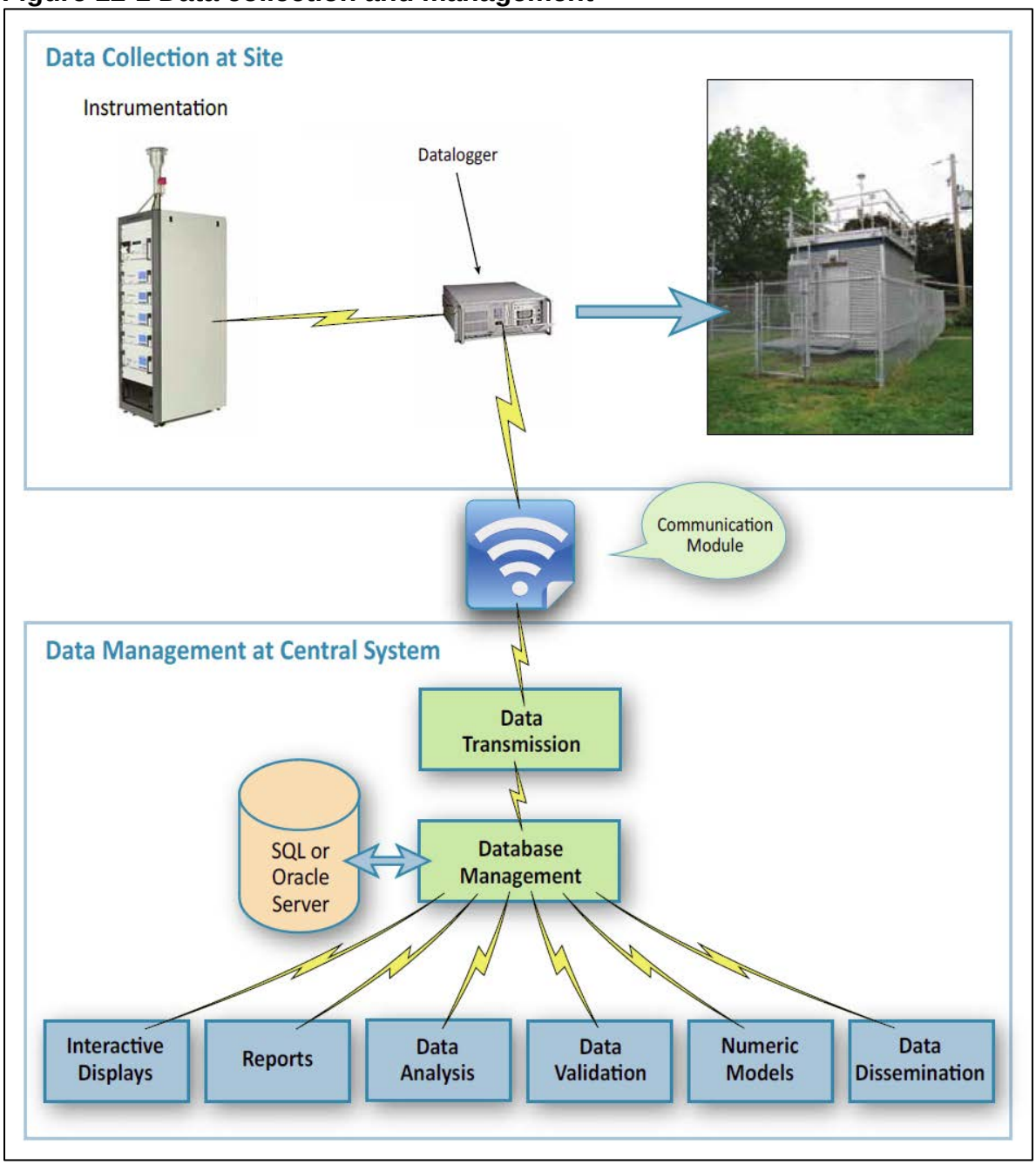
Most continuous instruments include both analog and digital data output options. *Networks* are encouraged to collect data using the digital output. This has the advantage of improving measurement sensitivity, as analog output is subject to electronic noise that affects the signal at low concentrations. Also, QC and metadata information are available only digitally, while analog output only provides data.

The following sections discuss considerations for the NAPS data collection processes.

12.1.1 Sample Rates and Averaging Intervals

Sample rates are the intervals at which a datalogger retrieves a value measured by an instrument, which is subsequently used to generate averaged values. Most modern dataloggers are capable of sample rates of at least once per second and can be configured to calculate and store data intervals such as 1-minute, 5-minute and 1-hour averages.

Figure 12-1 Data collection and management



For NAPS Program reporting purposes, at least 1-hour averaging interval data are required. It is also recommended that 1-minute data be stored to validate the 1-hour data, zero/span checks and multi-point verifications. Datalogger output should be configured to ensure that any averages calculated from shorter time intervals include at least 75% of valid data (e.g., at least 45 1-minute data intervals in a 1-hour average).

It is important to note that the averaging period stored in the datalogger can be either hour-ending or hour-beginning.

Data reported to the NAPS database must be in the **hour-ending format** (e.g., minute data collected between 01:01 and 02:00 are averaged and reported as the 02:00 hour).

In the case of semi-continuous monitors (e.g., PM monitors), discrepancies can occur between the actual sample times and the times recorded by the datalogger. For example, in a beta attenuation monitor, the filter is loaded with PM for a period of time before a measurement is made. The concentration reported at the end of the measurement cycle corresponds to the sample measured during the previous hour. To report data correctly, a time adjustment in the datalogger is necessary to ensure that the time associated with the sample is not offset by an hour.

12.1.2 Datalogger Reading Verification

It is important to ensure that datalogger readings match those of the instruments. Discrepancies in data stored by the datalogger could occur because of calibration issues with the instrument analog-to-digital converters or from time-stamps that do not match between the datalogger and the instrument.

Datalogger readings should be verified against instrument digital readings during commissioning, as well as after any changes to the data collection system. Additional periodic checks (e.g., monthly) are also recommended to ensure that signal drift over time, or any other data collection issues, have not affected the recorded data.

12.2 Data Validation Process

Networks are responsible for ensuring that continuous data are collected and validated following documented procedures in accordance with the *Guidance*.

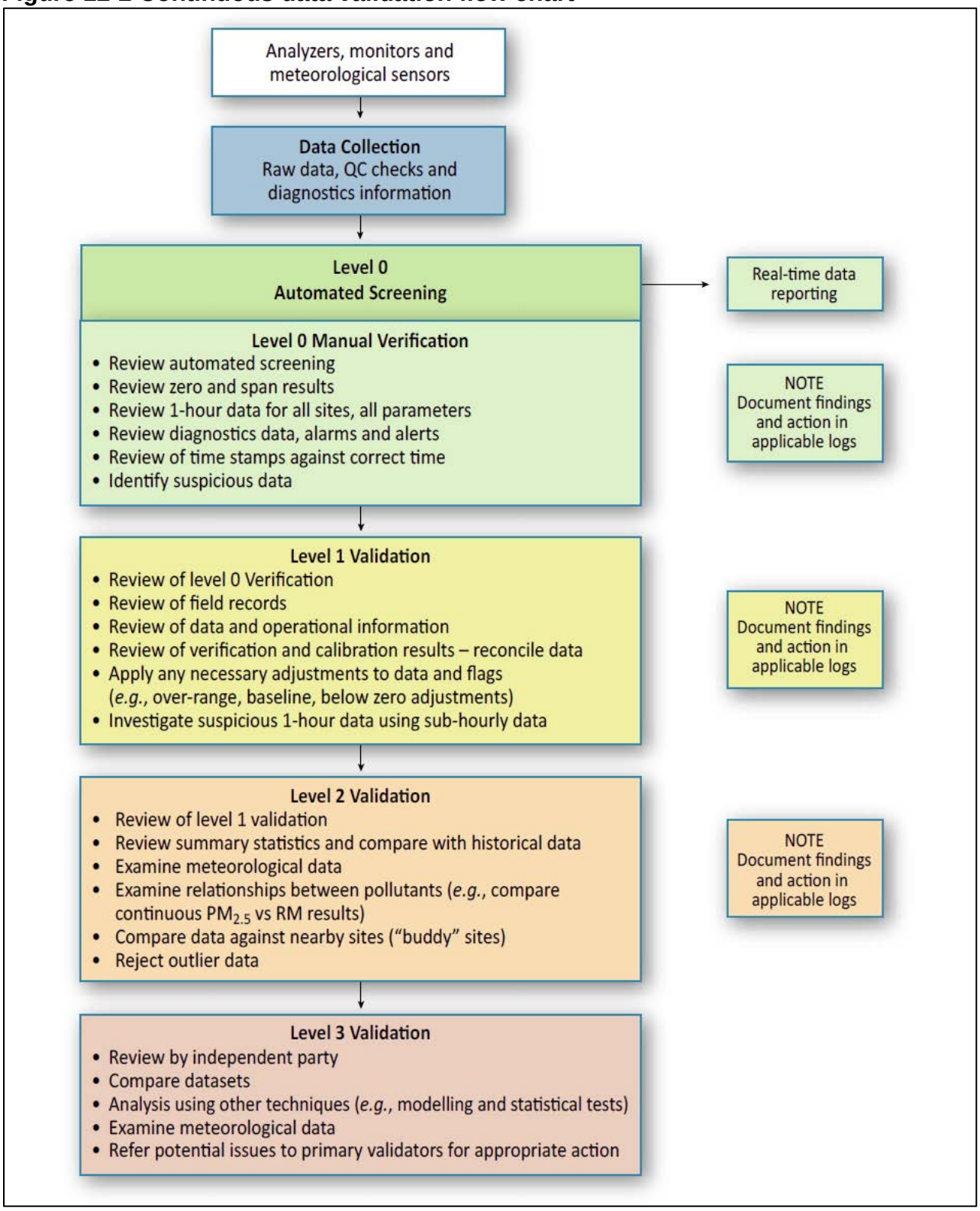
Data verification and validation is a stepwise process that involves increasingly detailed analysis of the data (Figure 12-2). *Networks* should validate data to at least Level 0. The level is determined by their reporting application and available resources.

The verification and validation are performed at a set frequency, and the data are reviewed over specified periods (Table 12-1).

Table 12-1 Data verification and validation review

Level	Frequency	Period of data reviewed
Level 0 verification	1–7 days	1–7 days
Level 1 validation	following multi-point verification or calibration	1–6 months
Level 2 validation	6–12 months	6–12 months
Level 3 validation	annual	1 or more years

Figure 12-2 Continuous data validation flow chart



12.3 Data Flags and Validation Logs

Individual data points are identified as valid or invalid using various flags. Data flags are stored in databases using determined codes.

As data are reviewed, validation logs should be used to provide a record of the validation process by summarizing and justifying the decisions to **validate**, **invalidate** or **qualify** data. During the automated screening process, flags are applied and data can be changed automatically based upon set rules. Automated changes should be reviewed during the manual verification and validation process. Data adjustment logs and flag modification logs create an audit trail for all edited data, thereby saving time and effort if, at a later date, questions arise regarding specific data. Most central data systems are able to store this information in their database.

Validation log entries should include all the following information:

- name of person who performed the validation
- when the validation was completed
- parameter(s) reviewed
- identification of data adjustments and flag modifications
- brief description of any actions performed to address instrument and data issues
- identification of anomalous data or outliers
- justification for changes made.

Data available from the CWAQD are reported as valid (represented by the value) or invalid (represented with the code -9999), with no attached flags. However, it is recommended that monitoring *Networks* maintain descriptive data flags for internal data review, audit and archival purposes (Section 6.0).

12.4 Level 0 Verification

The process of Level 0 verification involves both automated and manual screening and flagging. Most dataloggers can automatically flag values based on instrument status and data completeness. They are also able to log instrument operational information, which can be an efficient and effective way to identify and mitigate instrument issues leading to data quality problems.

Central data systems are able to apply screening criteria (or rules) to change and flag data. These criteria can be optimized over time to reflect specific site conditions.

Automated screening includes:

- identifying periods of missing data (e.g., communication errors and power failures)
- comparing data to upper and lower limits (e.g., physical limits, such as instrument thresholds, or limits established based on experience or historical data)
- comparing to rate-of-change thresholds that indicate data has either changed too rapidly or not changed at all.

In addition to automated screening, frequent manual review of data (Table 12-1) is recommended.

Manual review could result in a reversal of an automated screening decision or identify potential issues that were not flagged.

