FRAMEWORK FOR THE BRITISH COLUMBIA AIR MONITORING NETWORK

FINAL REPORT
STI-906059.05-3229-FR

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June 2008

BRITISH COLUMBIA
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1. INTRODUCTION

1.1 OVERVIEW

The British Columbia (BC) air monitoring network is one of the largest per capita in Canada. There is a particularly significant monitoring effort in the Greater Vancouver Regional District (GVRD) (22 air quality monitoring sites) and a growing effort in the rest of the Province (78 monitoring sites). The sites are operated as a mix of permitted and ministry-run monitoring efforts. Historically, BC's air quality network developed on a case-by-case basis—no overarching framework existed to guide the network's growth. Each region within the Province has taken different steps in planning, maintaining, and growing its regional monitoring system; additional guidance to improve consistency and the fair distribution of resources is now needed. An overarching principle for the BC network is to determine a way to maximize information obtained efficiently, effectively, and within budgetary constraints.

This draft framework was prepared to

- guide network changes with a greater understanding of the relevance of new and existing stations and parameters measured, and whether resources could be diverted to meet higher air quality priorities;
- provide the BC Ministry of the Environment (MoE) with the ability to optimize its air monitoring network to achieve the best possible scientific value and protect public and environmental health and welfare in a cost-effective manner; and
- lay out the core components of the network and provide a foundation for future growth that includes preventing regional disparity (over-and under-representation), ensuring consistency in monitoring methods and parameters among regions, preventing "monitoring monoculture" (such as only monitoring for SO_2 and H_2S), improving data quality, and optimizing capital and human resources.

Without a strategy for future development, several problems can occur in the network, including regional disparity (over- and under-representation), inconsistency in monitoring methods and parameters among regions, reduced data quality, and wasted capital and human resources. A strategy is needed so that the network is based on a structured, provincially consistent, and scientifically sound framework.

This framework document is intended to be a living and evolving document built on discussion with and feedback from the regions. Future versions of the framework will include discussion of the air quality database, data validation, and data analysis guidance and requirements.

1.2 GOALS OF THE FRAMEWORK

The MOE will periodically evaluate the existing network to optimize coverage and representativeness, minimize redundancy, and conserve capital and human resources. The most recent evaluation of the network was used to support preparation of this framework. The MoE has several goals for its monitoring framework:

1. Provide a more *systematic approach* to network design. Plan for network growth that includes identifying new data needs and new sampling or analysis technology, increasing multiple-pollutant sites, and increasing network coverage.
2. Focus on *data quality* over data quantity by reducing network redundancies while preserving long-term trends sites and shifting to more continuous monitoring methods over manual methods.
3. Improve *consistency* (monitoring, data handling, data validation, data analysis, etc.) across the Province.
4. Balance regional *flexibility* with provincial consistency.

The framework discussed in this document fits within the adaptive management framework/environmental management system (EMS) approach used by the MoE. An EMS typically consists of the following steps: Plan, Do, Check, and Act. Goals are established in the Plan stage. The Do stage requires implementation of the plan, including training and implementing operational controls. In the Check stage, the plan is monitored and corrective actions are taken. In the Act stage, the plan is reviewed, including reviewing progress and acting to make needed changes to the EMS.

The goal of this framework is to guide decision making about allocating monitoring instrumentation and funds with a focus on where in the Province monitors should be placed, what data from monitors should be used for, and why monitors may be needed. Information about how to site, install, and operate monitors is covered in other documents. For example, monitoring operations and instrumentation are handled in standard operating procedures (SOPs) and instrument operation manuals.

1.3 FRAMEWORK ORGANIZATION

This framework document contains a summary of monitoring objectives, monitoring decision processes, and monitoring network details. The MoE is currently preparing quantitative measures to guide the monitoring decision process. The MoE is also developing data quality objectives, monitor siting guidance, SOPs, quality assurance (QA) guidelines, and data validation procedures for dissemination on the Internet.

2. MONITORING OBJECTIVES

This section describes key pollutant concentration targets and typical monitoring objectives. This information is relevant to the following sections of the report.

2.1 POLLUTANT CONCENTRATION TARGETS

Air pollutant concentrations of concern in the monitoring network include the Canada-wide Standards (CWS) and the National Ambient Air Quality Objectives (NAAQO). Air pollutants that have been identified by agencies as needing to be managed are targeted for either CWS or NAAQO development, but not both.

2.1.1 CWS

The CWS, shown in **Table 2-1**, are intended to be achievable targets that will reduce health and environmental risks within a specific timeframe. These standards are set for ozone and particulate matter with a diameter less than or equal to 2.5 micrometers (µm), $PM_{2.5}$.

Table 2-1. Canada-wide standards.

Pollutant	Averaging Time	Target Goal
Ozone (O_3)	8 hours	65 ppb
$PM_{2.5}$	24 hours	30 $\mu g/m^3$

To be reported by 2010

2.1.2 NAAQO

NAAQO identify benchmark levels of protection for people and the environment. NAAQO guide federal, provincial, territorial, and regional governments in making risk-management decisions, playing an important role in air quality management (e.g., local source permitting, the air quality index (AQI), and as benchmarks for developing provincial objectives and standards). NAAQO are viewed as effects-based long-term air quality goals.

Until 1998, Canada had a three-tiered system of NAAQO (**Table 2-2**). Objectives were established under this system for sulfur dioxide, carbon monoxide, nitrogen dioxide, total suspended particulates and ground-level ozone. The maximum acceptable level was considered the achievable target for federal and provincial air quality management actions. The three-tiered system of NAAQO has been replaced to reflect current understanding of the continuum of health and environmental effects caused by air pollution.

The current framework establishes a single-level NAAQO, which is a national goal for outdoor air quality that protects public health, the environment, or aesthetic properties of the environment. It is primarily effects-based but reflects technological, economic, and societal information. The current framework represents the air quality management goal for the protection of the general public and the environment of Canada.

Table 2-2. Three-tiered system of NAAQO used in Canada until 1998.

Pollutant	Averaging Time	Maximum Desirable Level	Maximum Acceptable Level	Maximum Tolerable Level
Sulfur dioxide (SO_2)	annual 24 hours 1 hour	11 ppb 57 ppb 172 ppb	23 ppb 115 ppb 334 ppb	— 306 ppb —
Total Suspended Particulate (TSP)	annual 24 hours	60 µg/m^3 —	70 µg/m^3 120 µg/m^3	— 400 µg/m^3
Carbon Monoxide (CO)	8 hours 1 hour	5 ppm 13 ppm	13 ppm 31 ppm	17 ppm —
Nitrogen Dioxide (NO_2)	annual 24 hours 1 hour	32 ppb — —	53 ppb 106 ppb 213 ppb	— 160 ppb 532 ppb
Ozone (O_3)	annual 24 hours 1 hour	— 15 ppb 51 ppb	15 ppb 25 ppb 82 ppb	— — 153 ppb

2.1.3 Air Quality Index (AQI)

An AQI is a way of transforming complex air quality measurements into a single number or descriptive term. The BC AQI follows Federal guidelines: Good is 0 to 25, Fair is 26 to 50, Poor is 51 to 100, and Very Poor is 100+. An AQI in excess of 50 represents the point at which the BC MoE becomes concerned about the impact level on human health <http://www.env.gov.bc.ca:8000/pls/aqiis/air.info>.

The AQI is computed hourly using continuous measurements of common air pollutants. The AQI is the reported value of the pollutant with the highest AQI number. When BC issues the AQI, it typically notes which pollutant is "driving" the AQI. The AQI for a given concentration of each pollutant is determined from a set of linear interpolations which start at zero and go through break points at AQI values of 25, 50, and 100. These break points represent the limits of good, fair, and poor air quality, respectively. The ambient values of the break points for the different pollutants measured over a set of averaging periods are shown in **Table 2-3**.

Table 2-3. AQI breakpoint values used in British Columbia.

