Guidelines for Air Quality Dispersion Models Critical Review & Recommendations

Prepared for:

Water, Air & Climate Change Branch
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GLOSSARY OF ACRONYMS

AAQOs	Provincial Ambient Air Quality Objectives
AERMET	meteorological processing model in AERMOD
AERMOD	AMS/EPA Regulatory MODel
AERSCREEN	screening-level version of AERMOD
ATCOOL	a model used to determine visible plume length, extent of ground-level and cloud formation for water vapour emissions from large cooling towers
AURAMS	AES Unified Regional Air-quality Modelling System
BPIP	Building Profile Input File
CAC	Common Air Contaminants
CALMET	Meteorological program in the CALPUFF Model
CALPUFF	a non-steady state Gaussian puff model developed by the Sigma Research Corporation for the California Air Resources Board
CAL3QHCR	a CALINE3-based model that predicts dispersion of inert pollutants from motor vehicles at roadway intersections
CCME	Canadian Council of Ministers of the Environment
CFD	Computational Fluid Dynamics
CAMx	Comprehensive Air Quality Model with Extensions
CMAQ	Community Multi-scale Air Quality - photochemical and pollutant transport model
CO	carbon monoxide
CTDMPLUS	Complex Terrain Dispersion Model
CTSCREEN	screening-level version of CTDMPLUS
CWS	Canada-Wide Standards
DEGADIS	Dense Gas Dispersion Model
ETA	generally known as the Meso ETA Model - a hydrostatic meteorological forecast model developed by the National Center for Environmental Prediction (NCEP)
FDM	Fugitive Dust Model
FOG	a Gaussian plume based model specifically designed for estimating plume visibility and the potential for ground-level fogging from the dispersion of water vapour emissions
GC/MS	gas chromatography /mass spectrometry
GEP	Good Engineering Practice
GVRD	Greater Vancouver Regional District
HGSYSTEM	a collection of computer programs to predict the source term and dispersion of accidental chemical releases, with an emphasis on denser-than-air gases
ISC3	Industrial Source Complex Model (Version 3)

ISC3-PRIME	ISC3 model with Plume RIse Model Enhancements
ISC3-PRIME-S	screening-level version of ISC-PRIME
IWAQM	Interagency Workgroup on Air Quality Modeling
MC2	Mesoscale Compressible Community Model
MIXH	program developed by the MWLAP for calculating screening-level mixing heights
MM5	5th generation Pennsylvania State University/NCAR meteorological Mesoscale Modeling System
MODELS3	a comprehensive modelling framework currently being developed by the USEPA
MPRM	Meteorological Processor for Regulatory Models
MWLAP	Ministry of Water Land and Air Protection
NAAQOs	National Ambient Air Quality Objectives
NCDC	National Climate Data Center
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
OCD	Offshore and Coastal Dispersion Model
OLM	Ozone Limiting Method
PLUVUE-II	a model used for estimating the visual range reduction and atmospheric discolouration caused by plumes from particulate matter, oxides of nitrogen or sulphur oxides
PM	particulate matter with a nominal aerodynamic diameter of less than or equal to 30 microns
$PM_{2.5}$	particulate matter with a nominal aerodynamic diameter of less than or equal to 2.5 microns
PM_{10}	particulate matter with a nominal aerodynamic diameter of less than or equal to 10 microns
POI	Point of Impingement
PSD	Prevention of Significant Deterioration
PVMRM	Plume Volume Molar Ratio
QA/QC	Quality Assurance / Quality Control
RAMS	Regional Atmospheric Modelling System
REMSAD	Regulatory Modeling System for Aerosols and Deposition
RTDM	Rough Terrain Diffusion Model
SACTI	Seasonal/Annual Cooling Tower Impacts Model
SAIC	Science Applications International Corporation
SCREEN3	an easy-to-use dispersion model for obtaining pollutant concentration

	estimates based on screening-level procedures
SENES	SENES Consultants Limited
SLAB	a model that treats denser-than-air releases from ground level or elevated jets, liquid pool evaporation and instantaneous volume sources
SO_2	sulphur dioxide
SODAR	Sound Detection and Ranging
SRDT	Solar Radiation and Temperature Gradient method for classifying atmospheric stability
USEPA	United States Environmental Protection Agency
VALLEY	a steady-state, complex terrain Gaussian plume dispersion model for estimating 24-hour and annual average concentrations for emissions from up to 50 point and area sources
VISSCREEN	a model used to calculate the potential impact of a plume of specified emissions for specific transport and dispersion conditions
WYNDvalley	an Eulerian grid air quality dispersion model suitable for modelling dispersion at low wind speeds in valleys

1.0 INTRODUCTION

The Ministry of Water, Land and Air Protection (MWLAP) has long recognized the need to produce a guideline for the application of air quality dispersion models for regulatory purposes in British Columbia. Various drafts of such a guideline have been produced by Ministry staff, but have never been finalized into a formal guideline document. In order to promulgate a final version, the Ministry retained SENES Consultants Limited (SENES) to conduct a critical review of the most recent (1998) version of the draft guidelines.

The objective of this critical review was to evaluate the existing draft guidelines with respect to their approach, completeness and content, and to provide a direction for revisions and completion of a final guideline document. The review included:

- the gathering of technical information;
- comparing approaches used by other jurisdictions;
- incorporating operational realities based on the historical application of models in this province and the B.C. regulatory framework; and
- presenting options and recommendations for developing a final version of the guidelines.