Manual verification includes:

- reviewing automated screening flags, instrument operational information and alarms
- reviewing 1-hour data for all parameters using tabular and graphical displays
- reviewing 1-minute data for completeness and instrument malfunctions
- verifying that zero and span check results are within specifications
- verifying (at regular intervals) that time-stamps throughout the collection process agree with the correct time.

Data identified as suspect during Level 0 verification should be noted. If corrective action is warranted, the cause of the problem should be identified and assigned to appropriate personnel as soon as possible to avoid data loss. Corrective actions may involve remote systems adjustments, troubleshooting, on-site repair or removal of instruments for repair. All issues and corrective actions must be documented.

12.5 Level 1 Validation

Level 1 data validation begins with a review of all data and information from Level 0 and includes both 1-hour and 1-minute data. Next, reviewers evaluate the issues identified and consult available documentation (e.g., electronic or paper logbooks), after which appropriate flags and adjustments are applied to the data. This level of validation is performed at regular intervals (Table 12-1) and after any instrument malfunction, repair or adjustment (e.g., calibration) that may affect data validity.

The following sections describe Level 1 validation activities, in the recommended order.

12.5.1 Review of Field Records

Along with the documentation reviewed for Level 0 Verification, additional documentation (e.g., station and instrument maintenance logs) should be reviewed and evaluated for data validation.

12.5.2 Review of Operational and Instrument Parameters

Level 1 Validation should include consideration of any instrument-specific operational limitations that may invalidate data. These specifications are generally listed in SOP or manufacturer manuals. Examples include leak checks and environmental temperature controls.

12.5.3 Review of Multi-point Verification Results

Multi-point verifications (Section 11.0) are an important part of the data validation process. These

verifications ensure that measurement uncertainty remains within established acceptance criteria. Following multi-point verification, reviewers must reconcile zero and span checks with multi-point verification results to determine whether any data are to be invalidated (flags changed) or to apply corrections based on the multi-point verification results.

If the multi-point verification results exceed acceptance criteria, data should be invalidated to the previous point in time when measurements were valid, unless data correction can be justified (Table 11-4a and Table 11-4b).

To avoid potential data loss due to violation of multi-point acceptance criteria, corrective action (calibration or instrument maintenance) should be initiated when QC check tolerance limits are exceeded (Table 11-3).

12.5.4 Over-range Values

In some cases, an uncharacteristically high value may be recorded at a site. For example, a wildfire may cause an extreme value that is outside the operating range of the instrument. In these cases, it is desirable to retain the value and change the flag to indicate that an exceptional event occurred. Data validation logs should indicate an over-range value and note that it likely underestimates the actual concentration.

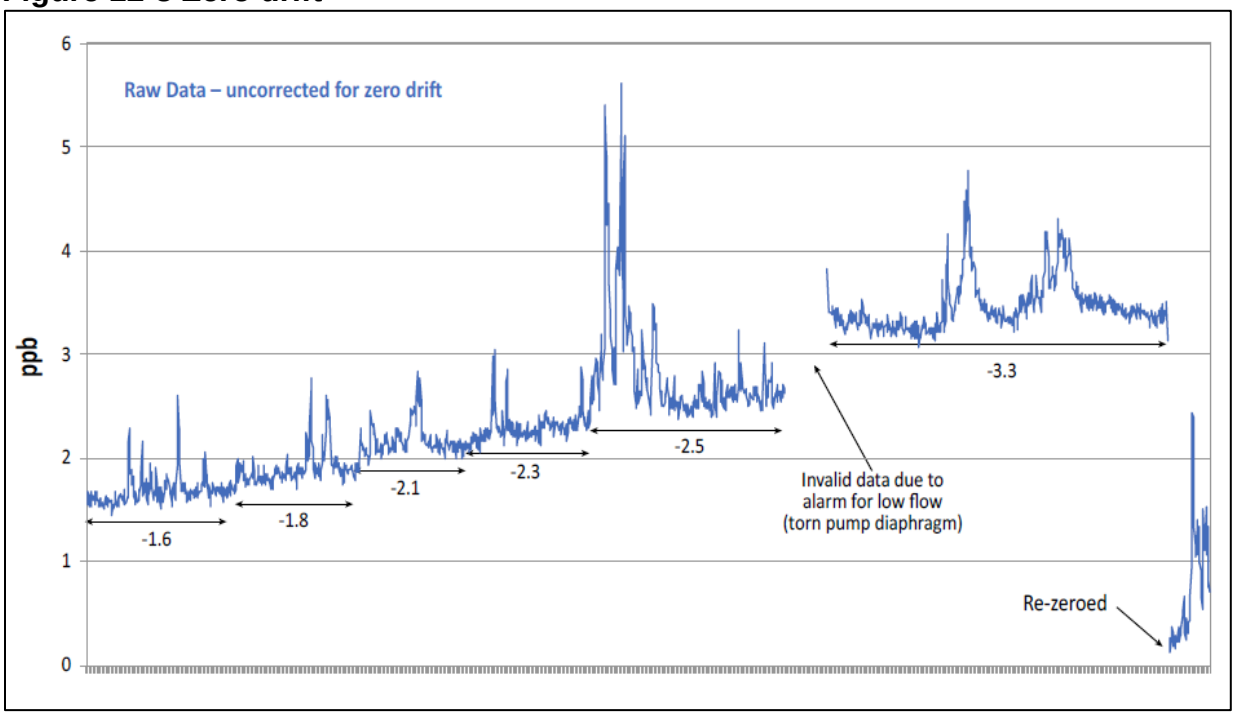
12.5.5 Review of Automatic Zero Adjustments

Several analyzers can perform zero adjustments based on automated zero checks. If automated zero adjustments are made, it is important that they be reviewed because zero-check results could become unreliable due to equipment failure or other issues.

12.5.6 Baseline Adjustments

Analyzer zero drift is common in many analyzers and may appear when the daily minimum concentration (referred to as the *baseline concentration*) increases or decreases over a period of days or weeks. Zero drift can be confirmed by reviewing zero checks using graphs and tables (Figure 12-3). The zero point of the multi-point verification will indicate if the cause of the drift is the analyzer or depletion of the scrubber used for zero checks.

Figure 12-3 Zero drift



Baseline drift correction is performed when deemed necessary or when tolerance levels (Table 11-4a) are exceeded (for readers' convenience, the table is shown again as Table 12-2).

Generally, data affected by analyzer drift can be corrected by adjusting the data using the multi-point verification zero-point result. Because drift is not usually constant over time, all zero-check results should be evaluated to determine the appropriate correction(s) that should be applied.

Excessive drift correction will cause significant uncertainty of the hourly data and possible invalidation, though longer-term averages may be reasonably accurate.

Table 12-2 Multi-point verification: Zero-point tolerance levels for gas analyzers

Activity	Instrument	Tolerance Level[1]
Zero point	CO	0.08 ppm
	NOX	1.0 ppb
	O3	1.0 ppb
	SO2	0.5 ppb

1 When exceeded, instrument zero adjustment is required.
Note: Frequent adjustment of the instrument should not be necessary and can lead to increased data uncertainty, which usually indicates instrument issues that need to be addressed.

Rapid or excessive change in zero is not considered drift and may signal an analyzer malfunction, which could result in invalid data.

Although drifts in span results may be noted, **adjustments based on span results are not recommended**. Upscale adjustments should be limited to analyzer calibration against traceable reference standards.

12.5.7 Below Zero Adjustments

Zero noise is defined as a measure of the deviations from zero while sampling constant zero air and may result in an instrument reading negative values.

For consistency, 1-hour instrument values that are determined to be valid, even if negative, should be adjusted to zero (e.g., a valid −1 ppb O_3 should be reported as 0 ppb O_3).

It is important to distinguish normal instrument noise (refer to instrument manual for specifications) from instrument malfunction, as data affected by the latter **should be invalidated**.

Note: Adjustments of negative values to zero should be applied **after** baseline adjustments are performed and **only** applied to 1-hour averages (rather than sub-hourly averages).

Table 12-3 lists the applicable zero adjustment criteria by parameter.

Table 12-3 Zero adjustment criteria

Averaging Interval	Parameters	Criteria
Sub-hourly	all	All negative values determined valid shall remain negative prior to aggregation into hourly averages.
1-hour	$PM_{2.5}$ ($\mu g/m^3$)	$PM_{2.5}$ value ≥−3 and <0 are adjusted to 0. $PM_{2.5}$ value <−3 are flagged as invalid.
	all gases (ppb)[1]	Below-zero values determined valid are adjusted to zero (values <−3 should be further investigated prior to setting to zero).

1 ppm for CO

12.5.8 Derived Parameter Relationship of $NO/NO_2/NO_X$

During data validation, it is important to ensure that expected relationships are preserved. NO_2 is not measured directly when using a chemiluminescent analyzer, but rather derived from the difference in measured concentrations of NO_X and NO in the sample. If adjustments are applied to NO, NO_2 or NO_X (e.g., baseline or zero), it will be necessary to apply adjustments to the other parameters to preserve the relationship where $NO + NO_2 = NO_X$.

For analyzers that use a single reaction cell that switches from NO to NO_X mode (as they are not measured simultaneously), a ±2 ppb difference is allowed for the 1-hour average of the NO_X value compared to the sum of NO and NO_2 values.

As a final note, any technical system audit performed by a third party that identified issues must

be addressed prior to finalizing Level 1 validation.

12.6 Level 2 Validation

Level 2 data validation begins with a review of all data and information to confirm that issues identified during Level 1 have been addressed. The validation process continues by broadening the analysis to consider additional information obtained from other related data.

Level 2 validation should be performed every 6 to 12 months, reviewing 6 to 12 months of data and using hourly averaged data.

Two primary types of data are used for this level of validation: dependent data, which are measured from the same site, and independent data, which are obtained from similar or nearby sites (Figure 12-4).

The next step is to generate summaries in various statistical forms and time-series plots of dependent data. Plotting data can show relationships that are difficult to detect when reviewing large amounts of tabular data. Dependent data are used to verify that the data follow expected behaviour and relationships as well as to screen for outliers (e.g., unusually high or low values that are not expected at the given site) using defined criteria.

Independent data can be used as an additional check to validate suspect data and assess regional or similar site-type behaviour. For example, large pollution events such as wildfires could be identified by examining data on a large regional scale. Data points identified as outliers in Level 1 can be determined valid by citing similar spikes or dips during the same approximate time period at nearby locations.

Meteorological data (e.g., wind and pollution roses, back trajectories) can also be reviewed to identify any suspect data.

Some examples of data relationships are listed below:

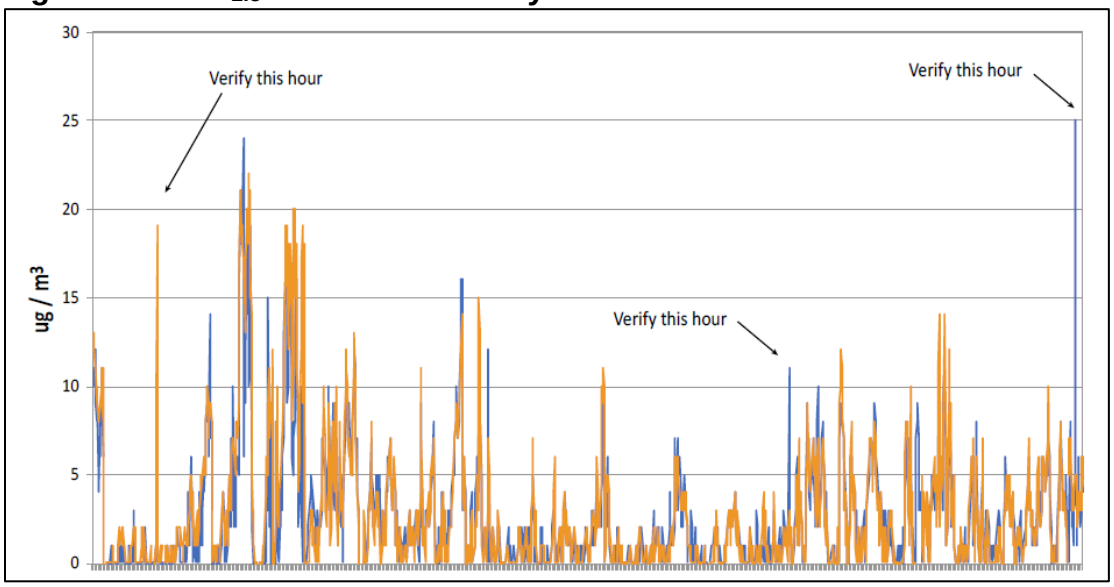
- O_3 and NO_2 are often inversely correlated. NO reacts quickly with O_3, which can result in low O_3 near NO sources (e.g., in urban areas impacted by traffic sources).
- O_3 is formed through photochemical processes in the atmosphere; concentrations often increase with higher UV and temperature (e.g., diurnal highs towards the latter part of the afternoon or day, and seasonal highs during spring and summer).
- Pollutant events are often confirmed by examining multiple parameters that may exhibit similar behaviour and extend over a wide area.
- Pollutant levels might change abruptly if meteorological conditions change (e.g., weather fronts, storms, wind direction and speed).
- Pollutant levels surrounding the monitoring site (e.g., spikes in SO_2) would be expected only from nearby sources.