Parameter	Sulfur Dioxide (SO_2) ppm		Carbon Monoxide (CO) ppm		Nitrogen Dioxide (NO_2) ppm	Ozone (O_3) ppm	PM_{10} µg/m^3
Averaging Time	1-hr	24-hr	1-hr	8-hr	1-hr	1-hr	24-hr
AQI = 25	0.17	0.06	13	5.0	0.105	0.05	25
AQI = 50	0.34	0.11	30	11.0	0.210	0.08	50
AQI = 100	2.00	0.30	64	17.4	0.530	0.15	100

2.1.4 Air Quality Health Index (AQHI)

Another important air pollution metric is the Air Quality Health Index (AQHI), which reports on the health risk posed by a mixture of pollutants including ground-level ozone, PM, and NO_2. The AQHI is a national initiative, developed in partnership with federal, provincial, and municipal governments and agencies. The AQHI takes into account how the level of exposure to multiple pollutants, even at low levels of exposure, can affect health. The index rating for the AQHI is the sum of the health risks from each of the pollutants in the index. In BC, the AQHI is reported on the Internet (http://www.airplaytoday.org/).

2.2 MONITORING OBJECTIVES

Monitoring networks may be used to meet a variety of purposes. Key monitoring objectives in BC and an overview of measurements/monitoring needed to meet the objectives are shown in **Table 2-4**. The table illustrates that key monitoring objectives can have different data requirements in terms of pollutants measured and sample duration and frequency.

Table 2-4. Key BC monitoring objectives and data needs.

Monitoring Objectives	Data Needs
Compliance with CWS	Continuous (i.e., 1-hr) ozone and $PM_{2.5}$ mass
Track progress toward NAAQO	Continuous SO_2, NO_2, CO; 24-hr average TSP
Public reporting of AQI or AQHI	AQI: Continuous SO_2, NO_2, ozone, CO, or PM_{10} AQHI: Continuous ozone, $PM_{2.5}$, PM_{10}, and NO_2
Assessing trends	Regular measures[a] of any single parameter for more than five years
Source apportionment	Speciation of $PM_{2.5}$, air toxics, or volatile organic compounds (VOCs); can be combined with other parameters
Airshed management and planning	Regular measures of pollutants identified in the plan
Assessing, tracking background concentrations (airshed, regional, global)	Continuous or periodic measures of criteria pollutants; high sensitivity monitoring is required. Other pollutants may be of interest

[a]Where measurements meet completeness requirements for the metric of interest (e.g., 75% of 24-hr measurements needed to create annual average).

Other monitoring objectives important to the provincial network are to support air quality management plans (AQMPs); assess population exposure to pollutants; assess pollutant transport; assess environmental impact; monitor specific emissions sources; monitor background conditions; and evaluate models.

2.3 DATA QUALITY OBJECTIVES

The data quality objective (DQO) process is used to establish performance or acceptance criteria, which serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of a study. Guidance on the DQO process is provided by the U.S. Environmental Protection Agency (2006). DQOs for the provincial monitoring network are being developed by the MoE.

3. MONITORING DECISIONS

3.1 STEPS IN THE DECISION PROCESS

Throughout the Province, new monitors are requested by communities, required by permit applicants, needed to support AQMPs, and called for to support research or other measurement needs. The overall thought process for deciding whether a monitor is required in a community is shown in **Figure 3-1**.

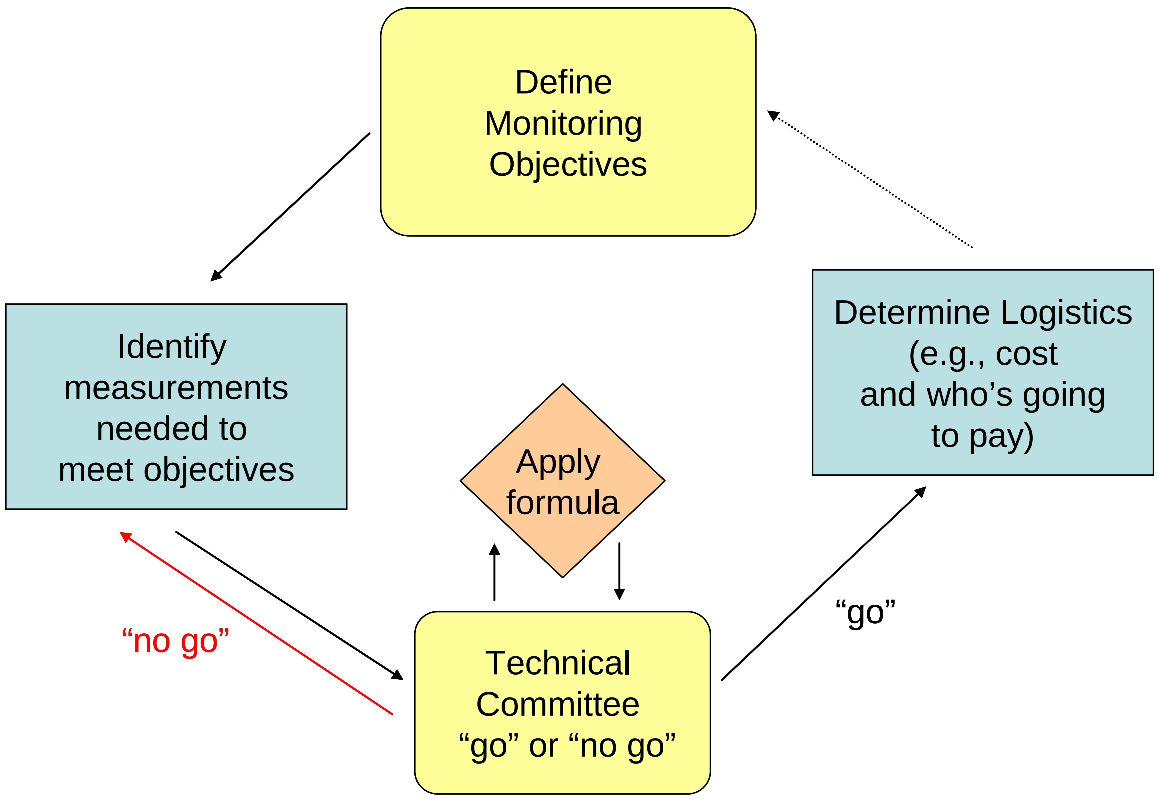

Figure 3-1. Schematic diagram of the decision process.

New monitor requests should define monitoring objectives and identify measurements needed to meet those objectives. The MoE Technical Committee will use selection criteria to determine if the request makes sense. A formula will be used to determine whether the site is "go" or "no go". A "go" decision then leads to determining logistical information, particularly cost and financial responsibility. It may be necessary to restart the process to narrow the monitoring objectives and data requirements to fit the budget available.

To support the decision-making process, a series of definitions is required. The MoE currently classifies sites into five basic types as outlined in **Table 3-1**: core, hot spot, permittee, mobile, and special study. Site-type classification is based on the sites' locations and permanence, not by the sites' financial sponsors. **Table 3-2** summarizes the potential monitoring objectives that could be filled by the different site types. Note that a core site could be used to meet any of the monitoring objectives identified in the table, but cannot meet all the objectives at the same time.

Table 3-1. Site types, description/purpose, and type of monitoring to be conducted.

Site Type	Description/Purposes	Type of Monitoring
Core site	Likely urban scale-, higher population-based (e.g., over 25,000); full complement of measurements.	Minimum of three pollutants (ozone, $PM_{2.5}$, NO_2). Could be funded by MoE, community, permittee, or a combination.
Hot spot	High concentration site or near-source site – typically a small community, neighborhood scale, permanent site.	Could be a single parameter.
Permittee	Permit-defined location; typically “fenceline” to track a specific facility.	Permit-defined parameters; could be a single parameter.
Surveillance/mobile	Semi-permanent; typically used to establish baseline or fill data gaps. Established for 1 to 3 years to assess monitoring objectives.	Could be a single parameter.
Special study	Short-term studies to support source apportionment, assessment of spatial variability, or identification of parameter(s) of interest.	Can include moving monitor (vehicle, aircraft), non-routine measurements (e.g., passive sampling, PM speciation), or research-grade instrumentation. Can include long term background monitoring of CAC’s/Toxics

Table 3-2. Monitoring objectives by site type.