SENES was assisted in completing this review by Mr. Roger Brode of MACTEC Federal Programs, Inc. (formerly known as PES, Inc.). The main focus of Mr. Brode's was on the sections of this report dealing with the two alternative approaches for the overarching philosophy for air quality modelling guidance in British Columbia (Section 2.0), and the model applications (Section 3.0).

In conducting this review, SENES has assumed that the options and recommendations presented in this report may be subject to further discussion and multi-stakeholder consultation.

2.0 PHILOSOPHY FOR AIR DISPERSION MODELLING

Considering the complex framework of regulatory permitting requirements that must be addressed through air quality modelling analyses, it is crucial that the modelling guidelines used for assessment processes be organized in a manner that promotes consistency in permitting decisions, and that incorporates a philosophy of continual improvement in environmental quality. In that context, it is worth considering the roles and responsibilities defined for the Ministry of Water, Land and Air Protection.

2.1 MISSION OF THE MINISTRY OF WATER, LAND AND AIR PROTECTION (MWLAP)

The Ministry's Service Plan for the period 2002/2003-2004/2005, dated February 2002, outlines a mission statement for MWLAP that includes:

- to protect and enhance the quality of British Columbia's …air in a way that contributes to the economic development of the province;
- limit adverse effects of British Columbians' individual and collective activities on the environment;
- implement a plan for improving air quality in threatened airsheds.

Interpretation

SENES Consultants Limited interprets this to mean:

- protect and enhance air quality;
- protect the public; and
- do not unduly burden industry.

2.2 ROLES OF THE MWLAP

The following roles have been tailored for the air quality portion of the mandate from the "Summary of Roles and Responsibilities" of the MWLAP "FACTSHEET" dated 17 January 2002:

- establish the foundation for human and environmental health (via ambient air quality standards, policies, etc.) **using a science-based and risk-based approach** (emphasis added);

- establish appropriate …policies, best management practices, and stewardship agreements for those who use the environment and **ensure environmental objectives are met** (emphasis added); and
- monitor and report on the quality of the province's air.

Interpretation

SENES Consultants Limited interprets this to mean:

- use models based on well established science;
- ensure that modelling results can be linked to risk-based outcomes;
- carefully define how air quality objectives must be met by models; and
- ensure that every modelling assessment is judged as leading to an improvement in air quality (e.g., addresses equivalency to Prevention of Significant Deterioration requirements of Canada-USA Agreement on Air Quality along the BC borders with Washington and Alaska).

2.3 MWLAP RESPONSIBILITIES

The following responsibilities have been tailored for the air quality portion of the mandate from the "Summary of Roles and Responsibilities" of the MWLAP "FACTSHEET" dated 17 January 2002:

- develop … policies for air quality based on best available science and an ecosystem-based approach;
- develop … policies for: industrial air .. emissions and discharges; non-point source emissions; and toxics and pesticides;
- regulate some discharges and emissions through a permitting system;
- monitor and report on …air quality, including regulatory compliance;
- communicate expectations, standards and goals relating to air pollution to government agencies, industry, individuals and communities;
- ensure air protection standards are met;
- provide leadership on climate change;
- allow for economic development based on clear, reasonable environmental outcomes, with discretion as to how to achieve these outcomes; and
- work in partnership with the provincial emergency program to prevent and respond to air emergencies.

Interpretation

SENES Consultants Limited interprets this to mean:

- the modelling approach must be clear and unambiguous;
- the modelling approach must deal with all types of sources, such as point and non-point, area (pesticides) and unexpected releases;
- the modelling must link to the permitting system;
- monitoring should be an integral part of the modelling approach;
- the modelling process must be clearly defined and transparent to government, industry, individuals and communities;
- Criteria Air Contaminants (CACs), as well as Greenhouse Gases (GhGs), must be considered in the modelling approach; and
- a specific series of modelling tools must be available to respond to environmental emergencies.

2.4 PROPOSED PHILOSOPHY FOR AIR QUALITY MODELLING

SENES Consultants Limited strongly believes (1) that the provincial modelling guidance should stem from a well-considered philosophy on how the modelling should be conducted, and (2) that it will not be feasible for the MWLAP to provide a transparent modelling process to government, industry and the public community in B.C. without first defining a modelling philosophy.

SENES has outlined two possible approaches that B.C. could adopt, but recommends soliciting the opinions of other members in the B.C. air quality modelling community before deciding on any specific approach. The first approach is similar to the approach taken by the U.S. Environmental Protection Agency (USEPA) in their Guideline on Air Quality Models. The USEPA approach is limited to two tiers: screening and refined modelling. The second alternative approach recommended by SENES for consideration by MWLAP relies almost exclusively on use of the CALPUFF model, a non-steady-state puff dispersion model, based on its ability to incorporate multiple surface and upper air meteorological inputs, its ability to utilize outputs from mesoscale prognostic models, and its ability to simulate the effects of temporally and spatially varying surface (terrain and land use) and meteorological conditions on plume transport, transformation and diffusion.