Further investigation of suspect data may determine instrument malfunction or other equipment issues at the site affecting data.

Suspect data and outliers should nevertheless be considered valid unless there is sufficient

evidence to invalidate. Justification for decisions regarding validity of suspect data and outliers should be documented in data validation logs.

Figure 12-4 $PM_{2.5}$ data of two buddy sites



12.7 Level 3 Validation

Level 3 validation is defined as a review of validated data by someone independent of both field operations and the previous data validation process. The intent of this level of review is not to repeat previous validation tasks, but rather to ensure that data have undergone an independent review.

The independent reviewer should have extensive knowledge of air pollution and meteorology and be familiar with the sites to evaluate data based on expected or historical behaviour.

Data reviews performed on an annual basis can identify issues that are not evident on a monthly basis but become apparent when data are viewed over a longer time period. The reviews should include at least one year of data, along with comparisons to other existing data sets. Data identified as suspect should be brought to the attention of the previous data validators for investigation, modification or justification.

12.8 Post Validation

Regardless of what level of validation is performed, all data should be reviewed by the *Network* as a whole at the end of each calendar year. This review can include an inspection of annual plots and summary statistics (including comparisons to historical mean, maximum and minimum values). If errors in the data are suspected or discovered, an investigation should be conducted and data should be corrected as necessary.

13.0 DATA COLLECTION AND VALIDATION: INTEGRATED DATA

For integrated methods, samples are collected in the field and analyzed at the NAPS laboratory in Ottawa using ISO 17025–accredited analytical methods. Validation of these data is performed by field, laboratory and NAPS data management personnel and requires review of information generated at every step of the process: sample media preparation, shipping, sampling in the field, reception and analysis in the laboratory.

Networks participating in the NAPS Program are responsible for sample handling and sampler calibration and maintenance.

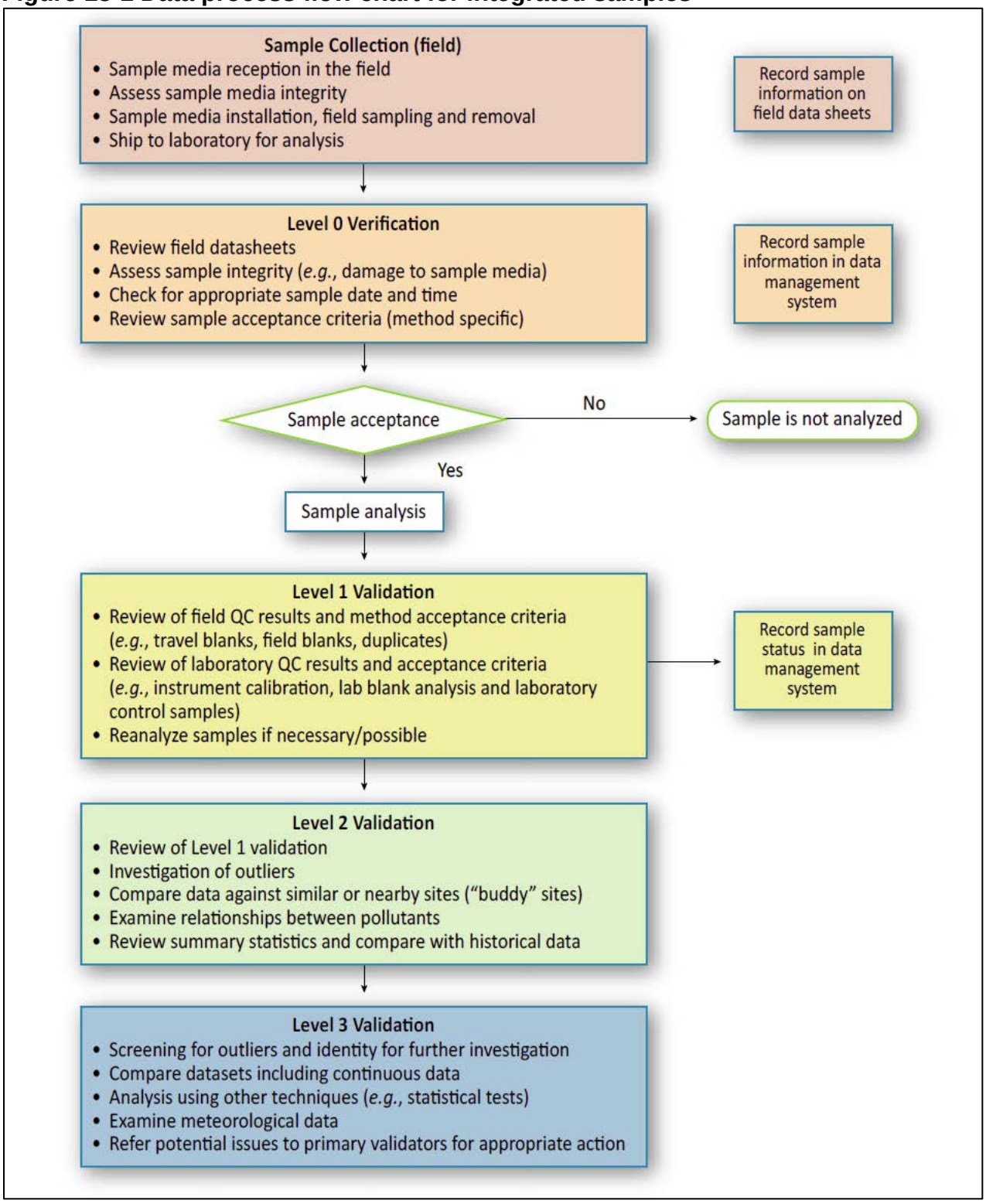
The data collection and validation requirements and recommendations are intended to ensure that final reported data meet the NAPS Program DQO. Additional detailed procedures are documented in specific field and lab SOP and methods.

Data verification and validation for integrated samples is a stepwise process that involves increasingly detailed analysis of the data (Figure 13-1).

Table 13-1 Data verification and validation review

Level	Frequency	Reviewed by
Sample collection	as scheduled	*Network*
Level 0 verification	upon receipt of sample from field	sample-handling lab
Level 1 validation	after analytical measurement	sample analysis laboratory
Level 2 validation	Less than 1 year	sample analysis laboratory and NAPS data management
Level 3 validation	annually or less often	NAPS data management

Figure 13-1 Data process flow chart for integrated samples



13.1 Integrated Sample Metadata

Field metadata specific to integrated samples is important to assess sampler performance and the conditions under which samples were collected. Metadata are also generated throughout the laboratory analysis. Defined qualifier codes are assigned to samples and analytical results as warranted.

13.2 Sample Collection

Collecting integrated samples involves:

- sample media (e.g., filters, cartridges and canisters) preparation in the laboratory
- transportation to the site
- set-up of the samplers and operation on the appropriate date and period
- collection of samples from sites
- transportation to the laboratory.

Sample collection procedures must ensure adequate identification, tracking and sample integrity.

The NAPS laboratory provides datasheets along with the sample media to field personnel. The sample media is labelled with identification information that must be recorded on the associated field datasheet.

The following information must be recorded on field datasheets:

- site name and ID number
- sample ID
- sampler type (model, serial number)
- sample type (e.g., routine, duplicate, field blank, travel blank)
- date and time of sampling (both start and end)
- instrument operational parameters (e.g., flow, volume, pressure)
- environmental parameters (e.g., ambient pressure and temperature).

Sample qualifiers recorded at the time of collection can be used by lab personnel to aid in the verification and subsequent validation of samples.

Examples of sample qualifiers recorded on field datasheets include:

- sampling equipment status (e.g., warnings, malfunctions)
- sampling media not received
- damaged sampling media
- sample duration out of range
- sampling system failed leak or flow check
- environmental events (e.g., fires, construction).

Additional comments related to sample integrity or other sampling conditions (such as unusual weather) should also be noted on the field datasheets in the appropriate comment section.

It is important that field datasheets are **legible** and **complete** and that samples are properly

packaged and returned to the lab as soon as possible. Certain sampling media have limited shelf life and should be used according to the SOP. There may also be sample-specific handling and shipping procedures to preserve sample integrity.

13.3 Level 0 Verification

Level 0 verification is related to sample integrity upon receipt from the field and prior to analysis. All samples collected in the field are shipped to the laboratory along with field datasheets. Upon receipt, samples and paperwork are inspected to verify the following:

- **Contamination or damage**: Visually assess for damage or potential sample contamination, and review issues noted on the field datasheets and other issues that may have arisen during shipment to the lab.
- **Documentation completeness**: Ensure field datasheets and any other required sample documentation is present, legible and complete. Follow-up with the *Network* may be necessary if questions arise or additional information is required.
- **Canister leak checks**: Leak checks are performed in the field, but in the case of VOC canisters, leakage can occur during transit. As a result, canister pressure should be measured upon receipt and compared to the final sample pressure recorded in the field. Acceptance criteria should consider the sampling location, as the altitude at which the sample is collected can differ from the lab, resulting in differences in measured pressure.
- **Flow rate and volume**: Ensure flow and volume information recorded on the field datasheet and from instrument readings are within acceptance criteria.
- **Sample date and time**: Ensure sample was collected on the scheduled date, for the specified period of time. All times should be in local standard time, and sample dates should coincide with the applicable NAPS sampling schedule of once every three days or once every six days.
- **Sample shipment and holding time**: Ensure sampling holding time criteria, as listed in method specific SOP, have not been exceeded to help ensure the integrity of the sample.

After a review of field datasheets and other recorded information, samples are assigned qualifier codes prior to analysis. Certain codes (e.g., damaged or unexposed sample media) will result in a sample being invalidated and archived with no further analysis performed.

13.4 Level 1 Validation

Following sample verification, valid samples undergo gravimetric and/or chemical analysis. Subsequently, the laboratory performs Level 1 validation, which generates the analytical results and includes the following:

- **Review of field QC results**: Field quality controls include travel and field blanks plus duplicates that are checks to evaluate sample integrity throughout the sample collection process.
- **Review of laboratory QC results**: Laboratory QC checks ensure that equipment is calibrated and maintained and that methods are followed. These checks include analysis of lab blanks, instrument calibration, and verification of reagents and calibration

standards. Laboratory analysis conditions, such as temperature and humidity constraints, are important for certain methods. Detailed procedures and acceptable criteria are specified in lab methods and SOP.

Suspect analytical results are investigated and may require further review of field datasheets and QC checks. In some cases, reanalysis may be required.

13.5 Level 2 Validation

Level 2 validation is performed by the NAPS laboratory that generated the results and the NAPS data management, beginning with the review of Level 1 data.

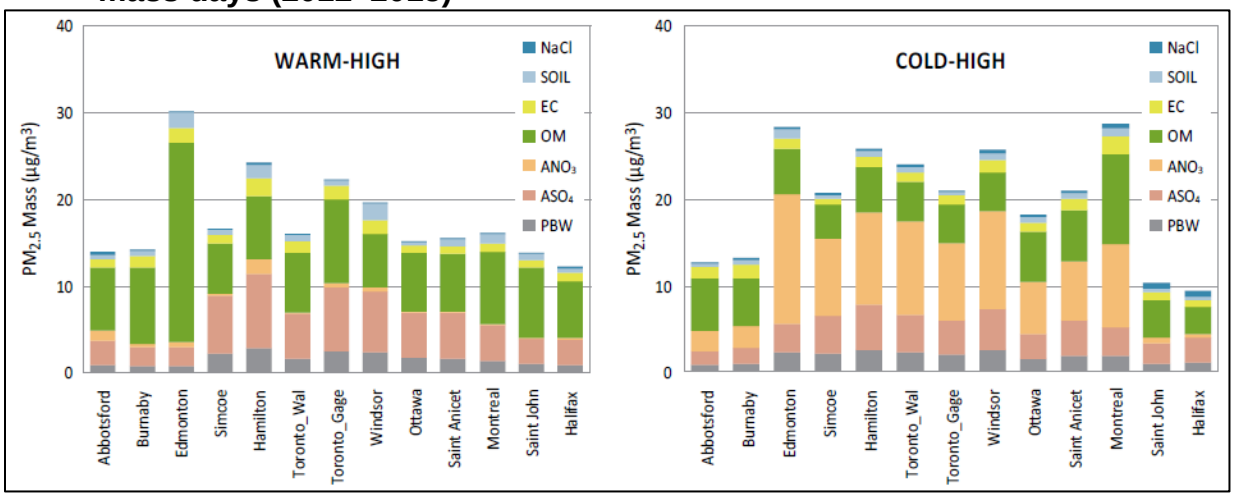
Level 2 validation is to:

- check for outliers
- examine relationships between pollutants
- review summary statistics and compare with historical data.