Monitoring objective	Core Site	Hot Spot	Permittee	Surveillance/ Mobile	Special Study
CWS compliance	X			X	
NAAQO progress	X				
AQI or AQHI reporting	X	X			
Trends	X	X	X	X	
Source apportionment	X	X	X		X
Air shed management	X	X	X	X	X
Population exposure	X	X			X
Transport assessment	X				X
Compliance with permit	X		X		
Environmental impact assessment	X		X	X	X
Background	X			X	X
Model evaluation	X				X

3.2 MAKING THE DECISION TO INSTALL A NEW MONITOR

The MoE Technical Committee will use the criteria in **Table 3-3** to assist in forming their site-selection decisions. *Quantitative measures need to be developed to guide the decision process.* The considerations for monitoring are as follows:

- The first step is to assure that the community meets the population threshold. Early consensus is that all communities with more than 25,000 people should have at least one monitoring site for $PM_{2.5}$ and ozone to be able to track the CWS. Areas with “large area served” designation are also important to ensure that parts of BC with sparse monitoring and low population are considered.
- If concentrations are known, communities measuring concentrations closer to the standard are a higher priority than communities measuring lower concentrations.
- Areas with increasing population have priority over areas where population is decreasing.
- Areas with increasing emissions, new facilities, or high emissions relative to other areas have priority.

- Sites monitoring more than a single parameter are more desirable than those monitoring a single parameter. For core sites, a full complement of measurements (NO_x, SO_2, PM_{10}, $PM_{2.5}$, O_3) and H_2S monitoring, where applicable, is desirable.
- Areas with an existing air quality management plan or one being developed have priority over those without.
- Partnerships and permittee and community involvement are desirable.

Table 3-3. Site selection criteria.

Consideration	More Desirable	Less Desirable
Population or area served[a]	Larger	Smaller
Potential health impact	High (closer to standard, high AQHI)	Low
Population change	Increasing	Decreasing
Emissions	New facilities; increasing	Decreasing
Area served	Large	Small
Number of parameters addressed	More	Fewer
AQMP	In place, planned	Not in place or planned
Partnerships, non-MOE funds	Available	Not available
Permittee involvement	Involved	Not involved
Community involvement	Involved	Not involved

[a] Population that falls within the geographic area of representation of a monitor.

Table 3-5 provides site selection priorities by site type. The table lists the consideration and the more desirable characteristics for site selection. Core site selection is consistent with these more desirable characteristics. For the other site types, the considerations may be consistent with core site selection, have lower priority, or may differ.

Table 3-4. Site selection criteria by site type.

Consideration	More Desirable	Core	Surveillance/ Mobile	Hot Spot	Special Study
Population or area served	Larger	✓	Lower priority	n/a	Lower priority
Potential health impact	High (closer to standard, high AQHI)	✓	✓	✓	✓
Population change	Increasing	✓	Lower priority	Lower priority	Lower priority
Emissions	New facilities; increasing	✓	Lower priority	Lower priority except for near-source	Lower priority
Area served	Large	✓	Lower priority	Small	Lower priority
Number of parameters addressed	More	✓	Lower priority	Lower priority	✓
AQMP	In place, planned	✓	✓	Lower priority	✓
Partnerships, non-MOE funds	Available	✓	✓	✓	✓
Permittee involvement	Involved	✓	✓	✓	✓
Community involvement	Involved	✓	✓	✓	✓
Other			Higher priority to areas in which other monitors do not exist		Higher priority to complex airshed

✓ = Same priority as listed
n/a = not applicable

3.2.1 Core Sites

Core site development is outlined in the decision tree shown in **Figure 3-2**. For sites that meet the population or area served requirements, the first consideration is whether the community has existing monitoring in place. If monitoring is in place, but not all core pollutants are measured, the missing pollutants are added to the site. If a community has no monitoring, the MoE will review the network recommendations, investigate emissions and population density, and establish a representative site. For core sites, the MoE will perform a periodic network assessment to determine if more monitoring is needed. The U.S. EPA recommends that network assessments be conducted every five years.

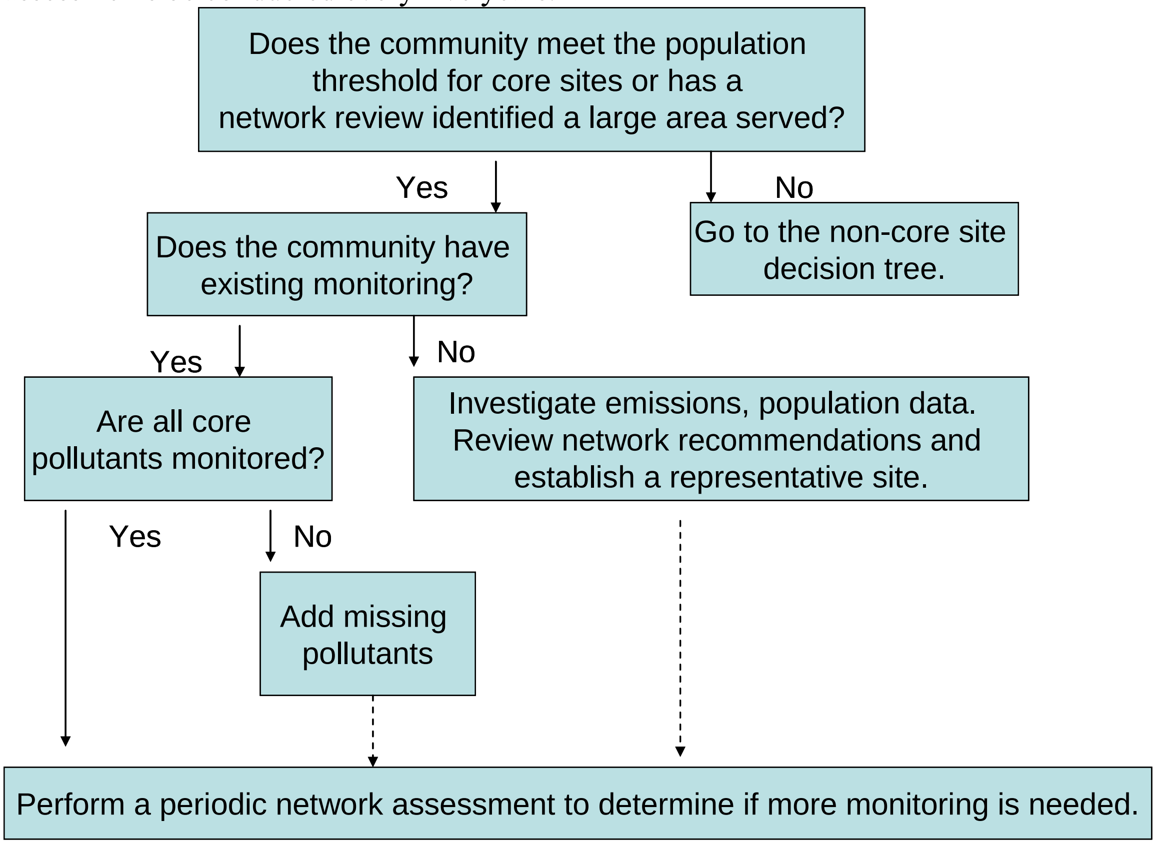

Figure 3-2. Decision tree for core sites.

3.2.2 Surveillance/Mobile and Hot Spot Sites

If the proposed community is smaller than the core site requirement and is selected for monitoring, **Figure 3-3** offers a decision tree for considering a surveillance/mobile site. If monitoring does not currently exist in the community, surveillance monitoring or a special study should be conducted to determine concentrations for one to three years to assess monitoring objectives. If monitoring is already being conducted and concentrations are above or near CWS or established health-effect levels, a long-term monitoring “hot spot” site should be established. If concentrations are lower than CWS or health-effect levels and population or emissions are expected to increase, surveillance monitoring is recommended to periodically check air quality. If population or emissions are not expected to increase in the area, less frequent checks of air quality are required.