2.4.1 Overview

To a large extent, British Columbia has historically relied on the detailed regulatory modelling guidance developed by the USEPA. It would be unreasonable, and unnecessary, to try to reproduce the USEPA's guidance. On the other hand, the use of dispersion models is evolving rapidly as newer, refined modelling techniques are used in place of the simplified approaches that have been the basis for most air quality assessments over the past two decades. The regulatory review process used by the USEPA to respond to these changes is often onerous and time consuming, and have not always kept pace with new developments. Some much needed revisions and updates to the USEPA's regulatory modelling guidelines were released in mid-April 2003.[1]

There are a number of reasons for choosing to stay with the older and simpler modelling methods:

- the complexity of the more refined models requires a relatively long learning curve to be able to: (1) use the model correctly, or (2) provide effective regulatory review of model applications;
- simpler models (e.g., ISC3) have a relatively good history for regulatory applications and their strengths and weaknesses are understood;
- the models are easier to use and rely on standard, inexpensive meteorological data inputs from one station; and
- the models are relatively inexpensive to run.

However, British Columbia has some unique challenges (complex mountainous terrain, coastal land/water boundaries, frequent atmospheric stagnation conditions, etc.) that must be addressed to fulfill the roles and responsibilities of the Ministry. While models such as ISC3 can provide reliable results in many cases, the simplified modelling approaches also have some significant drawbacks, especially in the unique situations found in British Columbia. In particular, the simpler models do not provide reliable results for:

- atmospheric stagnation conditions (important in mountainous terrain);
- coastal land/water boundaries;
- stable and unstable (A,B, E and F stability) atmospheric conditions;
- air flow over and around complex terrain features;
- wind shear at different levels above the surface; and
- non-standard sources (e.g. very hot plumes that can escape the building wake/cavity zone).

Furthermore, the use of simple models, whose original formulation dates back to the mid-1970's, would not be consistent with the MWLAP's stated responsibilities of using the best science-

[1] U.S. Environmental Protection Agency (USEPA) 2003. *Revision to the Guideline on Air Quality Models: Adoption of a Preferred Long Range Transport Model and Other Revisions.* 40 CRF Part 51; 6560-50-P, April 2, 2003.

based approach for protecting the province's air quality because newer, more scientifically up-to-date models are available and are already being widely used in B.C.

2.4.2 Proposed Philosophy

Over the past three decades, the traditional approach to modelling evolved from the USEPA's tiered approach to the application of regulatory models. For major new sources of air emissions, proponents could undertake a preliminary impact assessment using screening-level modelling techniques to determine whether the proposed new emission source could cause a *"significant"* increase in ambient air pollutant concentrations. It was assumed that the screening models always produced conservative estimates of potential air quality impacts, such that the use of more refined modelling techniques would always result in lower predicted impacts. Consequently, if the predicted impacts using screening-level techniques were lower than the "significant" impact criteria, no additional modelling was required of the proponents. If the significance criteria were exceeded using the screening-level models, more refined techniques could then be applied to ascertain whether the impacts would still meet ambient air quality standards or, in areas of non-attainment of the standards, Prevention of Significant Deterioration (PSD) criteria.

The selection of refined modelling techniques depended on the complexity of the source emissions (single, multiple or complicated sources), whether the source was located in simple or complex terrain, the type of surrounding land use, and the need for short-term versus long term impact assessment. There were many preferred modelling techniques depending on the circumstances, but no single model that could be considered suitable for all, or even most, applications.

Over the past 10-15 years, the Industrial Source Complex (ISC) model has been the preferred model for most regulatory modelling applications, both in Canada and the United States, and increasingly around the world. This model was slated for replacement by the AERMOD model as the USEPA's preferred model for most regulatory applications in the U.S. However, in April 2003 the USEPA deferred a decision on the adoption of AERMOD as a replacement for ISC3 until a future date. As well, the CALPUFF model has also been gaining widespread acceptance over the past 5-6 years, and has been used on several occasions in B.C. The USEPA has adopted the CALPUFF model as a recommended model for long range transport of pollutants, as well as for transport and dispersion in the near field (<50 km) in some "complex wind" situations, on a case-by-case basis. The term "complex wind" appears to include stagnation conditions, fumigation and terrain-induced wind flows. Although the USEPA guidance for CALPUFF does not explicitly state that the CALPUFF model can be used for near field applications in simple terrain, it does not explicitly recommend against the use of the model for these situations either.

Therefore, it is the opinion of SENES staff that B.C. could consider two possible modelling philosophy options based on the available models and evolving modelling practices, both here in B.C. and elsewhere in North America. Choosing either option will determine the composition of any final modelling guideline document.

APPROACH #1 – Tiered Modelling Following USEPA

One direction that B.C. could choose for its modelling guidelines would be to continue to closely follow the USEPA's modelling guidance. The key elements for such an approach to future modelling in British Columbia could include:

- retaining a tiered approach to model applications, including screening techniques, refined modelling techniques and "best-estimate" models;
- in the near term (say until 2004) most of the assessments would be undertaken using a model with a proven track record, good validation statistics and known problems – ISC3;
- in those cases where ISC3 is not well-suited to the application, refined models could be used with **very specific guidance** (to avoid the many operational problems because they have not been extensively tested)
  - e.g., CALPUFF for situations where terrain influences air flow (drainage flows), land/water boundaries and areas with significant stagnation episodes;
- give industry as much warning (2-5 years) about a change in modelling approach as possible so that they can plan accordingly;
- when a more refined model (AERMOD, ISC3-PRIME) has been fully developed and tested (say in 2005), it should replace ISC3
  - retain the option to use refined models such as CALPUFF for situations where AERMOD is not suitable;
- a tiered approach should always be used in order to minimize the cost and time required to do an assessment and permit application. For the near term, the sequence of models would be:
  - SCREEN3
  - ISC3 (or ISC-PRIME) with regional meteorology derived from mesoscale models
  - ISC3 (or ISC-PRIME) with 1 year of on-site or 5 years of local airport meteorology (or equivalent).