Examples of Level 2 validation activities include:

- **Negative mass:** Gravimetric laboratory procedures include equilibration of filters at controlled conditions of temperature and humidity prior to each weighing, regular use of reference weights, and filter re-weighing. A negative mass may indicate issues with filter weighing either before or after the sample is collected.
- **Identification of outliers:** Data can be reviewed on time-series plots or sorted and screened to identify suspect data that are unusually high or low for a given pollutant at a site.
- **Expected pollutant relationships:** Chemical species may exhibit consistent relationships with other species. Certain species are expected at higher concentrations than related species from the same sample (e.g., crustal elements such as iron are expected to be higher in the coarse fraction than in the fine fraction of ED-XRF samples).
- **Complementary measurement checks:** In some cases, more than one measurement of a species is performed on a sample (e.g., metals analyzed by ICP-MS and ED-XRF). Measurements that do not agree are investigated.
- **Reconstructed PM mass balance checks:** Reconstructed mass from major chemical components of a sample is expected to be close to the gravimetric mass measured. This involves assumptions in mass calculations including particle-bound water. Reconstructed masses that do not agree with measured mass are investigated (Figure 13-2).
- **Pollutant events:** These events are often confirmed by examining multiple species that may exhibit similar behaviour and extend over a wide area.
- **Source-influenced pollutants:** Pollutant sources surrounding the monitoring site (e.g., spikes in VOC would be expected only from nearby sources).
- **Meteorological parameters:** Meteorological parameters may impact pollutant levels (e.g., stagnation events or inversions, temperature, wind direction and speed).

Figure 13-2 Reconstructed $PM_{2.5}$ mass by major component for the 10 highest mass days (2012–2015)



During Level 2 validation, data that do not appear representative of the time or place monitored are investigated. Therefore, when necessary, samples may be reanalyzed in an attempt to rule out issues with the original analysis.

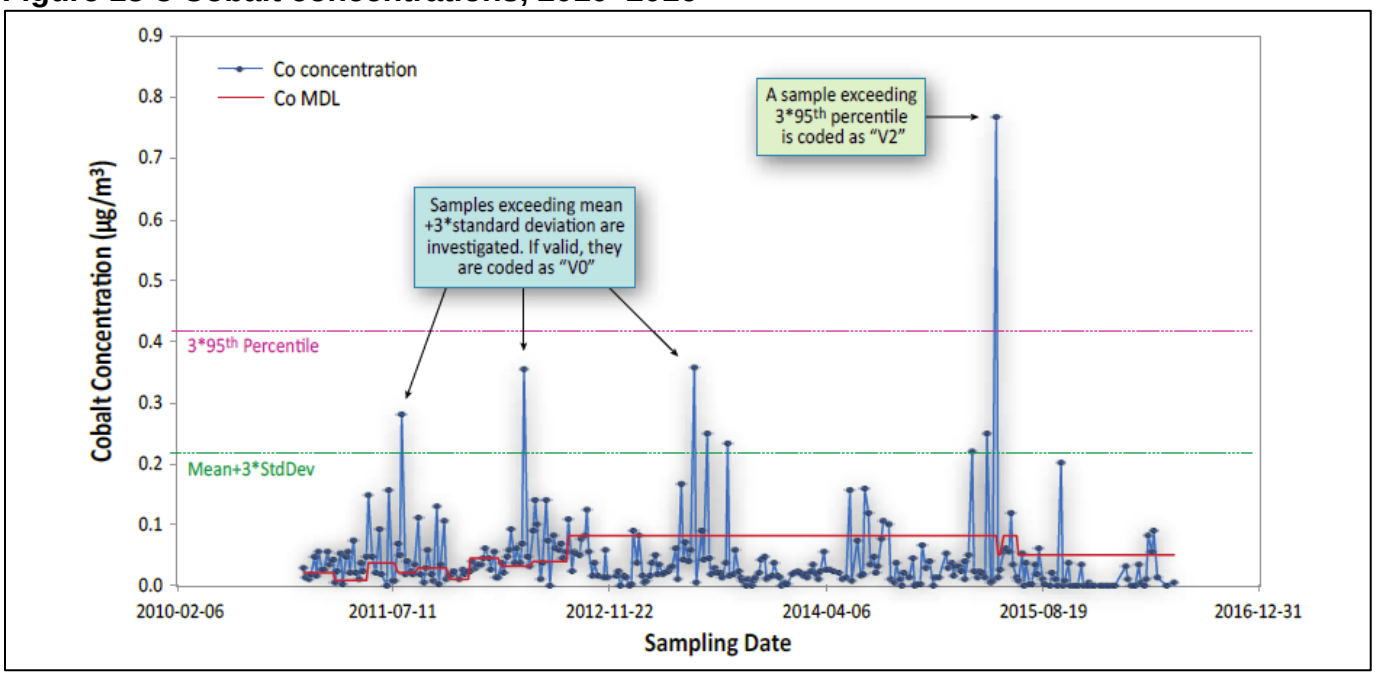
Suspect data or outliers should nevertheless be considered **valid** unless there is sufficient evidence to **invalidate**. Justification for decisions regarding validity of suspect data or outliers should be documented in data validation logs.

13.6 Level 3 Validation

Level 3 validation is defined as a review of validated data by someone independent of both field operations and the laboratory analysis process. The intent of this level of review is not to repeat previous validation tasks, but rather to ensure that data have undergone an independent review.

The independent reviewer should have extensive knowledge of air pollution and meteorology and be familiar with the sites to evaluate data based on expected or historical behaviour.

Figure 13-3 Cobalt concentrations, 2010–2016



Data reviews performed on a regular basis should include data from at least a one-year period, along with comparisons to other existing data sets.

Level 3 validation includes:

- screening for outliers and flagging for further investigation (Figure 13-3)
- comparing data sets, including continuous data
- comparing data against similar or nearby sites ("buddy" sites)
- analyzing using other techniques (e.g., statistical tests)
- examining meteorological data.

Data identified as suspect should be brought to the attention of the data originators for investigation, modification or justification.

13.7 Post Validation

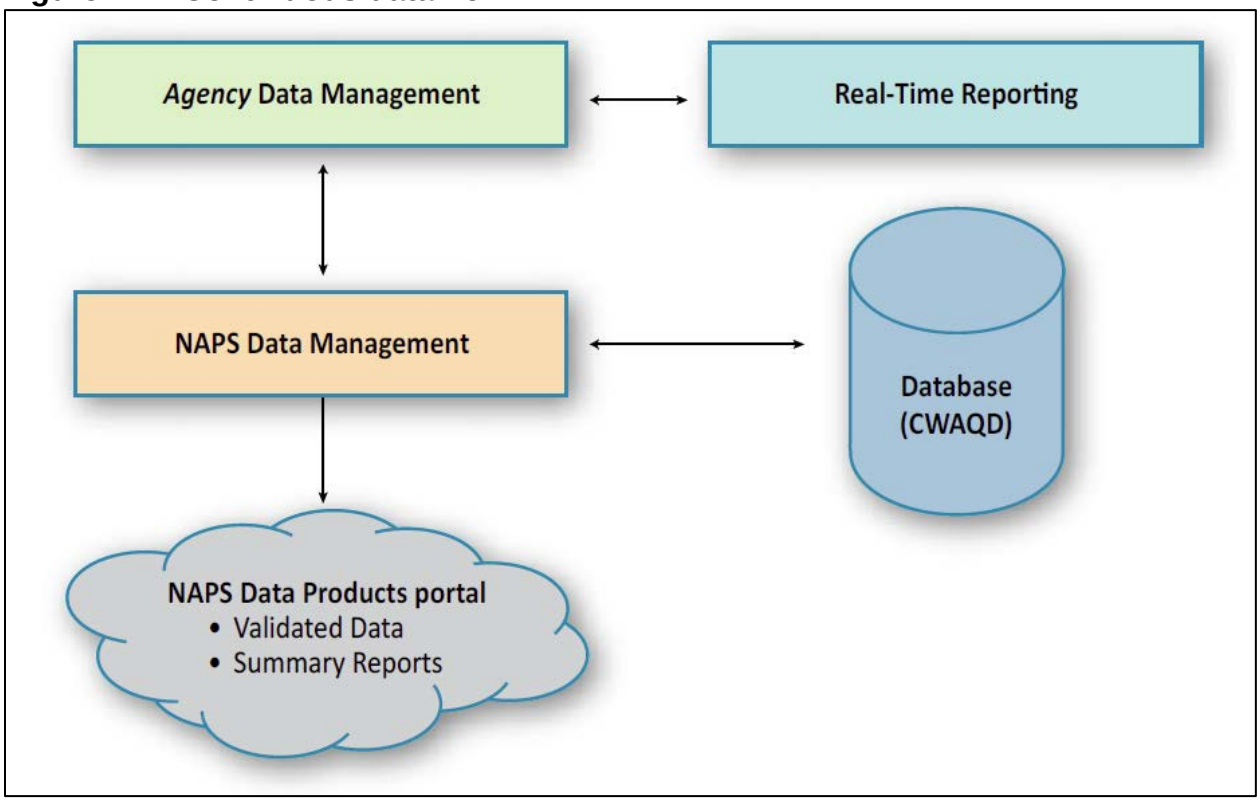
Data are posted on a quarterly basis to the public NAPS Data Products portal. *Networks* should review posted data and report issues or inconsistencies to NAPS Data Management. Other data users may find issues which should also be brought to the attention of NAPS Data Management. If changes are made to the data, updates will be posted to the portal and reflected in the "change log" documentation.

14.0 REPORTING REQUIREMENTS

14.1 Continuous Data Reporting

For continuous data, *Networks* are responsible for reporting quality-assured data, as specified in this *Guidance*, to NAPS Data Management for archiving in the CWAQD. NAPS Data Management coordinates continuous data dissemination to the NAPS Data Products portal (Figure 14-1).

Figure 14-1 Continuous data flow



14.1.1 Real-time Reporting of Continuous Data

Networks may make data available to the public in "near real-time." These data have typically undergone only the automated screening portion of data verification and should be made available with disclaimers indicating that data are not fully validated and reviewed.

Networks participate in national and international real-time reporting initiatives such as:

- **ECCC's AQHI**: The AQHI is a multi-pollutant index based on the combined concentrations of $PM_{2.5}$, O_3 and NO_2. This index was developed through a federal program coordinated jointly by ECCC and Health Canada and is designed to provide the public with health-risk information (e.g., low, moderate, high or very high health risk). ECCC, in partnership with a number of provinces and municipalities, reports AQHI

indices on their websites and nationwide through the Government of Canada website.

- **Info-Smog**: ECCC has been producing daily air quality forecasts and timely smog warnings for Québec. The Info-Smog Program is available for 95% of Québec's population. The index reports on three categories of air quality: good, fair and poor. When air pollutant concentrations are likely to reach or actually do reach levels harmful to the health and environment, ECCC issues a smog warning for the affected areas. The warning is accompanied by advice on protecting health and improving local air quality.
- **AirNow**: *Networks* can upload real-time data to the US EPA–sponsored AirNow website. The AirNow program provides regional summaries and maps with air quality indices and forecasts using data from participating sites across Canada, the United States and several countries worldwide.

14.1.2 Continuous Data Reporting to the CWAQD

The CWAQD is the national archive for continuous air pollutants (CO, $NO/NO_2/NO_X$, O_3, $PM_{2.5}$, PM_{10} and SO_2). *Networks* transfer their validated data to NAPS Data Management. Data transfer usually occurs annually (six months after calendar year-end) by File Transfer Protocol (FTP) or e-mail (for small data sets). Acceptable file formats are flat files (.xlsx or .csv), DR DAS custom and XML formats.

Final validated data should be submitted in hour-ending average format (e.g., minute data collected between 01:01 and 02:00 are averaged and reported as the 02:00 hour), in local standard time, **with no adjustment for daylight saving time**. All hourly data should be reported to at least 5 decimal places.

Invalid and missing data are noted with a flag and/or a -9999 value as defined in the transfer method SOP.