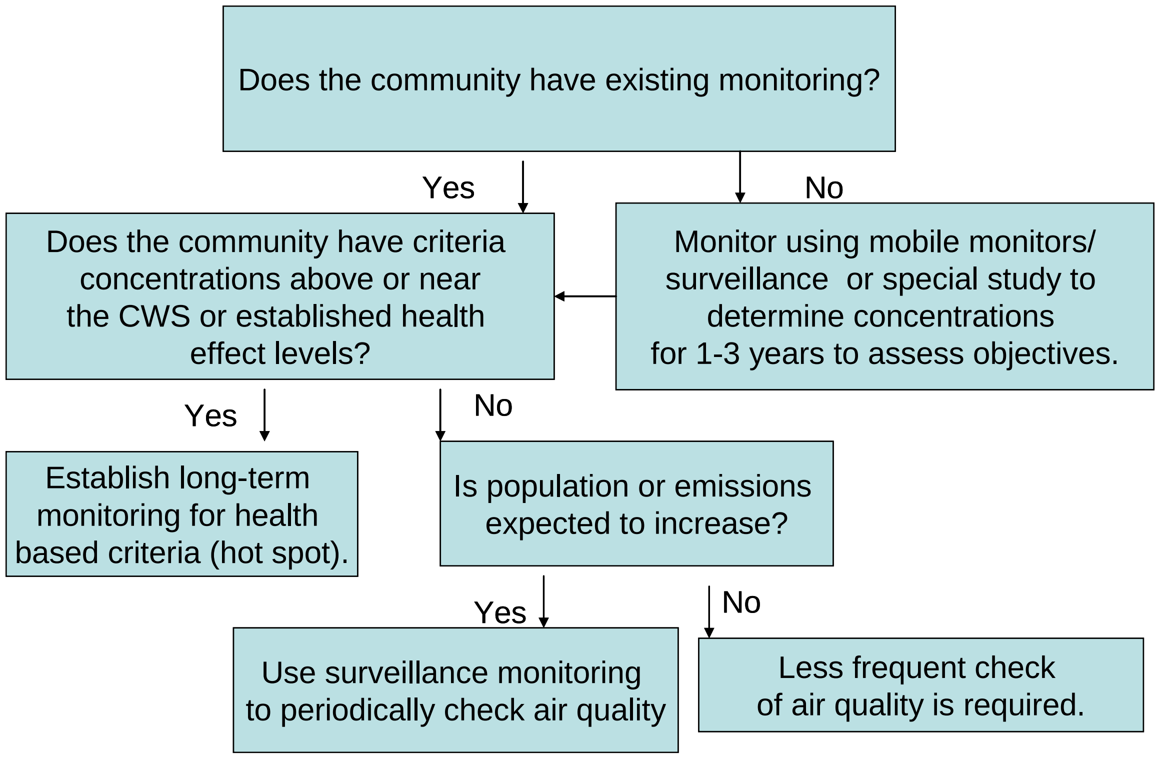

Figure 3-3. Decision tree for surveillance/mobile and hot spot sites.

3.2.3 Special Study Sites

For a special study, the community needs to show that a compelling scientific question is not being addressed by existing monitoring (**Figure 3-4**). New instrumentation can be added to an existing site, or new sites can be added depending on the monitoring objectives. Monitoring should be conducted for one to three years to assess monitoring objectives. This type of study can be seasonal, episode-specific, or continuous depending on monitoring objectives. After data are collected, the decision tree shown in Figure 3-3 can be followed.

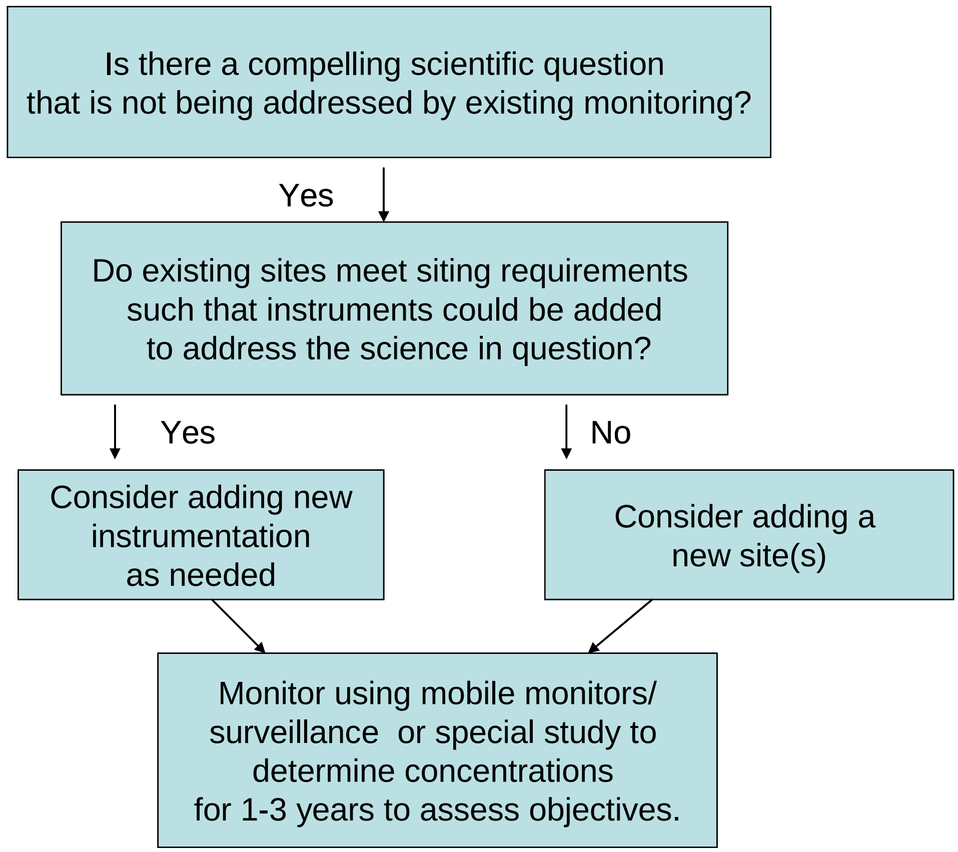

Figure 3-4. Decision tree for identifying special study sites.

3.2.4 Permittee Sites

Permittee sites are handled separately from the sites discussed in this section. However, these sites should be considered when assessing any monitoring network. The funds used to operate a potentially redundant permittee site may better serve public outreach, data analysis, emissions control, or addressing other environmental concerns.

3.3 STAGING MONITORS

The MoE envisions monitoring decision-making as an evolving process. For new communities and non-core sites, when monitoring has been approved and funds are made available, the surveillance step is to obtain a one- to three-year baseline of measurements (see **Figure 3-5**). Results can be considered as follows:

- If concentrations are low, i.e., well below maximum desirable levels or CWS, no further measurements would be made with the exception of possible surveillance every few years. Periodically, the MoE would assess whether new emissions sources have been added to the air shed or the population has increased significantly. In either case, surveillance monitoring could be restored.
- If concentrations are higher, i.e., ≥ 80% of the standard, a monitoring site may be considered a "hot spot" site and additional monitoring is likely warranted. Monitoring could include single parameter or a more ambitious special study might be initiated to more fully understand the sources of higher concentrations.