  In 2005, the tiered approach would be:
  - AERSCREEN/AERMOD with screening meteorology
  - AERMOD with regional meteorology derived from mesoscale models
  - AERMOD with 1 year of on-site or 5 years of local airport meteorology (or equivalent);

- allow use of special purpose models wherever applicable (e.g., highway models, dense gas models, computational fluid dynamics models, cooling tower models, plume visibility models, etc.), but with strict guidance.

The tiered approach used by the USEPA has served the needs of the modelling community fairly well over the years, allowing for flexibility in selecting a model that is most appropriate for a given application considering a number of factors. This approach also allows for adoption of newer models at appropriate levels within the hierarchy as they are developed and their capabilities demonstrated. The tiered approach is also generally consistent with the guidance recently developed in Alberta.

The evaluation results for AERMOD, particularly for complex terrain applications, suggest that the model represents a significant improvement over previous regulatory models, and has even outperformed the more complex CTDMPLUS model on several databases. Based on these model evaluation results, AERMOD would be suitable for a wide range of near field applications in both simple and complex terrain. There have also been some anecdotal reports that AERMOD has performed as well as, or better than, CALPUFF in a few cases, but the documentation to support these reports is not available. While AERMOD is somewhat more difficult to apply than ISC3, it is still considerably easier to apply and review than the CALPUFF model for similar applications.

In the case of strong localized influences on the wind field, plume impaction on elevated terrain may be the most important impact from an elevated source such as a tall stack, and the results of validation studies indicate that AERMOD appears to handle such situations very well. There are also a few features of AERMOD that should permit a better treatment of the localized terrain influences on wind field and near-stagnation conditions than with other plume models, such as ISC3. AERMOD has been designed to handle light wind conditions (wind speeds less than 1m/s) better than ISC3, and also incorporates an approach for treatment of horizontal meander that can be significant under such conditions. AERMOD can also accept multiple levels of site-specific wind measurements and will determine the transport direction for each source based on the wind direction from the vertical profile appropriate for the individual plume. Thus, a surface or low-level release may be influenced by the localized upslope/downslope or channelling effects, as reflected in the wind measurements, whereas an elevated source may be influenced by wind reflecting the synoptic level flow.

Another area of growing interest in regulatory modelling is the use of meteorology derived from mesoscale models to drive dispersion models, such as ISC3 and AERMOD, in addition to their use with initializing diagnostic wind field models like CALMET. While this approach is still relatively new and untested, is does hold some promise of being able to apply refined models like AERMOD for near field impact analyses with "representative" meteorological inputs in data sparse areas, without the additional time and expense of performing meteorological monitoring. Once fully developed, it may also allow for more standardization of meteorological inputs for such dispersion models, which could be of benefit to both applicants and reviewers. For this reason, it may be premature to discard the tiered approach to the B.C. modelling guidance.

The advantages of Approach #1 are that (1) it retains consistency with the USEPA approach over the long term, (2) lends additional credibility to the modelling results, and (3) benefits from future upgrades and validation studies of the AERMOD model. The disadvantage of this modelling philosophy for B.C. is that it does not satisfy the need to use the best science-based approach for air quality management in B.C. because the ISC3 and AERMOD models will not be suitable for many applications.

Furthermore, the recent decision by the USEPA to postpone adoption of the AERMOD model as a preferred regulatory model would mean that, at least for the coming 2-3 years, means that regulatory applications in B.C. would continue to rely on either the ISC3 or CALPUFF models for most situations. Given the constraints of the physical environment in this province, it is likely that the CALPUFF model would be frequently required for regulatory modelling applications instead of the ISC3 model, or even the AERMOD model, whenever the latter receives final approval from the USEPA. There are also non-technical reasons for using the CALPUFF model even for relatively simple applications related to public perception and acceptance.

APPROACH #2 – BC Appropriate Modelling

An alternative modelling philosophy would be to acknowledge the complexity of predicting air quality impacts in British Columbia's geophysical environment, and to designate the CALPUFF model as the preferred regulatory model for B.C., while allowing the use of less refined models if proponents can demonstrate that the less refined modelling approaches are still scientifically valid. The key elements of such a modelling philosophy would be:

- retain screening-level modelling techniques (SCREEN3, CTSCREEN, AERSCREEN - when available) for use on relatively small sources, or to obtain preliminary estimates of potential impacts, but not for actual permitting purposes of large emission sources;
- recommend CALPUFF as the first choice model for regulatory applications in B.C.;
  - allow use of the CALPUFF model with single-point meteorology input to CALMET if necessary;
  - allow use of less refined modelling techniques (ISC3-PRIME, AERMOD) only where suitable (e.g., simple terrain, short distance between source and receptor with no intervening topography that affects pollutant transport);

- allow use of special purpose models wherever applicable (e.g., highway models, dense gas models, computational fluid dynamics models, cooling tower models, plume visibility models, etc.).

Given the sparse distribution of meteorological monitoring data and the complexity of the terrain in this province, the advantage of Approach #2 of recommending CALPUFF for most modelling applications is that the model is better suited to the geophysical environment in the province in that it can better incorporate the effects of local terrain features and spatially varying surface characteristics on the wind flow. Given that it has been used for major projects in B.C. over the past 2-3 years, it already has a measure of acceptance and public credibility in this province.