Data in the CWAQD should always reflect the most current validated data. Changes to data should be resubmitted to NAPS Data Management by the *Network* and documented by both.

14.1.3 Posting Continuous Data to the NAPS Data Portal

Data received from *Networks*, from the previous calendar year, are prepared by NAPS Data Management and posted to the NAPS data portal in the form of hourly data and statistical summary files. Preliminary data are posted after *Networks*' submissions are compiled (late summer). A final version is posted after further review (by the end of the calendar year).

Detailed information on the format and the use of these files is available on the NAPS Data portal home page.

Data summaries are also reported for various averaging periods and statistical forms, including: 1-hour, 8-hour, 24-hour, daily maximum 1-hour, daily maximum 8-hour and daily means. 8-hour means are running 8-hour averages for each hour of the year, with the result reported for the end hour (Figure 14-2). Daily maximum 8-hour values are the maximum 8-hour mean values for each day of the year. 24-hour means are running 24-hour averages for each hour of the year, with the result reported for the end hour. Daily means are based on the average hourly concentrations recorded from 01 to 24 hours.

Figure 14-2 Calculation of Daily Maximum 8-hour Ozone

Date	Hour	1 h ppb	8 h ppb	DMax 8 h
03/25	17:00	44		
	18:00	45		
	19:00	44		
	20:00	42		
	21:00	39		
	22:00	33		
	23:00	20		
	24:00	14		
03/26	01:00	11	31.0	45.6
	02:00	11	26.8	
	03:00	15	23.1	
	04:00	13	19.5	
	05:00	19	17.0	
	06:00	21	15.5	
	07:00	19	15.4	
	08:00	11	15.0	
	09:00	30	17.4	
	10:00	36	20.5	
	11:00	39	23.5	
	12:00	42	27.1	
	13:00	44	30.3	
	14:00	46	33.4	
	15:00	47	36.9	
	16:00	47	41.4	
	17:00	47	43.5	
	18:00	46	44.8	
	19:00	46	45.6	
	20:00	42	45.6	
	21:00	39	45.0	
	22:00	38	44.0	
	23:00	38	42.9	
	24:00	35	41.4	

Table 14-1 Required significant figures and units by parameter

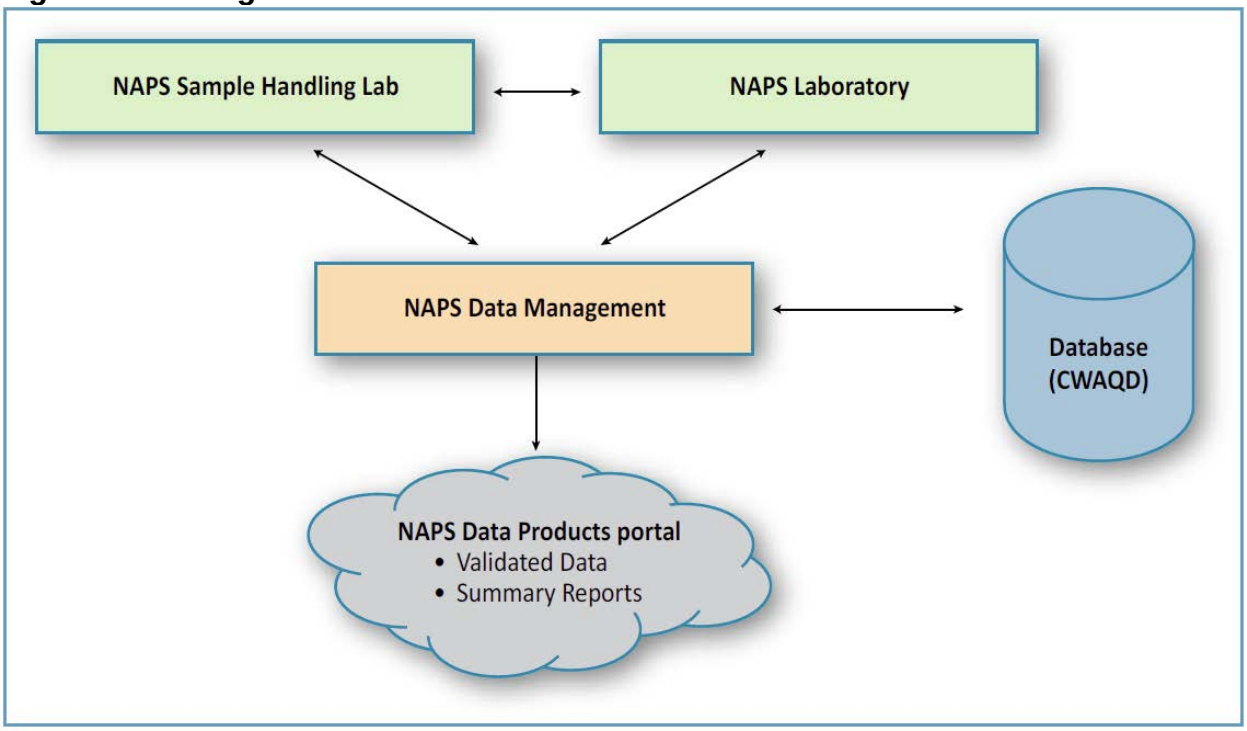
Parameter	Averaging time	Minimum significant figures and units[1]
CO	1 hour	0.01 ppm
$NO/NO_2/NO_X$	1 hour	1 ppb
O_3	1 hour	1 ppb
SO_2	1 hour	0.1 ppb
$PM_{2.5}$	1 hour	1 µg/m^3 at actual temperature and pressure

1 Rounding convention: for digits ≥ 5, round up to the nearest required significant figure; for digits < 5, round down to the nearest required significant figure (e.g., 4.5 rounds to 5 and 4.4 rounds to 4).

14.2 Integrated Data Reporting

The NAPS Data Management coordinates integrated data dissemination to the NAPS Data portal (Figure 14-3).

Figure 14-3 Integrated data flow



14.2.1 Integrated Data Reporting to the CWAQD

The NAPS Laboratory reports all sample information, analysis results and qualifier codes to NAPS Data Management. They are responsible for storing all sample information in the CWAQD as well as reporting validated data to the public.

The NAPS Laboratory also reports sample information (metadata) to NAPS Data Management. These reports contain:

- sample site ID
- sampling date, time and volume
- information on the sampling media and equipment
- all field and sampling lab information and qualifier codes.

The NAPS laboratory reports Level 1 validated data to NAPS Data Management. These reports also contain:

- information about sample preparation
- analytical method and equipment
- qualifier codes associated with the analysis.

The NAPS Data Management loads the reports into the CWAQD. At this point, NAPS Data Management collaborates with the NAPS Laboratory to conduct Level 2 validation of the data.

14.2.2 Integrated Data Reporting to the NAPS Data Portal

On a quarterly basis, NAPS Data Management reports Level 3 validated data, including associated validation codes, to the NAPS Data Products portal.

Integrated data are posted in Excel files to the portal by year. Detailed information on the format and the use of these files is available on the NAPS Data Products portal.

14.3 Other NAPS Data Reporting Requirements

NAPS data support air management policies and reporting obligations under major national and international air quality agreements such as the Canadian AQMS and the Ozone Annex to the 1991 Canada-US Air Quality Agreement. Data provided by NAPS support public information tools on air quality conditions, including governments' air quality websites, CESI and the US AirNow mapping site. Data are also used to track trends in ambient air quality in communities (urban and rural) across the country; support health and environmental research and analysis; conduct environmental assessments; verify emissions inventories; conduct source apportionment analysis; validate and calibrate air quality models, remote sensing and air quality forecasting; and develop and assess new monitoring technologies.

NAPS data support ECCC's risk management, monitoring and enforcement actions for targeted chemicals under the Chemicals Management Plan and CEPA. The NAPS Program has a large number of clients from government, consulting groups, Canadian and international non-governmental organizations, industry, academia, media and the public.

Below are some examples of reporting obligations that use NAPS data.

14.3.1 Data Reported to the Canadian Environmental Sustainability Indicators (CESI)

The CESI Program provides data and information to track Canada's performance on key environmental sustainability issues, including climate change and air quality, water quality and availability, and protection of nature.

Air quality indicators have been developed at the national, regional and station level. These indicators are a means to present the state of air quality and trends across Canada on an annual basis using data collected from the NAPS Program.

14.3.2 Ozone Annex to the 1991 Canada-US Air Quality Agreement

Beginning in 2002, as part of biennial progress reports, Canada and the United States agreed to provide the following ambient air quality information:

- ambient O_3 concentration trends, reported in the form of the applicable standards
- ambient VOC concentration trends
- ambient NO_X concentration trends.

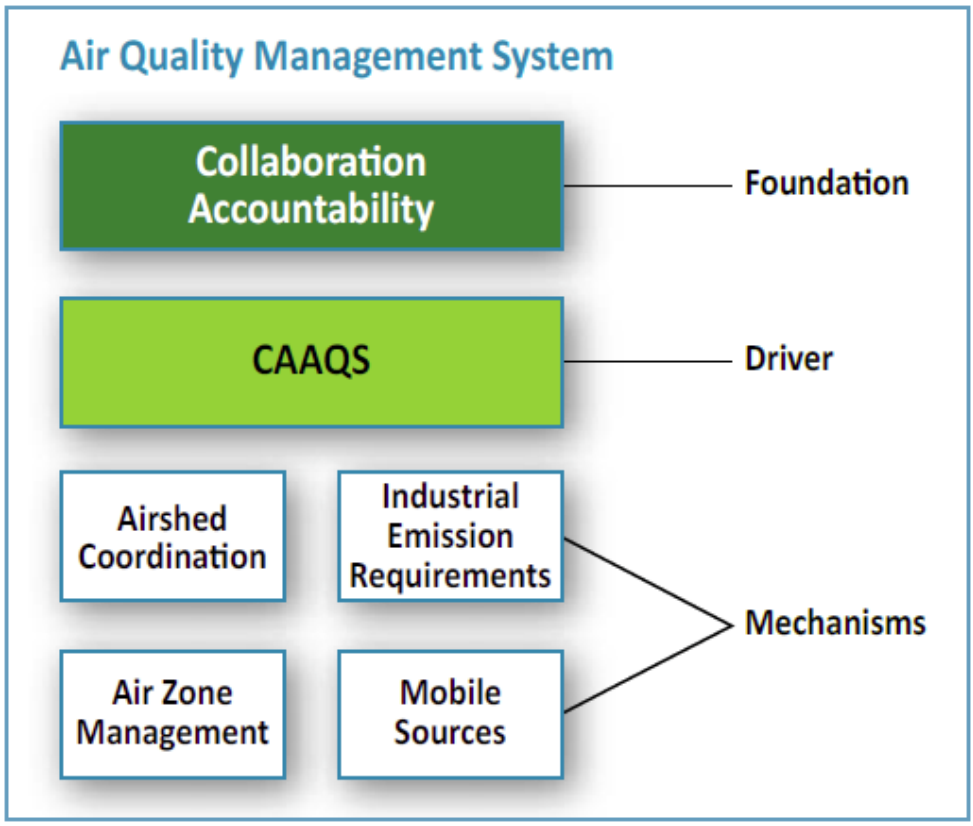
Ambient air quality information is reported for all relevant monitors located within 500 km of the border between Canada and the lower 48 states of the United States.

14.3.3 Air Quality Management System (AQMS)

In October 2012, jurisdictions, with the exception of Québec, agreed to begin implementing a new AQMS. Québec supports the general objectives of AQMS and is collaborating with jurisdictions on developing other elements of the system, notably air zones and airsheds. AQMS provides a comprehensive framework for collaborative action across Canada to further protect human health and the environment from harmful air pollutants through continuous improvement of air quality. The key elements of AQMS include new CAAQS, active air quality management at the local and regional levels, industrial emissions requirements for industrial sectors and equipment groups, and intergovernmental collaboration to reduce mobile source emissions (Figure 14-4).

CAAQS are established with the goal of protecting human health and the environment. They are intended to drive continuous air quality improvement across Canada.
The air quality data collected by the NAPS Program are used by governments to assess and report on air quality and develop programs to address priority air quality issues in air zones as part of AQMS.

Figure 14-4 Air Quality Management System



14.3.4 NAPS Annual Data Summary Reports

NAPS started publishing annual data summaries in 1972. NAPS Data Management continues to publish annual data summaries on national air quality to the NAPS Data Products portal.

15.0 ASSESSMENTS AND CORRECTIVE ACTION

This *Guidance* is intended to assist *Networks* in developing and implementing QA/QC for their ambient air monitoring program. By following these guidelines, the NAPS DQO should be met.