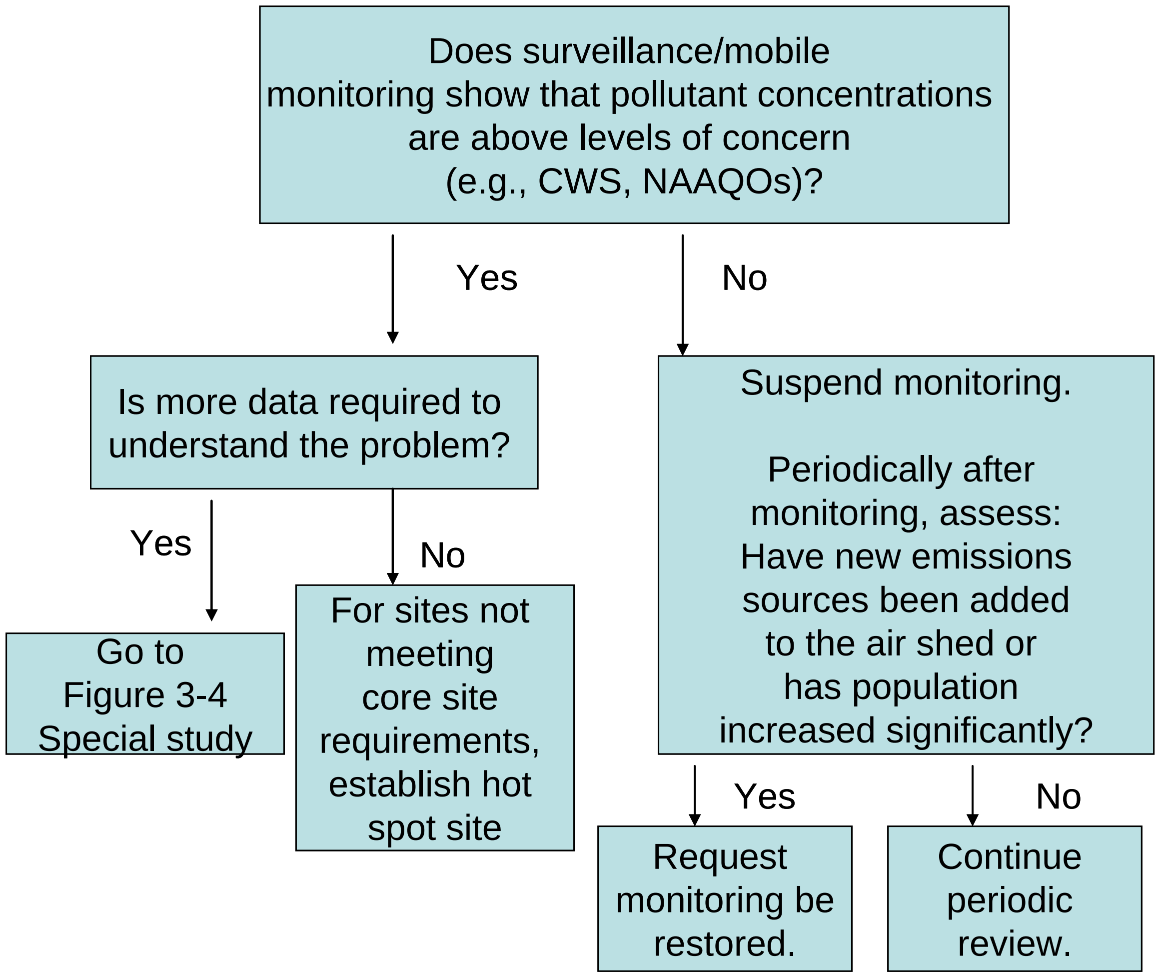

Figure 3-5. Process for evaluating the next steps in monitoring after initial measurements have been made.

In evaluating the monitoring objectives by site type, core sites should be given the highest priority followed by surveillance/mobile sites, hot spot sites, and special study sites. A surveillance/mobile site can evolve into a hot spot site (low population area), special study site (more information is needed) or core site (area grows to meet population target). All site types require periodic checks of population, emissions, and measured concentrations relative to monitoring objectives.

3.3.1 Community Based Monitoring

In some instances, communities wish to run and maintain air monitoring at their own cost where no MOE monitoring is set up, or where they wish to add sites additional to existing MOE ones. The framework allows for MOE to do monitoring in these instances on a short term basis if concentrations/populations do not justify longer term monitoring. Short term special studies, mobile or rotating surveillance monitoring is available for communities with smaller populations/lower concentrations and can be very valuable in assessing sources and concentrations quickly.

If an instance arises where rotating surveillance monitoring or short term studies offered by MOE is not satisfactory to the community, and they wish to maintain long term monitoring, MOE's response is as follows:

- The data will be accepted by MOE only under the following conditions:
    - Siting of the station is to EPA/MOE standards
    - Instrumentation is EPA/NAPs certified for ambient air monitoring in BC
    - Maintenance and operation is done according to EPA/MOE standards
    - Data is validated by MOE (a fee will be charged for this service)
    - Stations/Instrumentation are audited by MOE's air audit team (a fee will be charged for this service)

The goal of this framework is to provide adequate monitoring on a prioritized basis for all citizens of BC. Wherever possible, MOE staff should work with communities to provide the most effective monitoring option available according to the situation and criteria.

3.4 NETWORK REVIEW

An air monitoring network consists of many sites equipped with a range of instrumentation. Sites may have been installed to accomplish a single monitoring objective or several objectives, and these monitoring objectives may change or have changed over time. Site characteristics may also have changed so that a site is no longer suitable for collection of data to meet a particular monitoring objective. Some sites or instruments may be redundant, while new sites, instruments, or air pollutant measurements may be needed.

As a result of these changes, air monitoring networks may be characterized by unnecessary or redundant monitors or ineffective and inefficient monitoring locations for some pollutants, while other regions or pollutants suffer from a lack of monitors. Monitoring agencies need to adjust their networks to protect today's population and environment while maintaining the ability to understand long-term historical air quality trends. Moreover, monitoring networks can benefit from new air monitoring technologies and improved scientific understanding of air quality issues. Existing monitoring networks should be designed to address multiple, interrelated air quality issues and to better operate with other types of air quality assessments (e.g., source apportionment and emission inventory assessments). Reconfiguring air monitoring networks can enhance their value to stakeholders, scientists, and the general public.

Regional/local monitoring networks should be reviewed every five years to continue to eliminate redundant monitors; adapt to changing population, pollutant concentrations, regulations, and emissions; and adjust measurement protocols to ensure data quality. Permittee sites should be included in these reviews.

A network review was performed at the Provincial level in 2007 (Hafner and Penfold, 2007). The goal was to review the MoE's active air quality monitoring network (not including meteorological networks). The review covered each active monitor site in each region in BC (except the GVRD and Fraser Valley). Results helped build this document and provide examples of applicable analyses for future network reviews:

- Number of parameters monitored (**Figure 3-6**). Sites are ranked by the number of parameters measured at a particular site. Air quality monitoring sites hosting monitors collocated with other measurement instruments are likely more valuable than sites at which fewer parameters are measured. In addition, the operating costs can be leveraged among several instruments at these sites. This analysis can be performed by simply counting the number of other parameters that are measured at a physical site.

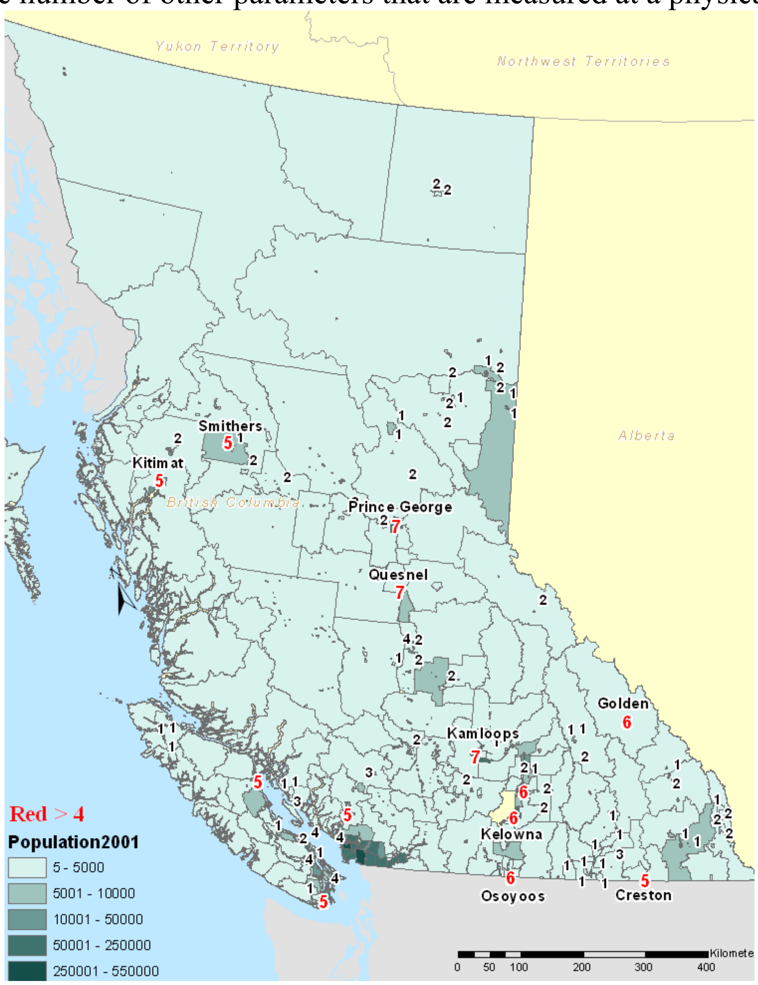

Figure 3-6. Number of parameters monitored in 2005 overlaid on population density (2001 census). Note that GVRD and Fraser Valley are excluded.