The USEPA has stated that there is a general consensus that the scientific merits of the CALPUFF modelling system have been established to a sufficient degree for the model to be used in PSD applications.[2] The USEPA has recently promulgated revisions to their Guideline on Air Quality Models (40 CFR, Part 51, Appendix W) that designate CALPUFF as the preferred model for long range transport applications (beyond 50 kilometres), and also identified CALPUFF as a model that may be used on a case-by-case basis for near field impact analyses for situations involving complex winds. This bolsters the notion of CALPUFF as a "best estimate" model. Based on comments from key people at the USEPA, there are indications that the USEPA may be moving in a direction similar to Approach #2, with CALPUFF serving as an "all purpose" model.

There are two main applications where use of the CALPUFF model could have a distinct advantage over use of a steady-state plume models such as ISC3 or AERMOD for near field impact analyses. One type of application where CALPUFF may be better than ISC3 or AERMOD is when there are strong localized influences on the wind field, such as valley channelling, upslope/downslope flows, and coastal areas. The other type of application where CALPUFF could provide some advantage is with stagnation conditions. Stagnation conditions may be especially important given the potential for a buildup of excessively high concentrations over time. Stagnation is also a condition that steady-state plume models are incapable of handling properly. Since many areas of B.C. record calm conditions up to 25% of time during the year, the ability to properly model stagnation conditions represents an essential requirement for many regulatory modelling applications in this province.

As with most model evaluation studies, performance evaluations of the CALPUFF model have focused on evaluation metrics typical of regulatory modelling applications (i.e., focused on

[2] U.S. Environmental Protection Agency (USEPA) 2003. *Summary of Public Comments and EPA Responses: 7th Conference on Air Quality Modeling, Washington, D.C., June 28-29, 2000.* Air Quality Modeling Group, Emissions and Analysis Division, Office of Air Quality Planning and Standards, February 2003.

predicting the high end of the concentration distribution). One of the main advantages of CALPUFF should be its ability to simulate the spatial and temporal variations of the concentration field better than steady-state plume models like ISC3 and AERMOD. This may be an important advantage of the CALPUFF model for risk-based assessments in which the accurate prediction of average exposure levels across the population in an area is more important than the prediction of the maximum concentration in any one location. However, neither SENES staff nor R. Brode are aware of any evaluation studies that have focused on differentiating CALPUFF's performance based on evaluation metrics geared to this capability. Furthermore, although the Service Plan for the MWLAP states that the Ministry's mandate is to use a science-based and risk-based approach as the foundation for protecting human and environmental health through ambient air quality standards and policies, it is not clear from the Service Plan how this would translate into the application of regulatory models.

Besides the limited amount of model evaluation results for CALPUFF, especially for near field applications, tests demonstrating the sensitivity of CALMET/CALPUFF to the wide range of user specified input parameters is also very limited. In order for CALPUFF to be used as a single "all-purpose" model, very detailed guidance will be needed on the proper application of the modelling system, especially CALMET. Otherwise, there will be a significant burden placed on applicant and reviewer to ensure that the modelling system has been applied appropriately and produces reasonable results.

Because CALPUFF is more difficult to run, and more difficult for MWLAP staff to verify results, there would be fewer modellers capable of successfully completing assessments and potential misapplications of the model for some assessments. However, this would only be a temporary situation as modellers and MWLAP staff become more comfortable with the model. With the recent deferral of the USEPA's decision on AERMOD, the latter model may not be adopted by other jurisdictions for another 2-3 years, by which time the practical experience in the use of the CALPUFF model will have increased, making it less likely to be abandoned in favour of AERMOD as a standard recommended model.

Another possible disadvantage for Approach #2 is that it is time-consuming to complete a CALPUFF run using even one year of meteorological data, let alone five years[3] of data to account for year-to-year variability. Further developments in computer technology are likely to improve the CALPUFF model performance over the next 5 years, but current computer technology will place significant limitations on the number of years of meteorological data that can be used for a CALPUFF modelling analysis.

[3] Note: The recently released USEPA guidance recommends using at least 3 years of meteorological data to run CALPUFF when the data are derived from National Weather Service stations.

Another possible disadvantage in adopting Approach #2 is that MWLAP would be out-of-step with guidance from some other regulatory jurisdictions at least for the short term, although the recent changes to the USEPA modelling guidelines lend much more support to the use of the CALPUFF model than ever before.

One concern regarding the adoption of CALPUFF as the “all purpose” model for British Columbia is that CALPUFF is a relatively new regulatory model, and experience with the model across the full range of applications implied in Alternative #2 is still quite limited. Most of the evaluation studies for CALPUFF available from the USEPA’s website, as well as from the IWAQM Phase 2 report, have focused on the performance of CALPUFF for long range transport applications. This is consistent with the fact that the USEPA initially proposed, and recently promulgated, CALPUFF as a refined model for long range transport applications. The IWAQM Phase 2 report also included a Q-Q plot of CALPUFF results (presumably for 1-hour averages) for the Lovett power plant near field complex terrain data base. CALPUFF appears to perform better than CTDMPLUS for Lovett, but still exhibits some overprediction, whereas AERMOD’s performance was unbiased for the Lovett data base. However, practical experience at SENES with near field application of the CALPUUF model for tritium releases in a coastal, complex terrain setting has shown good agreement with observed data. Given the growing use of the CALPUFF model in the past few years, there may be other examples of the successful application of the model for near field impacts that have not received widespread attention from the modelling community.