Routine assessments of network operations provide assurance that the monitoring systems and data management procedures are of sufficient quality to meet NAPS DQO, and they identify where improvements might be necessary (Table15-1).

Types of assessments performed in the NAPS Program include:

- Performance and systems audits that are conducted either by ECCC auditors or other organizations and that are separate from the host operating *Network.*
- The NAPS Inter-agency Measurement Study, in which participants analyze an unknown sample gas concentration provided by the NAPS Applied Metrology Laboratory.

- DQA, which involve the statistical analysis of air quality data to determine if reported data are meeting program objectives and DQO.

Note that audits and assessments of the NAPS Laboratory for analysis of integrated samples include:

- performance and systems audits by accredited bodies
- participation in blind sample tests and round robins with independent labs.

Table 15-1 ECCC audit and assessment schedule

Assessment type	Frequency
Performance or systems audit	every 2 years at selected sites (per *Network*)[1]
NAPS Inter-agency Measurement Study	every 3 years
DQA	annually

1 Number of sites will depend on time and resources available and may be performed upon request by a *Network*.

15.1 Performance and Systems Audits

Performance and systems audits are independent evaluations of data quality. A systems audit reviews the entire monitoring system documentation and procedures for the station siting, instrumentation calibration and maintenance, and data collection and validation. A performance audit focusses on station operation (e.g., instrument performance, inlet manifold, siting, maintenance, safety). These audits can be performed either independently or concurrently.

The *Network* should ensure that all site documentation is readily available (e.g., NQAP, SOP, field and QC records) and should ensure that all sites, instruments and data collection systems are easily and safely accessible. Discussions prior to the audit are useful for reviewing schedules and anticipated activities, and for addressing preliminary questions.

Prior to a scheduled ECCC audit, the *Network* will receive a letter and a questionnaire. The auditors will use the responses to familiarize themselves with individual site specifications and to better prepare for the audit. Example questionnaires are included in Appendix C.

A post-audit meeting to review major findings and corrective actions may be required. It should involve ECCC auditors and *Network* personnel (e.g., personnel from field operations, QA/QC, data management and reporting).

Specific components of both performance and systems audits are discussed below.

15.1.1 Performance Audit

Performance audit procedures are instrument-specific and generally follow procedures used for verification and calibrations. These include multi-point checks for gas analyzers and flow checks for continuous PM and integrated samplers.

The following are important considerations for performance audits:

- no adjustments should be made to the measurements system prior to the audit
- audit gases and measurement devices must be certified against the NAPS reference standards or other NIST traceable sources
- instrument readings should be stable before being recorded
- readings should be recorded from the data collection system and verified against the analyzer's display to ensure that readings are comparable.

Performance is evaluated by comparing audit results with the NAPS acceptance criteria (Section 11.0). To facilitate comparisons, an Excel workbook template is available for download from the NAPS document-sharing website. This workbook includes instrument-specific spreadsheets that calculate the differences between readings and reference standards, providing a pass/fail indication. Audit results that do not meet the acceptance criteria should be addressed by the *Network* and may require corrective action.

15.1.2 Systems Audit

A systems audit is primarily an administrative review of all documentation for the entire monitoring process to ensure that the *Network* is following procedures outlined in this *Guidance* and in the *Network*'s NQAP.

An example of a system audit is available in Appendix C.

15.1.3 Audit Response

Within 30 days of an ECCC audit, auditors will provide a summary report to the *Network*. The report will include:

- audit date and site name
- audit team members
- *Network* staff involved in station operation
- summary and conclusions regarding audit results, required corrective actions and recommended improvements
- attachments or appendices that include audit results or performance evaluation spreadsheets used.

Within 90 days of receiving the audit report, the *Network* will provide an audit summary response that includes a plan to address findings and issues highlighted in the report. Findings that may compromise data quality or indicate that an instrument is not meeting acceptance criteria should be addressed as soon as possible to avoid data loss.

If the *Network* disputes any audit findings, the response should provide a detailed justification or rationale. All documentation of audits, including any findings, corrective actions, disputes and resolutions should be kept on file.

15.2 Inter-Agency Measurement Study

The NAPS Applied Metrology laboratory coordinates an inter-agency comparison study. The objective of the inter-agency measurement study is to provide information on the accuracy and method bias of the calibration systems used across the network.

For this study, gas cylinders containing an unknown concentration of NO, SO_2 or CO are sent to participants for analysis. Written procedures are also provided and should be followed closely to help ensure consistent application of the tests across participants.

After analyzing the cylinder, participants should return results and information promptly. The reference gas concentration in the cylinder is verified against primary standards at the NAPS Applied Metrology laboratory and is the average of all measured concentrations before and after testing by participants. For this study, values are expected to be within ±4% of the reference concentration.

Participants are contacted with the test results within 30 days after the return of the cylinder. Results outside of the ±4% limit should trigger an investigation and possible corrective action.

The final report summarizes the results from all participants.

15.3 Data Quality Assessments (DQA)

DQA involve the statistical analysis of air quality data to help determine if reported data meet NAPS DQO. These assessments can help *Networks* evaluate overall systems performance and revise guidelines or objectives as necessary.

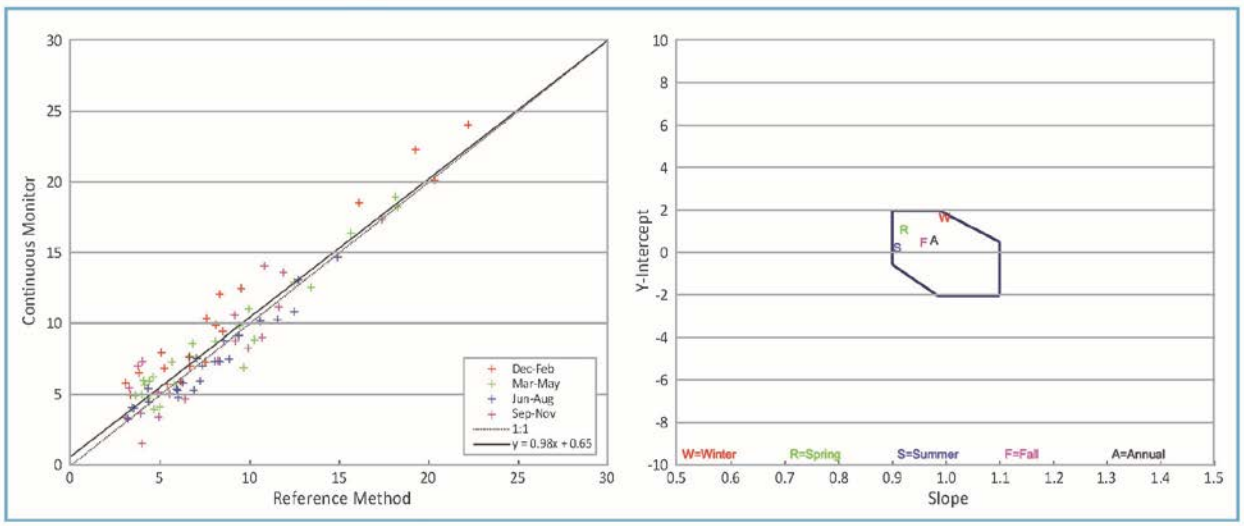
Assessments may include:

- *Network* Data Quality Reports
    - Precision and bias: estimates both bias and precision derived from the daily or weekly QC checks results for the four continuous gaseous methods (CO, NO_X, O_3, and SO_2). These reports should be aggregated for each method, for all methods at each site and for the *Network* as a whole. Summaries should also include annual QC checks completeness
    - Continuous PM performance: estimates instrument performance using the results from the flow rate QC checks and leak checks. Summaries should also include annual QC checks completeness
    - Annual data completeness: includes percent completeness for each continuous method per site. Data completeness information accompanies the pollutant-specific annual summary files available on the NAPS Data portal.
- ECCC Reports
    - Five-year NAPS audit summary report summarizing audit results by parameters and for all provinces and territories.

- ECCC and *Network* data Reports
    - Data comparisons such as between continuous $PM_{2.5}$ FEM versus integrated NAPS RM (Figure 15-1).

The assessments can help inform either the need for corrective action, or a reassessment of DQO for future updates of the *Guidance*.

Figure 15-1 Collocated $PM_{2.5}$ continuous monitor vs NAPS RM measurements



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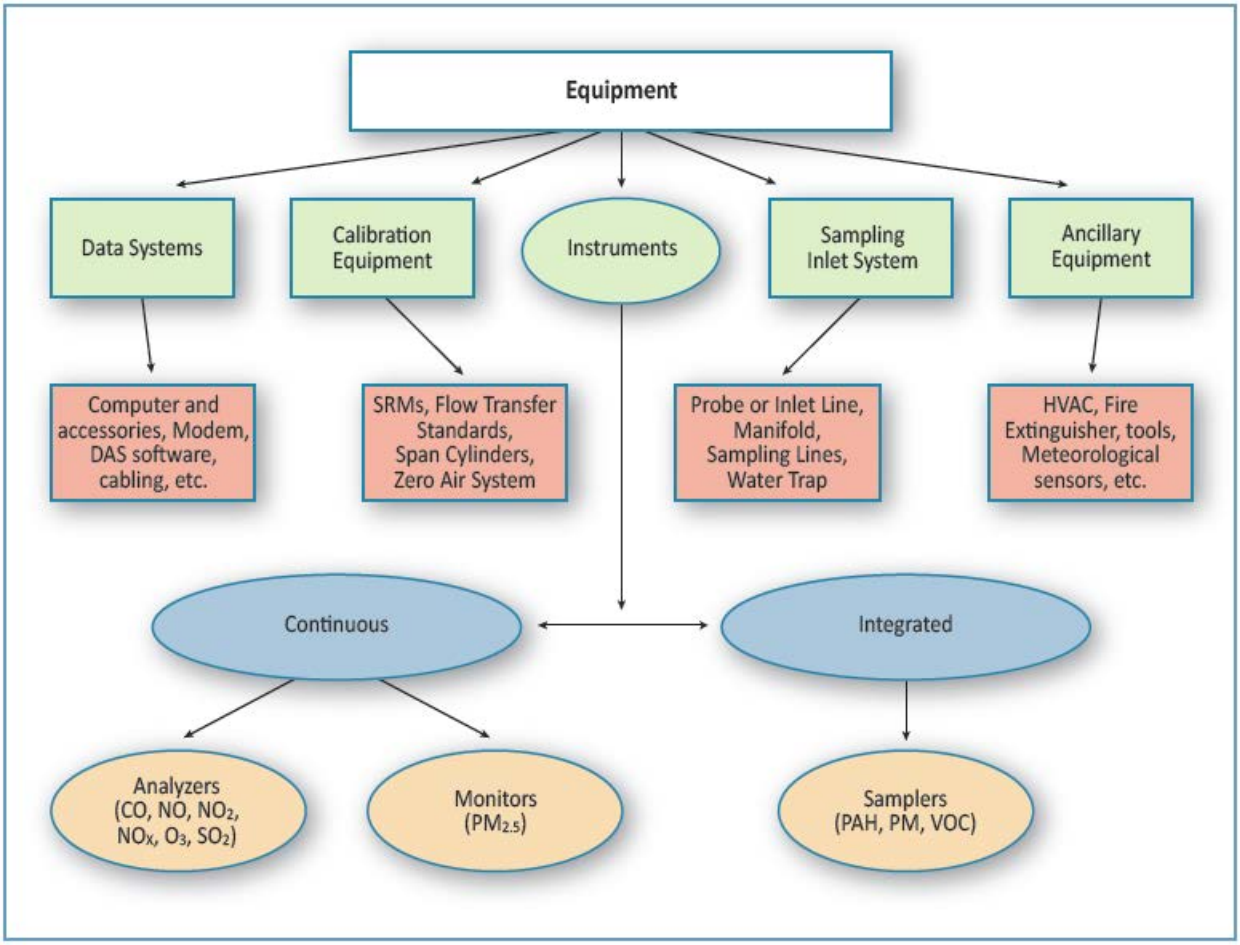
APPENDIX A – AMBIENT AIR MONITORING EQUIPMENT



APPENDIX B – NAPS METHOD AND SOP REFERENCE LIST

Methods and SOP are listed here for reference purposes. Updates are implemented regularly, and this list follows the latest revisions of the documents. The NAPS document sharing website should be referred to for the most complete current list.