- Trend impacts. Monitors with a long historical record are valuable for tracking trends. Monitors are ranked based on the duration of their continuous measurement records.
- Deviation from standard (**Figure 3-7**). Sites measuring concentrations that are very close to a standard exceedance threshold are ranked high in this analysis. These sites may be considered more valuable for compliance evaluation. Sites measuring concentrations well above or below the threshold do not provide as much information in terms of compliance. This technique contrasts the difference between the standard (e.g., CWS) and the actual measurements and is a simple way to assess a site's value for evaluating compliance. For this analysis, CWS for ozone and $PM_{2.5}$ can be used as well as maximum desirable levels from the NAAQO for SO_2, TSP, CO, NO_2, and ozone.

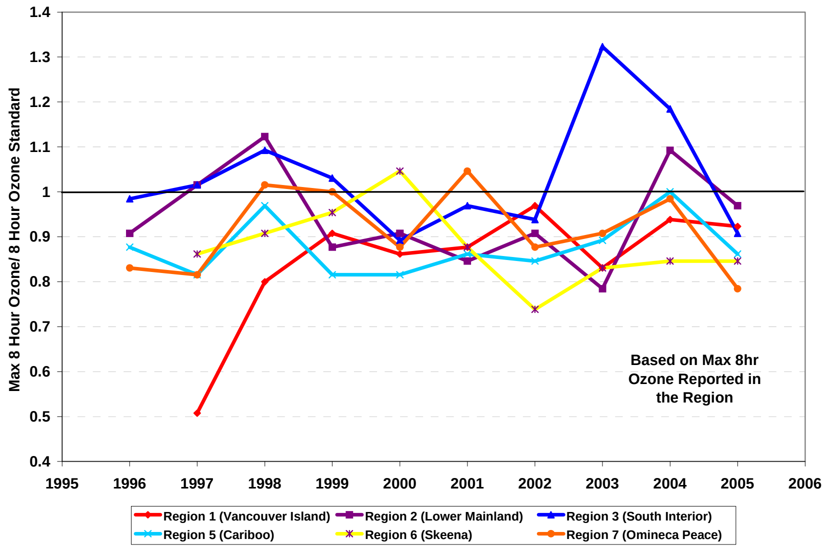

Figure 3-7. Comparison of 8-hr ozone to the standard by region, based on the maximum 8-hr value reported in each region.

- Measured concentrations (**Figure 3-8**). Individual monitors are ranked by the concentrations of pollutants they measure. Monitors in locations with high concentrations are ranked higher than monitors in areas with low concentrations. Results can be used to determine those monitors that are less useful in meeting the selected objective. The analysis is relatively straightforward, requiring only the site concentrations—the greater the concentration, the higher the site rank. If more than one standard exists for a pollutant (e.g., annual and 24-hr average), monitors can be scored for each standard.
- Area served (**Figure 3-9**). Sites are ranked by the amount of geographic area they represent. This technique gives the most weight to sites that represent large areas.

Figure 3-8. Twenty-four-hour $PM_{2.5}$ values for each region for 2005. If maximum values exceed the CWS, a site is considered to have high values (red). If measured concentrations are below this level, a site is considered to have low values (blue). Concentrations at many sites were above the CWS (30 µg/m^3). Note that GVRD and Fraser Valley are excluded.

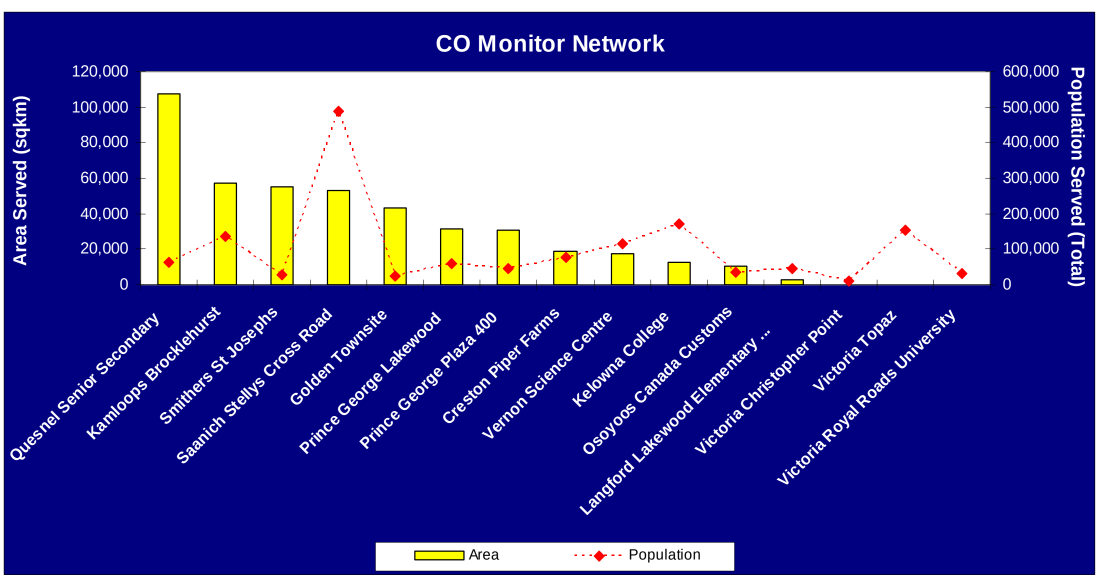

Figure 3-9. Summary of population and area served by site for CO. Small population- and small area-served sites may be candidates for reassessment.

- Population served (**Figure 3-10**). Large populations are associated with high emissions. Sites are ranked by the number of people they represent. Populations at the sub-division level that fall within the area of representation of a monitor are assigned to that monitor. This technique gives the most weight to sites in densely populated areas.