Another issue of possible concern with Approach #2 is allowing the use of less refined models if a proponent can demonstrate that the less refined modelling approaches are still scientifically valid. The B.C. modelling guideline would have to provide specific criteria to be used in judging the scientific validity of other modelling approaches in order to prevent ad hoc decisions on which models to use. The absence of such criteria could place a very significant burden on proponents of relatively small-scale projects that are otherwise trying to avoid the significant burden of applying the CALPUFF model.

3.0 MODEL APPLICATIONS

3.1 GENERAL OVERVIEW

Chapters 1, 2 and 3 of the draft B.C. modelling guideline provide a general discussion of the rationale for using air quality dispersion models, the broad categories of models available for regulatory applications, and the reasons that must be considered before choosing models from each category. Chapter 4 of the draft guideline provides some useful definitions of technical terms used in the document. The technical guidelines for model applications are contained in Chapters 5 through 10, with some additional technical specifications and guidelines in appendices. Chapter 11 provides an overview of the role of MWLAP meteorologists in ensuring that permitting decisions are based on scientifically defensible assessments. The chapter includes a comprehensive checklist that can be used in reviewing air quality analyses to ensure that all aspects of the analysis have been considered and accepted.

Section 3.2 of the guideline emphasizes the need to develop a modelling plan agreed to by the MWLAP staff before conducting any regulatory modelling analysis. The guideline does not, however, state that a formal modelling protocol[4] is required to be developed and submitted to the MWLAP staff for approval - only that a modelling plan should be discussed and agreed upon before any work is undertaken. The form of the consultations between proponents and the MWLAP staff is not defined. *Key questions left unanswered include:*

- *When do you need to have a formal modelling plan or protocol?*
- *What form should such a plan take?*
- *What is a reasonable timeframe for preparing, submitting, reviewing and agreeing upon a modelling plan?*

The BC modelling guideline should emphasize the need for the development and approval of a sound modelling protocol before beginning a modelling analysis in order to provide proponents with more certainty regarding the permitting process.

However, acceptance of a modelling plan or protocol by the MWLAP staff should not preclude the Ministry from requiring changes in the modelling analysis, if and when such changes are deemed necessary at any time during the permitting process. Although allowing the Ministry to require such changes after a protocol has been approved may prove problematic in some

[4] It should be noted that the recent revisions to the USEPA regulatory modelling guidelines require the submission and approval of a formal modelling protocol agreed to by all parties prior to accepting the use of the CALPUFF model for complex wind situations.

instances, it must also be recognized that unexpected difficulties and assessment needs can arise subsequent to the approval of a modelling protocol. *Therefore, the Ministry should retain some flexibility in the assessment and approval process to require changes to a protocol as the need arises.*

In its current format, the guideline provides a mixture of theory and practice, with specific guidance on some, but not all, technical issues. The discussion of theoretical aspects of dispersion modelling provides the rationale for some of the specific guidance that follows in each section of the report. The guideline document provides a large amount of technical information that is both informative and useful to modellers, as well as others who may wish to understand the modelling options available, the parameters that need to be considered and incorporated into an air dispersion modelling analysis, and the limitations of such analyses.

As such, the draft guideline is targeted at a broad audience that might include industry representatives, the general public, as well as atmospheric scientists who are already quite familiar with the terminology and most of the technical aspects being discussed in the guideline. In view of the fact that such a guideline document is likely to be used in semi-legal and legal proceedings related to permit applications and public reviews of permit appeals, it is both appropriate and indeed necessary that the guideline incorporate both general educational material on the concepts used in dispersion modelling, as well as the specific technical guidance on how models are to be applied in B.C.

It may be easier to split the information into two volumes: with Volume 1 providing the overview of concepts and policy guidance, while Volume 2 contains only the specific technical guidance (i.e., cookbook) on what is to be done in particular modelling situations. From a practical perspective, it may be less complicated to maintain consistency in modelling guidance if all of the material is incorporated into a single volume, but this would be an information management issue. However, splitting the guidance into two volumes, one with overall concepts and policy and the other with specific technical guidance, also has some merit. This would be similar to how the user's guides for some models are organized, and may make it easier for the modelling community to find the relevant information. It would also allow for updating the technical guidance as specific issues arise without changing the overall concepts.

The introduction to the draft guideline states that, while it is intended to be a cookbook on dispersion modelling, it is not possible to provide specific guidance on every conceivable aspect or situation that might arise. The guideline emphasizes the need for communication between those conducting the modelling, those reviewing the modelling results, and decision makers. Nevertheless, while it may not be possible to anticipate all potential aspects that might arise in any dispersion modelling analysis, it should to be possible to define the basic rules for modelling to a greater extent than is currently available in the draft guideline. *To a large extent, the lack of* *specific guidance stems from (1) the absence of a well-defined modelling philosophy to structure the guideline, as discussed in the preceding section, and (2) a variety of policy gaps on fundamental aspects of air quality management strategies for the province. Addressing these issues would facilitate the development of more specific guidance on dispersion modelling.*

In order to expedite the development of a final guideline, it may be preferable to develop the guideline in a phased approach, dealing with the most important, core issues first, and subsequently expanding the guidance to address special topics or in response to the development of new policies.

3.2 RECOMMENDED REGULATORY AIR QUALITY MODELS

Section 3.1 of the draft B.C. modelling guidelines discusses a 3-tiered approach to modelling, depending on the purpose and objectives of the modelling analysis. Models are divided into screening-level, refined and 'best estimate' categories. This is consistent with the classical tiered approach to modelling which assumes that most applications can be handled using simple models, relegating refined or best-estimate models for use only on a limited number of projects that have specific needs. This approach is also consistent with minimizing the impact on industry's bottom line (i.e., assessment costs).