Table B-1 NAPS Operations methods and SOP

Field methods and SOP	
Continuous instrument operation	
Title	**Author**
Continuous Measurement of Ozone in Ambient Air by Ultraviolet (UV) Photometry	ECCC, NAPS Operations
Operating Procedures for BAM-1020 $PM_{2.5}$ Monitors in the NAPS Network	ECCC, NAPS Operations
National Air Pollution Surveillance (NAPS) Network RM for the Measurement of $PM_{2.5}$ Concentration in Ambient Air Using Filter Collection and Gravimetric Mass Determination	ECCC, AAQS, AQRD
Continuous Measurement of Carbon Dioxide (CO) in Ambient Air by Nondispersive Infrared Photometry with Gas Filter Correlation (GFC)	ECCC, NAPS Operations
Continuous Measurement of Nitrogen Dioxide (NO_2) in Ambient Air by Chemiluminescence	ECCC, NAPS Operation
Continuous Measurement of Sulphur Dioxide (SO_2) in Ambient Air by Ultraviolent (UV) Fluorescence	ECCC, NAPS Operations
Thermo Synchronized Hybrid Ambient Real-time Particulate (SHARP5030) Monitor Operating Instructions	ECCC, NAPS Operations
Manual/integrated instrument operation SOP	
Title	**Author**
Partisol 2000i-D Dichotomous Operating Instructions	ECCC, NAPS Operations
Dichotomous Partisol-Plus model 2025 Sequential Air Sampler	ECCC, NAPS Operations
Met One Super SASS-Plus Operating Instructions	ECCC, NAPS Operations
Operating Instructions for RM Environmental VOC Sampler Model 910C with sequential 912	ECCC, NAPS Operations
Operating Procedure of Model 926 Carbonyl Sampler	ECCC, NAPS Operations
Environment Canada PUF Sampler Instructions	ECCC, NAPS Operations

Data management SOP	
Title	**Author**
Standard Operating Procedure for NAPS FTP	ECCC, NAPS data management
Sample management	
Title	**Author**
Procedures for Preparing and Receiving PAH Canisters and Filters	ECCC, AAQS, AQRD
Determination of the Weight of Particulate Matter Collected on Teflon® Membrane Filters	ECCC, AAQS, AQRD
Preparation, Shipping, and Unloading of ChemComb Cartridges	ECCC, AAQS, AQRD
VOC Sample Management Procedures	ECCC, AAQS, AQRD

APPENDIX C – TECHNICAL SYSTEMS AUDIT QUESTIONNAIRES

a) *Network*

(Attach organization flow chart if available)

KEY INDIVIDUALS	
PROVINCIAL/TERRITORIAL NATIONAL AIR POLLUTION SURVEILLANCE PROGRAM (NAPS) MANAGERS:	
QUALITY ASSURANCE OFFICER:	
FIELD OPERATIONS CO-ORDINATOR:	
DATA CO-ORDINATOR/ANALYSTS:	
FIELD OPERATORS:	

COMMENTS:

KEY RESPONSIBILITIES	
ACTIVITY	**RESPONSIBLE PARTY**
INSTRUMENT REPAIR	
CERTIFICATION OF STANDARDS (PROTOCOL GAS, FLOW STANDARDS, ETC)	
DATA VERIFICATION AND REDUCTION	

COMMENTS:

b) Site and system design

SITE SPECIFICATIONS		
SITE NAME		
SITE NUMBER/ID		
SITE ADDRESS		
CITY, PROVINCE		
SITE COORDINATES (WGS84 DATUM)	LATITUDE (DECIMAL DEGREES):	LONGITUDE (DECIMAL DEGREES):
ELEVATION (M):		
LIST OF MONITORED POLLUTANTS:	NAPS PARAMETERS: NON-NAPS PARAMETERS:	
DISTANCE TO NEAREST ROADWAY	NEAREST	
NAPS SITE CLASSIFICATION		
URBANIZATION	o LARGE o MEDIUM o SMALL o NON-URBAN	
NEIGHBOURHOOD POPULATION	o < 500 o 500–9,999 o 10,000–49,999 o 50,000–99,999 o 100,000–149,999 o > 149,999	
LOCAL LAND USE	o RESIDENTIAL o AGRICULTURAL o OPEN o FORESTED o COMMERCIAL o INDUSTRIAL o PARKS o WATER	
SITE TYPE	o GENERAL POPULATION EXPOSURE o REGIONAL BACKGROUND o POINT SOURCE–INFLUENCED o TRANSPORTATION-SOURCE INFUENCED	
PROVIDE A MAP OF SITE AND SURROUNDING TERRAIN AND FEATURES		
PROVIDE RECENT SITE PHOTOGRAPHS (ALL QUADRANTS FROM THE SITE AND LOOKING AT THE SITE)		

COMMENTS:

INSTRUMENT INFORMATION					
MANUFACTURER	**MODEL**	**SERIAL NUMBER**	**HEIGHT OF INLET ABOVE GROUND (M)**	**HEIGHT OF INLET ABOVE ROOF TOP (M)**	**UNRESTRICTED AIRFLOW IN AT LEAST 3 QUADRANTS (YES, NO)**

SAMPLING INLET SYSTEM/MANIFOLD DESIGN			
BRIEFLY DESCRIBE THE SAMPLE MANIFOLD TYPE USED.			
WHAT IS THE RESIDENCE TIME?			
WHAT MATERIAL IS USED FOR SAMPLING LINES?			
WHAT IS THE HEIGHT OF THE SAMPLING INLET?			
	YES	**NO**	**COMMENT**
IS MANIFOLD EQUIPPED WITH A BLOWER/PUMP?			
HOW IS THE AIR FLOW THROUGH THE MANIFOLD VERIFIED?			

COMMENTS:

c) Documentation and records

QUALITY ASSURANCE PROJECT PLAN (NQAP)			
TITLE	**AUTHOR**	**DATE OF LAST NQAP REVIEW**	**DATE OF LAST NQAP REVISION**

COMMENTS:

STANDARD OPERATING PROCEDURES (SOP)			
TITLE	**AUTHOR**	**DATE OF LAST SOP REVIEW**	**DATE OF LAST SOP REVISION**

COMMENTS:

NETWORK DOCUMENTATION			
ARE EACH OF THE FOLLOWING SITE REQUIREMENTS DOCUMENTED IN A NETWORK MONITORING PLAN OR NQAP OR OTHERWISE AVAILABLE AS OFFICIAL RECORDS?			
	YES	**NO**	**COMMENT**
STREET ADDRESS AND GEOGRAPHIC COORDINATES?			
MONITORED POLLUTANTS			
PHOTOGRAPHS OF EACH SITE AND ITS ASSOCIATED CARDINAL VIEWS?			
START-UP AND SHUTDOWN DATES?			
DOCUMENTATION OF INSTRUMENTATION AND MAINTENANCE RECORDS?			
WHO HAS CUSTODY OF CURRENT NETWORK DOCUMENTS?	NAME: TITLE:		
HOW OFTEN IS NETWORK SITING REVIEWED?	FREQUENCY:		

COMMENTS:

d) Routine operation

SITE MAINTENANCE	
ON AVERAGE, HOW OFTEN ARE SITES VISITED?	
ON AVERAGE, HOW MANY SITES DOES A SINGLE OPERATOR HAVE RESPONSIBILITY FOR?	
WHAT IS YOUR SCHEDULE FOR CLEANING MANIFOLDS?	

WHAT IS USED TO PERFORM THE CLEANING?			
	YES	**NO**	**COMMENT**
IS THERE A CONDITIONING PERIOD FOR THE MANIFOLD AFTER CLEANING?			
AT WHAT FREQUENCY ARE LINES CHANGED?			
AT WHAT FREQUENCY ARE PARTICULATE FILTERS FOR GAS ANALYZERS REPLACED?			
	YES	**NO**	**COMMENT**
DO SITES EMPLOY UNINTERRUPTABLE POWER SUPPLY (UPS) DEVICES?			

EQUIPMENT MAINTENANCE AND REPAIR			
WHO IS RESPONSIBLE FOR MAINTENANCE AND REPAIRS?			
	YES	**NO**	**COMMENT**
IS TRAINING PROVIDED?			
IS ANY ONGOING TRAINING AVAILABLE/PROVIDED?			
WHERE IS MAINTENANCE PERFORMED?	• FIELD STATION • HEADQUARTERS • SENT TO MANUFACTURER (AT THE DIRECTION OF EC NAPS) • SENT TO EC NAPS		
DESCRIBE ADEQUACY AND AVAILABILITY OF SPARE PARTS, INSTRUMENTS AND TOOLS.			
ARE MANUALS AND METHOD SOP AVAILABLE TO THE OPERATOR TO PERFORM ANY NECESSARY MAINTENANCE OR REPAIR?			

FIELD DOCUMENTATION			
WHAT TYPE OF LOGS ARE MAINTAINED FOR THIS SITE? (E.G., MAINTENANCE, CALIBRATION, SITE CONDITION/ MAINTENANCE, INSTRUMENTS) INDICATE IF ELECTRONIC (E) OR PAPER (P)			
WHO REVIEWS AND VERIFIES THE LOGS FOR ADEQUACY OF INFORMATION ENTERED?			
HOW IS CONTROL OF LOGS MAINTAINED?			
ARE THE COMPLETED LOGS ARCHIVED? IF SO WHERE?			
WHAT OTHER RECORDS ARE USED?			
	YES	NO	COMMENT
ZERO SPAN RECORD?			
GAS USAGE LOG? ADD DETAILS CAL/SPAN, EXPIRY DATES, ETC			
MAINTENANCE LOG?			
RECORD OF AUDITS?			
ARE CALIBRATION RESULTS AVAILABLE TO FIELD OPERATORS?			
PROVIDE EXAMPLE FIELD VERIFICATION/ CALIBRATION WORKSHEETS			

e) Verification and calibration/QC checks

MULTI-POINT VERIFICATION/CALIBRATION FREQUENCY (FIELD INSTRUMENTS)		
INSTRUMENT	**ZERO/SPAN CHECK TYPE (INTERNAL, WITH CALIBRATOR, ETC)**	**FREQUENCY**

COMMENTS:

TRACEABILITY OF CALIBRATION AND TRANSFER STANDARDS			
	YES	**NO**	**COMMENT**
ARE ALL FLOW-MEASUREMENT TRANSFER STANDARDS CERTIFIED?			FREQUENCY OF CERTIFICATION? BY WHOM?
ARE ALL GAS CYLINDERS CERTIFIED?			FREQUENCY OF CERTIFICATION? BY WHOM?
ARE ALL DILUTION CALIBRATORS CERTIFIED?			FREQUENCY OF CERTIFICATION? BY WHOM?
ARE ALL RELATIVE HUMIDITY TRANSFER STANDARDS CERTIFIED?			FREQUENCY OF CERTIFICATION? BY WHOM?
ARE ALL TEMPERATURE TRANSFER STANDARDS COMPARED? (TEMPERATURE PROBE ON DELTACAL)			FREQUENCY OF CERTIFICATION? BY WHOM?
WHERE DO FIELD OPERATORS OBTAIN GASEOUS STANDARDS?			
ARE COPIES OF CERTIFICATIONS OF ALL STANDARDS CURRENTLY IN USE READILY AVAILABLE TO QUALIFIED FIELD TECHNICIANS?			
WHO IS RESPONSIBLE FOR MAINTAINING FIELD TRANSFER STANDARDS?			

COMMENTS:

f) Data collection and management

SOFTWARE DOCUMENTATION			
	YES	**NO**	**COMMENT**
DOES DOCUMENTATION EXIST FOR ALL DATA PROCESSING SOFTWARE?			
IS SOFTWARE PURCHASED, WRITTEN IN HOUSE, OR PURCHASED, WITH MODIFICATIONS IN HOUSE?	SOFTWARE TITLE: DATE OF LATEST VERSION:		
	YES	**NO**	**COMMENT**
IS A USER MANUAL AVAILABLE TO DATA MANAGEMENT PERSONNEL FOR ALL SOFTWARE CURRENTLY IN USE?			
ARE COMPUTER SYSTEM CONTENTS BACKED UP REGULARLY?			
WHAT IS THE RECOVERY CAPABILITY? (HOW MUCH TIME AND DATA WOULD BE LOST)			
	YES	**NO**	**COMMENT**
ARE COMPUTER SYSTEM CONTENTS BACKED UP REGULARLY?			
ARE THESE TESTS DOCUMENTED?			
HOW ARE SOFTWARE VERSIONS TRACKED?			
	YES	**NO**	**COMMENT**
IS A UNIQUE LOG-IN REQUIRED FOR PROGRAMS WHERE DATA CAN BE CHANGED?			
ARE RAW VALUES MAINTAINED WITHIN THE DATA MANAGEMENT SYSTEM?			
IS THERE A PROCESS IN PLACE FOR ADJUSTING DATA WHERE NEEDED?			
DOES THE DATA MANAGEMENT SYSTEM SUPPORT THE FUNCTIONALITY FOR VALIDATION BY MULTIPLE USERS WITH DIFFERENT LEVELS OF REVIEW?			