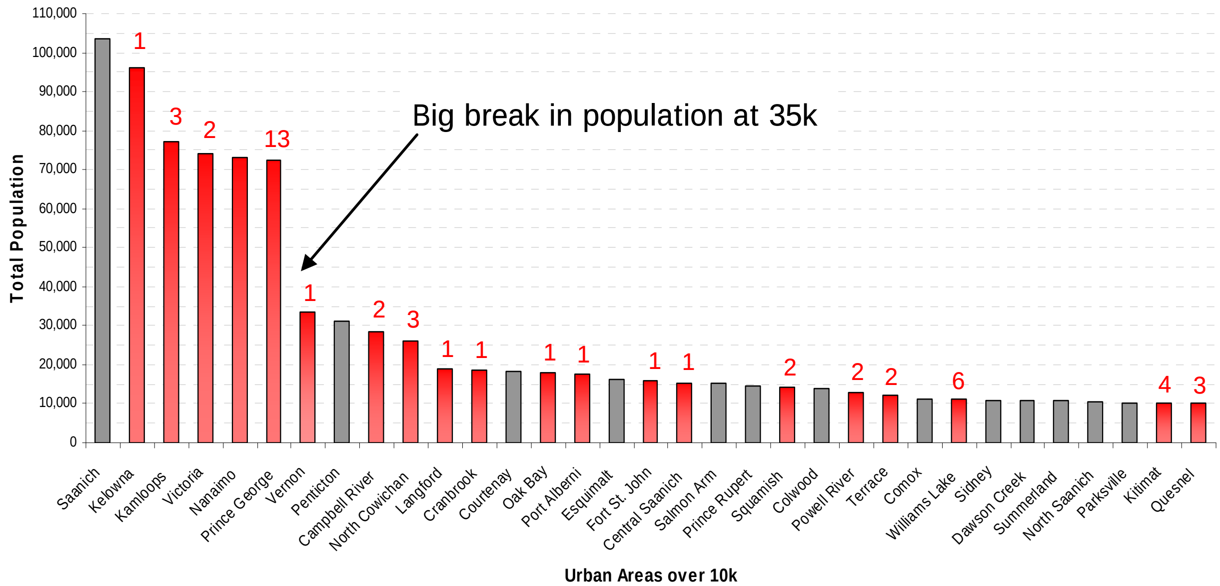

Figure 3-10. Community (urban) population annotated with monitor coverage. Red—monitor present (number represents count of monitors); grey—no monitor within community. There are 74 monitors in areas under 10,000 (small towns and rural areas not shown).

- Population change (**Figure 3-11**). High rates of population increase are associated with potential increased emissions activity and exposure. Sites are ranked by population increase in the area of representation. The total population change at the sub-division level that falls within the area of coverage of a monitor is assigned to that monitor. This technique gives most weight to sites in areas with high rates of population growth and large areas of representation.

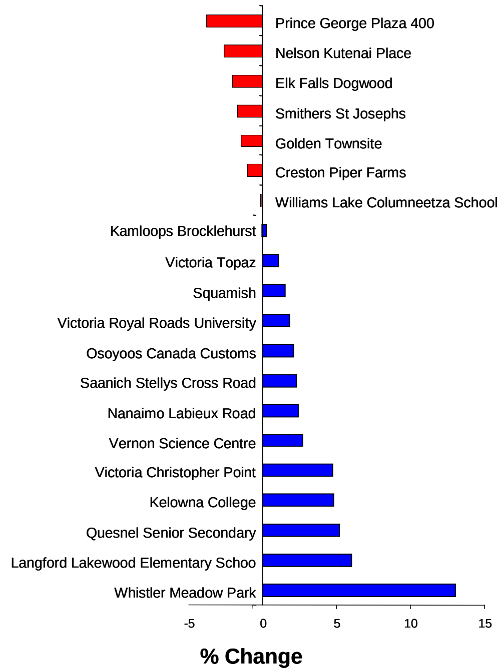

Figure 3-11. Example of percent change in population (1996-2001) in areas surrounding ozone monitoring sites.

- <u>Principal component analysis (PCA)</u> (**Figure 3-12**). PCA can be applied to find monitoring sites that show a pattern of variability similar to those of other monitoring sites. PCA assigns each monitor to a group of monitors at which pollutant concentrations behave similarly. This analysis can be useful for identifying redundancy in a network. It is also useful in selecting sites for other analyses (e.g., source apportionment). Hourly or daily samples with a high percent of data completeness at each site are required to perform the analysis.

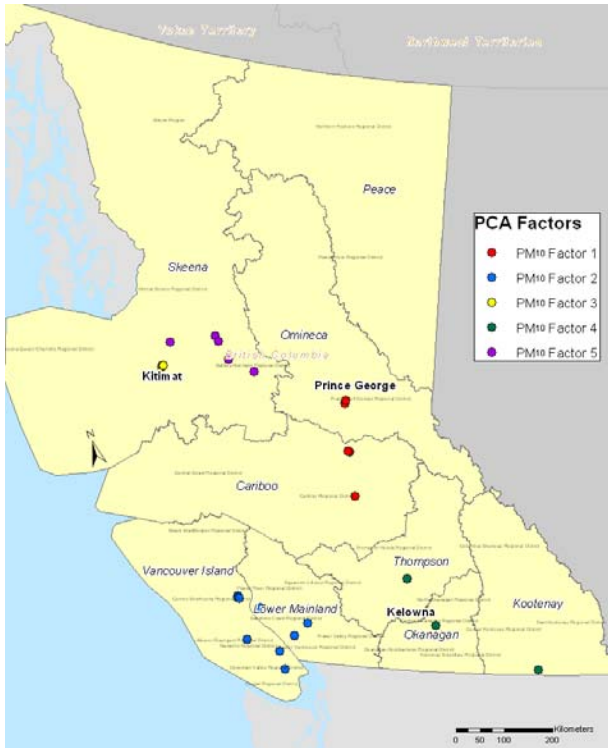

Figure 3-12. PCA results for PM_{10} concentrations. Similar temporal patterns were found among some site groupings; however, correlations between sites within factors were not strong.

- Emission inventory comparison (**Figure 3-13**). Emission inventory data are used to find locations where emissions of pollutants of concern are concentrated. Utilizing gridded emissions from Environment Canada and point source locations from BC, monitors can be assigned emission estimates depending on where they are located relative to gridded emission estimates. Monitors that are located in areas of high emission estimates are ranked high. Regional-level emission estimates can also be compared to the number of monitors within each region.

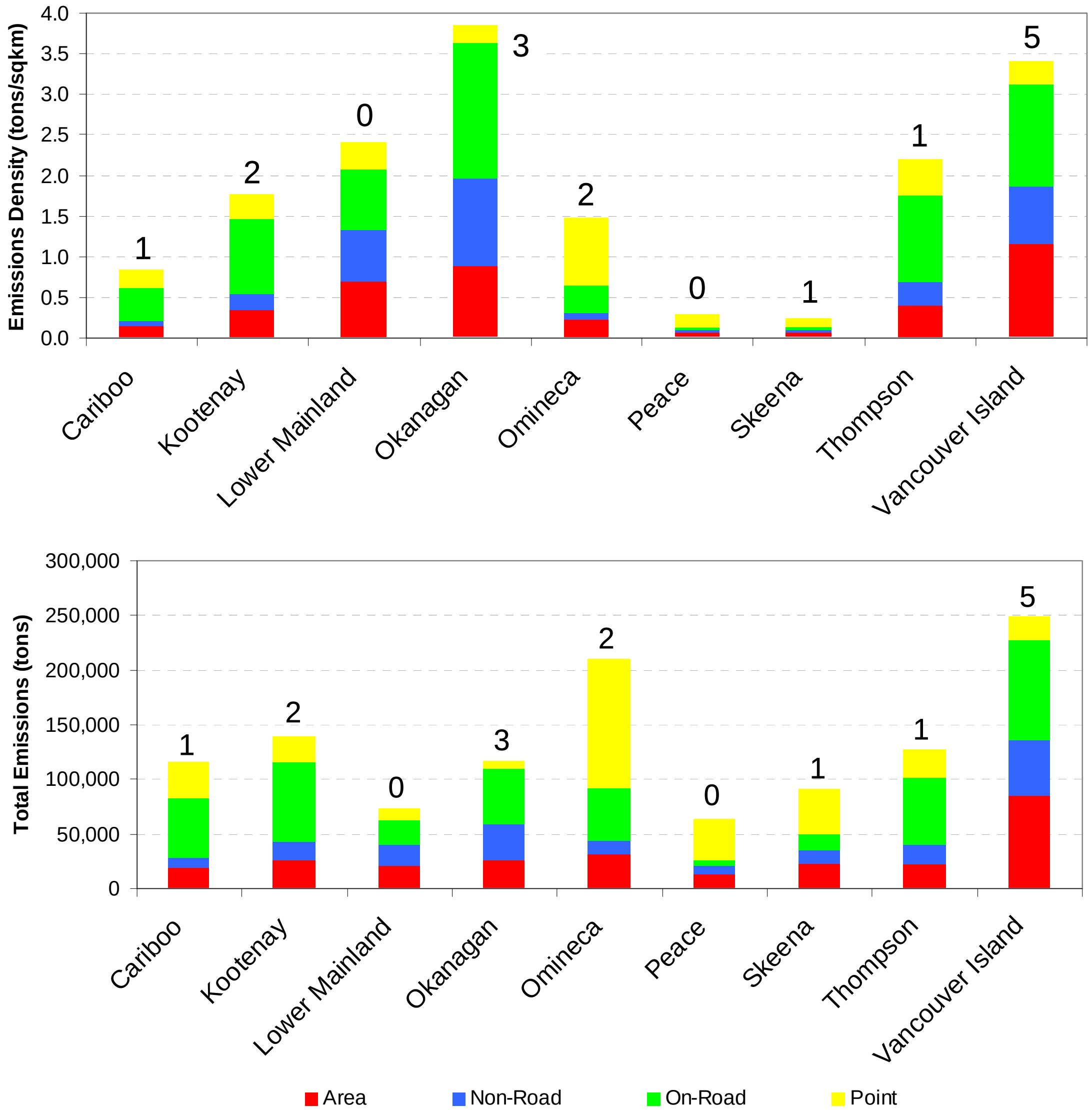

Figure 3-13. CO emissions density and total emissions by region (with number of CO monitors by region).