Recommended screening-level models in the draft B.C. guidelines include: SCREEN3, ISC-PRIME-S (in screening mode), and CTSCREEN. Recommended refined models are listed as AERMOD, ISC-PRIME, RTDM, and CTDMPLUS. The CALPUFF model is recommended as the only 'best-estimate' model.

Section 5.2 of the draft guidelines states that the choice of which model represents the "best" model to use in a particular situation can be difficult. The choice depends on relative trade-offs between different model treatments, the end use of the results, and specific source/receptor relationships. As a general statement, the guidance document is correct, but the overall goal of the guidance document should be to define more clearly which models to use and when, leaving room for discretionary use of alternative models.

However, the classical tiered approach to modelling that has been used for the past 20 years was necessary because no single model could address all, or most modelling situations involving both simple and complex terrain, fumigation, land/water boundaries, deposition, stagnation, etc. With the development of models such as CALPUFF, there is now an overarching question about whether there is still any need for a tiered approach given the ability of the newer models to address most regulatory modelling needs. An alternative approach would be to designate a refined or best-estimate model that is, from a scientific perspective, most suitable for the physical environmental setting in B.C. as the preferred model, and allow use of less refined models only for those applications where it can be demonstrated that a more refined model is not necessary. For example, if the nearest sensitive receptors are very close to the source, in simple or intermediate terrain, etc., it may still be appropriate to use simple screening-level models, or models such as ISC-PRIME. In this case, the regulatory requirement would be to use the best science as a first choice, consistent with the Ministry's stated service goals, and place the onus on proponents to justify using less scientifically-defensible techniques based on need.

A fundamental assumption of the tiered approach to model selection is that the simpler modelling techniques always yielded more conservative results. It was assumed that screening-level models would always predict higher ground-level concentrations than refined modelling techniques, and that the refined models would predict higher impacts than the 'best-estimate' models. Comparisons among models such as ISC3, AERMOD and CALPUFF have shown that this assumption is no longer valid. Under non-steady state atmospheric conditions, the CALPUFF model can predict ground-level concentrations from point sources that are higher than would be predicted by either the ISC3 or the AERMOD model. Under the right set of circumstances, it is possible that CALPUFF could also predict higher impacts than the SCREEN3 model, although no comparisons of model results are available to verify this. Therefore, it is now much more difficult to rely on the tiered modelling approach for ensuring that air quality objectives can be met because it is less certain which model will provide the more conservative result.

A key aspect of the development of dispersion models for application in the U.S. regulatory framework has been the focus on predicting the maximum concentration for any given averaging time resulting from industrial source emissions. The performance of the models has focussed on how well they can predict the maximums at any point in the modelling domain, and not on how well they predict lower, but more frequently occurring concentrations throughout the modelling domain. In contrast to the U.S. regulatory environment, industrial source permitting decisions in B.C. are not limited to the consideration of maximum predicted impacts alone, but on the broader aspects of the air quality impacts as a whole. Consequently, lower concentrations at locations other than the point of maximum impact, and the frequency of occurrence of predicted concentrations at sensitive receptor sites (e.g., old age homes, schools, hospitals) may be important factors in permitting decisions in B.C. Furthermore, the stated mandate of the MWLAP of using a risk-based approach to protecting human health and the environment suggests that long-term average impacts may at times be more important than short-term maximum impacts. As such, regulatory models that are most suitable to the U.S. regulatory framework may not necessarily be the most suitable models for the regulatory decision making process in B.C.

As discussed in the preceding section, the choice of staying with the classical tiered approach to modelling versus moving to the use of a newer model such as CALPUFF as the preferred model for B.C. must stem from an overall policy decision on which modelling philosophy should be adopted by the MWLAP. *For the development of modelling guidelines, staying with the tiered approach would mean that much of the information currently provided in Section 3.0 of the existing draft guidance document could be retained and expanded upon. Choosing the alternative approach of designating the CALPUFF model as the preferred model for B.C. would require a complete re-writing of this section of the draft guidelines.*

3.2.1 Screening-level Models

Screening-level models are discussed in Sections 3.1 and 5.1 of the draft modelling guidelines, which includes a good listing of potential reasons for running screening models (Section 3.1). The guideline suggests that screening-level models are to be used in permitting situations only for small sources, to assist in planning studies for larger sources, for stack height determinations and to provide early indications for the need to go to refined and/or best estimate models. The SCREEN3 model can be used for single source, simple terrain modelling, while for multiple sources the guidance recommends using either the ISCST3-S or ISC-PRIME-S model as a better alternative than creating a single representative source as described in Appendix A.3 (following USEPA guidance) of the guidelines. The ISC-PRIME-S model is recommended in the guidelines for simple terrain, single or multiple sources where building downwash is a factor. The CTSCREEN model is recommended for point sources in intermediate or complex terrain.