COMMENTS:

DATA COLLECTION (CONTINUOUS DATA)			
	YES	**NO**	**COMMENT**
DO YOU FOLLOW A PRESCRIBED PROCEDURE, DESCRIPTION, OR A CHART THAT SHOWS A COMPLETE DATA FLOW FROM POINT OF ACQUISITION TO POINT OF SUBMISSION? IF YES, IDENTIFY THE AUTHOR.			
ARE DATA HANDLING PROCEDURES DOCUMENTED FOR DATA FROM CONTINUOUS ANALYZERS?			
INDICATE BELOW THE FORMAT AND MEDIUM OF DATA SUBMITTED TO THE DATA PROCESSING SECTION			
REPORTING *NETWORK*	**DATA MEDIUM**		**FORMAT**
HOW ARE RAW DATA RECORDS ARCHIVED AT THE SITE?			
DESCRIBE ALL FIELDS THAT ARE INCLUDED WITH RAW DATA (FLAGS, DIAGNOSTICS, VERIFICATION/CALIBRATION RESULTS, ETC.)			
HOW OFTEN ARE DATA RECEIVED AT THE PROCESSING CENTRE FROM THE FIELD SITES AND MONITORING NETWORK?			
HOW ARE THE DATA ENTERED INTO THE DATA MANAGEMENT SYSTEM? MANUAL OR AUTOMATED TRANSCRIPTION?			
HOW ARE DATA STORED AT THE PROCESSING CENTRE?			
HOW FAR BACK ARE DATA STORED?			
WHAT METADATA ARE STORED IN THE DATA MANAGEMENT SYSTEM?			
ARE DATA SCREENED AGAINST USER-DEFINED RULES AND ACCEPTANCE CRITERIA WHEN LOADED INTO THE DATA MANAGEMENT SYSTEM?			
HOW ARE YOU ALERTED TO AN INSTRUMENT MALFUNCTION?			

IS THERE DOCUMENTATION ACCOMPANYING THE DATA REGARDING ANY MEDIA CHANGES, TRANSCRIPTIONS, AND/OR FLAGS THAT HAVE BEEN PLACED INTO THE DATA BEFORE DATA ARE RELEASED TO THE PROCESSING CENTER? DESCRIBE.			
IS THERE A PROCESS IN PLACE TO VERIFY THE TIME-STAMP ASSOCIATED WITH EACH DATA RECORD IS ACCURATE?			
DATA VALIDATION AND CORRECTION (CONTINUOUS DATA)			
	YES	**NO**	**COMMENT**
DO DATA VALIDATION GUIDELINES EXIST THAT OUTLINE THE VALIDATION PROCESS?			
ARE FIELD LOGBOOKS OR SITE OPERATOR INPUT USED DURING THE DATA VALIDATION PROCESS?			IF YES, HOW IS THIS INFORMATION USED IN TERMS OF DATA VALIDITY?
HOW MANY DATA REVIEW STEPS EXIST?			
WHO IS RESPONSIBLE FOR EACH STEP?			
IS THERE A REQUIREMENT FOR THE MINIMUM NUMBER OF DATA POINTS THAT ARE NEEDED TO CREATE A VALID HOURLY AVERAGE?			
HAVE VALIDATION CRITERIA, APPLICABLE TO ALL DATA PROCESSED BY THE REPORTING NETWORK, BEEN ESTABLISHED AND DOCUMENTED?			IF YES, INDICATE DOCUMENT WHERE SUCH CRITERIA CAN BE FOUND (TITLE, REVISION DATE).
ARE ZERO/SPAN RESULTS OR OTHER CALIBRATION DIAGNOSTICS FLAGGED BY THE DATALOGGER?			
ARE AMBIENT DATA CORRECTED BASED ON ZERO/SPAN RESULTS?			IF SO, PLEASE DESCRIBE:
DO DOCUMENTED DATA VALIDATION CRITERIA ADDRESS LIMITS FOR THE FOLLOWING AND IS THERE A PLAN IN PLACE IF ACCEPTANCE CRITERIA ARE NOT MET?			
OPERATIONAL PARAMETERS SUCH AS STATION TEMPERATURE, RANGE TESTS AND/OR FLOW RATES			

ZERO/SPAN CHECKS FOR GASEOUS ANALYZERS			
OTHER CHECKS UNIQUE TO A MEASUREMENT SYSTEM (FLOW, TEMPERATURE, PRESSURE, ETC.)			
OUTLIER TESTS AS PART OF THE SCREENING PROCESS			
MANUAL DATA CHECKS			
ARE THERE METRICS IN PLACE TO COMPARE VALIDATED DATA TO DATA QUALITY OBJECTIVES?			
ARE CHANGES TO THE DATA DOCUMENTED?			
HOW ARE DATA MARKED AS INVALID?			
ARE JUSTIFICATIONS FOR INVALIDATING DATA DOCUMENTED?			
ARE CHANGES PERFORMED ACCORDING TO CURRENT SOP OR NQAP?			IF NOT, DESCRIBE:
WHO HAS AUTHORITY FOR APPROVING CORRECTIONS?			
HOW ARE THESE CORRECTIONS DOCUMENTED?			
ARE DATA VALIDATION SUMMARIES PREPARED AT EACH CRITICAL POINT IN THE MEASUREMENT PROCESS OR INFORMATION FLOW AND FORWARDED WITH THE APPLICABLE DATA SET TO THE NEXT LEVEL OF VALIDATION?			PLEASE INDICATE THE POINTS WHERE SUCH SUMMARIES ARE PERFORMED
ARE DATA EVER DELETED?			IF YES, WHAT CRITERIA ARE APPLIED FOR DATA TO BE DELETED?
WHAT CRITERIA ARE APPLIED TO CAUSE DATA TO BE REPROCESSED?			
ARE GROUPS SUPPLYING DATA PROVIDED AN OPPORTUNITY TO REVIEW DATA AND CORRECT ERRONEOUS ENTRIES?			IF YES, HOW?

ARE ZERO/SPAN AND VERIFICATION/ CALIBRATION DATA REVIEWED AS PART OF THE VALIDATION PROCESS?			
DO DATA VALIDATION ACCEPTANCE CRITERIA EXIST FOR THESE CHECKS?			
DESCRIBE THE DATA HANDLING PROCESS WHEN THESE CHECKS ARE OUTSIDE OF ACCEPTABLE LIMITS:			
ARE ZERO/SPAN AND VERIFICATION/CALIBRATION DATA CHECKED PRIOR TO SUBMISSION?			
IS A FINAL DATA PROCESSING CHECK PERFORMED PRIOR TO SUBMISSION OF ANY DATA?			
ARE CALIBRATION AND/OR AUDIT RESULTS REVIEWED AS PART OF THE VALIDATION PROCESS?			WHO IS RESPONSIBLE FOR REVIEWING THESE RESULTS AND DETERMINING DATA VALIDITY?
DESCRIBE THE VALIDATION PROCESS FOLLOWED IF THESE CHECKS ARE OUTSIDE OF VALIDATION ACCEPTANCE CRITERIA:			
HOW ARE CHANGES TO DATA DOCUMENTED?			
DATA COLLECTION (MANUAL/INTEGRATED DATA)			
	YES	**NO**	**COMMENT**
ARE THERE ANY NAPS-SUPPORTED MANUAL/ INTEGRATED SAMPLING METHODS SUPPORTED AT THE SITE?			
ARE CHAIN-OF-CUSTODY PROCEDURES IN PLACE?			
ARE THE APPROPRIATE CALIBRATION EQUATIONS SUBMITTED WITH THE DATA TO THE PROCESSING CENTER (AS REQUIRED)?			

PROVIDE A BRIEF DESCRIPTION OF THE PROCEDURES AND APPROPRIATE FORMULAE USED TO CONVERT FIELD DATA TO CONCENTRATIONS PRIOR TO INPUT INTO THE DATABASE.			
ARE ALL CONCENTRATIONS REPORTED IN ACTUAL CONDITIONS?			
ARE DATA REDUCTION AUDITS PERFORMED ON A ROUTINE BASIS?			
ARE AUDITS DONE BY AN INDEPENDENT GROUP?			
DATA DISSEMINATION AND REPORTING			
	YES	**NO**	**COMMENT**
DOES THE *NETWORK* GENERATE DATA SUMMARY REPORTS?			
DO THESE REPORTS UNDERGO QUALITY CONTROL REVIEW PRIOR TO RELEASE?			IF YES, WHO IS RESPONSIBLE FOR QC REVIEW?
ARE THE DATA USED FOR IN-HOUSE DISTRIBUTION?			
ARE THE DATA PRESENTED IN ANY PUBLICATION?			
LIST REPORTS ROUTINELY GENERATED			
REPORT TITLE	**DISTRIBUTION**		**PERIOD**
	YES	**NO**	**COMMENT**
ARE THE DATA SUBMITTED TO OTHER ORGANIZATIONS?			
WHO WITHIN THE REPORTING *NETWORK* IS RESPONSIBLE FOR SUBMITTING THE DATA?			
IS THE DATA SUBMITTAL APPROVED BY AN OFFICER OF THE *NETWORK*?			
HOW OFTEN ARE DATA SUBMITTED?			

HOW AND/OR IN WHAT FORM ARE DATA SUBMITTED?			
ARE REQUIREMENTS FOR DATA CODING AND SUBMITTAL DOCUMENTED?			
ARE THESE REQUIREMENTS FOLLOWED CLOSELY?			
IS THERE A PROCESS IN PLACE TO MAKE CHANGES TO DATA IF NEEDED AFTER FINAL SUBMISSION?			IF YES, WHO HAS THE AUTHORITY TO APPROVE THESE CHANGES?
HOW FREQUENTLY ARE DATA UPDATED BASED ON CHANGES TO DATA?			
HOW ARE CHANGES TO HISTORICAL DATA IDENTIFIED?			
HOW LONG ARE RECORDS KEPT?			

COMMENTS:

INTERNAL REPORTING			
LIST INTERNAL QUALITY CONTROL REPORTS BELOW			
REPORT TITLE			FREQUENCY
	YES	NO	COMMENT
DO REPORTS INDICATED INCLUDE A DISCUSSION OF CORRECTIVE ACTIONS INITIATED BASED ON QUALITY CONTROL CHECK RESULTS?			

APPENDIX D – PERFORMANCE AUDIT QUESTIONNAIRE

- Who are the operators of the NAPS stations selected for audit? Are these operators on your staff or hired on contract? How many stations are operated by these staff/contractors?
- How frequently do operators visit each station; what activities are usually performed during these visits?
- How frequently are gas analyzers zeroed and spanned? Are these manual or automated?
  O_3 _____
  NO_X _____
  SO_2 _____
  CO _____
- Are the zero/span values flagged by the datalogger? Are ambient data corrected based on zero and span results? If so, how?
- What action threshold values, if any, apply to zero and span results?
- How are you alerted to an instrument malfunction? How do you determine the date/time beyond which you can no longer be sure valid data was obtained?
- Are spare instruments available in the event of a malfunction requiring removal of an instrument from a station for repair? Who repairs malfunctioning instruments?
- Are logbooks (hard-copy or electronic) maintained for each station to record all activities performed during site visits? Are these records available at the station at all times, or do they remain with the operator?
- What makes/models of calibrators are in service in your network? How many of each?
- Who calibrates gas analyzers and PM monitors and samplers? Are calibrations performed at stations or off site?
- When are instruments calibrated? (i.e., based on what criteria)
- Who certifies your calibrators for 1) ozone concentration, and 2) flow? How frequently?
- What makes/models of flow transfer standards (certified flowmeters) are in service in your network? How many of each?
- Who certifies your flow transfer standards? How frequently?
- Who provides and/or certifies your gas calibration standards?
- What are you using as calibration verification (span) standards for CO, NO_X and SO_2 (e.g. gas, permeation device)? Who is your provider for span gases?
- What makes/models of dataloggers are in service in your network?
- What is the station operator's role in the ambient data validation process? Who are the other staff involved in the data validation process in your network? Briefly describe respective responsibilities if shared.
- Do you follow formal documented procedures for 1) station operation and 2) data validation? If so, who authored these documents?
- Do you have an audit program in place? Describe briefly (e.g., who, frequency, coverage, type).
- How may Environment Canada improve its audit program to increase its value relative to your organization's quality objectives for ambient air monitoring?