- Removal bias (**Table 3-5**). Measured values can be interpolated across a domain using the entire network. Sites are then systematically removed and the interpolation repeated. The absolute difference between a concentration measured at a site and the concentration predicted by interpolation with the site removed is the site's removal bias. Greater bias or uncertainty indicates a more important site for developing interpolations to represent concentrations across a domain. Those sites with low bias may be providing redundant information.

Table 3-5. Removal bias results for PM_{10}. Base Conc represents the interpolated annual average concentrations (in $\mu g/m^3$) when all PM_{10} sites (with 2005 data) are used. Removed Conc is the interpolated value of the site location when the interpolation is run minus that site. Removal Bias is the Base Conc minus Removed Conc.

Site Name	Region	Base Conc	Removed Conc	Removal Bias
Fort Nelson Chalo School	Omineca	16.92	23.34	-6.42
Powell River Cranberry Lake	Lower Mainland	9.62	12.65	-3.02
Osoyoos Canada Customs	Southern Interior	11.45	14.24	-2.79
Whistler Meadow Park	Lower Mainland	12.41	15.12	-2.71
Kitimat Riverlodge	Skeena	11.02	12.80	-1.78
Nelson Kutenai Place	Kootenay	33.35	35.00	-1.66
Nanaimo Labieux Road	Vancouver Island	11.35	12.16	-0.81
Golden Hospital	Kootenay	41.50	42.14	-0.64
Williams Lake CRD Library	Cariboo	18.64	19.13	-0.49
Quesnel West Correlieu School	Cariboo	20.33	20.81	-0.48
Terrace BC Access Centre	Skeena	12.58	12.71	-0.13
Crofton South	Vancouver Island	12.22	12.16	0.06
Prince George Gladstone School	Omineca	23.74	23.57	0.17
Williams Lake Columneetza School	Cariboo	18.24	17.33	0.91
Saanich Stellys Cross Road	Vancouver Island	13.60	12.64	0.96
Williams Lake Skyline School	Cariboo	18.64	17.65	1.00
Quesnel Maple Drive	Cariboo	20.33	19.30	1.03
Houston Firehall	Skeena	22.54	19.24	3.30
Creston PC School	Kootenay	37.38	29.33	8.05

Analysis at a regional or community level is needed periodically. Annual review of data is ideal. In-depth statistical and economical analysis and community/stakeholder involvement is recommended in the network review process (recommended at least every five years).

3.5 COMMUNICATION

It will be important for the MoE and regional monitoring staff to effectively communicate the monitoring decision process, plans, and objectives to the communities. By working directly with stakeholders and the community, expectations can be kept at a realistic level. It is vital that stakeholders understand the type of monitoring to be conducted, scheduled length of monitoring, monitoring objectives, and costs.

4. MONITORING DETAILS

4.1 MONITORING INSTRUMENT SELECTION

The goals of the MoE are to ensure provincial consistency in monitoring methods, priorities, and objectives; use high quality instrumentation to meet current monitoring objectives and standards; and use US EPA Federal Reference Method (FRM) monitoring methods wherever continuous PM methods are used to ensure high quality data comparison across regions. For core, permittee, surveillance, and hot spot sites, the MoE requires U.S. EPA FRM and Federal Equivalent Method (FEM) instruments. For special studies sites, research grade instruments are permissible. Furthermore, when old instruments are to be replaced, it is recommended that sufficient overlap be made between the old and replacement instruments so that relationships can be established for trends sites. Standard operating procedures (SOPs) are available from the MoE.

4.2 MONITORING SITING

Monitor siting guidance is to be provided on an MoE web site.

4.3 DATA VALIDATION

The quality and applicability of data analysis results directly depend on the inherent quality of the data. In other words, data validation is vital because serious errors in data analysis and modeling results can be caused by erroneous individual data values. Standard quality requirements for sampling and analysis should be applied across the Province. It is the monitoring agency's responsibility to prevent, identify, correct, and define the consequences of difficulties that might affect the precision and accuracy, and/or the validity, of the measurements.

Once the quality-assured data are provided to the MoE, additional data validation steps need to be taken. Established data validation guidelines for speciated $PM_{2.5}$ data are available in the $PM_{2.5}$ workbook (Main and Roberts, 2001), through the IMPROVE program documentation (http://vista.cira.colostate.edu/improve/), and through the U.S. EPA (http://www.epa.gov/ttn/amtic/pmqainf.html).

The framework calls for collocated data (such as those from FRM monitors with continuous PM instruments) so that analysts can explore and understand the relationships and potential biases. Also, the Province needs to allow sufficient funds for replicate laboratory analyses so that data uncertainty is understood.

It is vital to understand data quality (uncertainty, precision, accuracy) so that regional data can be compared to data collected throughout the Province, nation, and with data collected in the United States. If Canadian laboratories are used, they should be encouraged to enter into inter-laboratory comparisons with U.S. laboratories for speciation. If U.S. laboratories are used, the QA information should be obtained, reviewed, and disseminated to regional data analysts.

To ensure data quality, the MoE needs to

- require that data are reported with consistent units, naming conventions, etc.;
- provide up-to-date standard operating procedures and ensure that they are used consistently;
- schedule regular meetings among the monitoring staff to share ideas and lessons learned; and
- encourage regular reporting from the regions with respect to data completeness. Data should be regularly reviewed; timely data validation is required to minimize the generation of additional data that may be invalid or suspect and to maximize the recoverable data.

The MoE has established protocols for data validation that will be available soon on the Internet.

4.4 DATA ANALYSIS

By collecting high quality data, subsequent data analyses are enhanced. Analyses should be performed regularly. To encourage more regular analysis of air quality data, the MoE will work with the regions to develop data analysis guidelines and a template for annual reports. Analyses likely to be provided in the annual reports include summary statistics by parameter and site, comparison to CWS, summary of AQI or AQHI, perspective plots (e.g., comparison of a site or region's concentrations relative to the entire Province), and trends.

5. SUMMARY

This monitoring network framework is intended to be a living document to be expanded on in the future and enhanced by feedback from the monitoring community. The goals for moving forward with monitoring in BC include using this framework to

- focus on quality over quantity in monitoring;
- take a provincial scope and provide provincial consistency;
- ensure effective community coverage;
- use monitors efficiently;
- allow the monitoring plan to adapt to changing needs; and
- develop, adapt, and communicate data validation, data analysis, and network assessment guidance.

6. REFERENCES

Main H.H. and Roberts P.T. (2001) $PM_{2.5}$ data analysis workbook. Draft workbook prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, by Sonoma Technology, Inc., Petaluma, CA, STI-900242-1988-DWB, February.

U.S. Environmental Protection Agency (2006) Guidance on systematic planning using the Data Quality Objectives Process: EPA QA/G-4. Prepared by the U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C., EPA/240/B-06/001, February. Available on the Internet at <http://www.epa.gov/quality/qs-docs/g4-final.pdf>.