Screening models provide 1-hour average concentrations. Issues surrounding factors to be used in converting the 1-hour averages to 3-hour, 8-hour or 24 hour average concentrations are addressed in Section 10.8 of the draft guidelines. The guidance document provides conversion factors, describes their limitations, and then recommends against their use in favour of using refined models where averaging periods greater than 1-hour are important. This suggests that the guidelines recommend the use of screening models only for predicting 1-hour average concentrations from small point sources. *If this is indeed the case, the guidelines should clearly state that screening-level models are not to be used for any other averaging times, or for area and volume sources. The guidelines should also clearly define what is considered to be a small source, or what is considered to be a sufficiently small air quality impact, based on screening-level modelling, which would obviate the need for proponents to re-do the assessment using refined or best estimate models.*

However, the overall unanswered question in the guidelines is whether screening-level models still have any role to play in regulatory permitting applications? If the MWLAP stays with the 3-tiered modelling philosophy outlined in the draft guidelines, the use of screening models for regulatory permitting applications would be fairly limited (small point sources with relatively small impacts). *If the guidance is that screening techniques only be used for small sources, there* *is no need to prepare a representative source for combined emissions from multiple sources. Consequently, it is recommended that Appendix A.3 be eliminated from the guidelines.*

There are also some concerns about running a model such as ISC3 (or ISC-PRIME) with screening meteorology (e.g., ISC-PRIME-S). The primary concern with this type of approach is in the treatment of mixing height and the fact that the mechanical mixing height estimate used in the SCREEN3 model (and a similar approach described in the draft B.C. modelling guidelines) can overestimate the mixing height that may be calculated by PCRAMMET for use in ISC3. This may result in higher predicted concentrations from a refined model than from the use of screening meteorology in a model such as ISC-PRIME-S due to limited mixing effects. This tendency has been documented in a comparison between SCREEN and ISC (Brode 1991).

It should also be noted that the draft B.C. guidelines specifically refer to the use of the METISC utility program available from the Oregon Department of Environmental Quality (DEQ) website. It should be noted that, with the recent retirement of Pat Hanrahan from the Oregon DEQ, the air modelling page is apparently being redesigned, and the METISC program is currently not available from this website.

If MWLAP adopts the CALPUFF model as the preferred model for B.C., proponents would have to provide justifications for using simpler screening techniques instead of the preferred model. The screening techniques could also be useful in obtaining preliminary estimates for larger sources when trying to determine whether or not to include a source in the inventory when determining a background concentration level based on modelling of existing sources (see Section 4.5.4 below). Screening techniques may also be the only simple alternative for those locations that lack any meteorological monitoring data (note, however, that a full three dimensional weather model could be used to generate data in data-sparse areas).

For these reasons, SENES recommends retaining the SCREEN3 model for relatively small, elevated point sources in simple terrain. In complex terrain locations where there is no meteorological data, CTSCREEN may be the only alternative model. The AERSCREEN model is under development and may be used in future instead of SCREEN3 or CTSCREEN by about 2005. It is suggested that the models be retained for use in those screening situations, but any permits issued should be conditional and subject to further verification with actual meteorological data and refined modelling techniques.

3.2.2 Refined Models

The draft guidelines suggest that refined models are to be used for most regulatory applications. The recommended models include:

RTDM	point sources in intermediate or complex terrain where limited meteorological data are available, but use ISC-PRIME where building downwash is a factor;
ISC-PRIME	multiple point, area or volume sources in simple terrain, as well as for building downwash;
CTDMPLUS	point sources in intermediate or complex terrain, where building downwash is not a factor; and,
AERMOD	all sources and terrain types

The guidance document appears to have replaced the ISCST3 model with ISC-PRIME. If this is so, the guideline should state that clearly.

The guideline recommendation to use ISC-PRIME in lieu of RTDM in intermediate or complex terrain when building downwash is a factor contradicts guidance elsewhere in the document recommending use of ISC-PRIME only for simple terrain applications. *The guideline needs to state that the BPIP-PRIME program is required for downwash-related data input to the ISC-PRIME model.* The USEPA has recently dropped the RTDM model from its hierarchy of complex terrain models, and *it is recommended that the RTDM model also be eliminated from the B.C. modelling guideline*.

If CALPUFF is chosen as the preferred model for B.C., the primary limitation would be for projects in which building downwash effects were important. Although the CALPUFF model has a building downwash algorithm, it may not produce results equivalent to those derived from the PRIME algorithm in ISC-PRIME or AERMOD-PRIME, which is currently only available in a beta-test version. *Because the PRIME algorithm for building downwash effects is newer than the downwash algorithm used in CALPUFF, the guidance may need to specify the use of either ISC-PRIME or AERMOD-PRIME to verify downwash effects where such effects are a critical factor the approval of a permit application.* However, it should also be noted that the CALPUFF model's developers, Earth Tech, have indicated to the USEPA that the PRIME algorithm has been installed in CALPUFF, and that it is Earth Tech's intention to have PRIME available as an option in the model's code to support the USEPA action in adopting CALPUFF as a recommended regulatory model.

With respect the CTDMPLUS model, the model has been retained by the USEPA as a recommended model for complex terrain applications in the recent revisions to the USEPA guidelines. However, the CTDMPLUS has only been used once in 10 years in B.C. The limited use of this model indicates that it has little practical value for regulatory applications. The level of effort required to obtain meteorological data to run the model is too great for the small benefits in improved prediction accuracy compared to just using CALPUFF.

On the other hand, the USEPA has proposed keeping CTDMPLUS in the modelling guideline after AERMOD is promulgated for situations involving a well-defined hill or ridge, and where a detailed analysis of the spatial pattern of impacts is of interest. This may be the case for risk-based decision making, especially with special receptors located on the hill or ridge. This seems to be a reasonable role for CTDMPLUS, and the MWLAP may wish to retain the model in the B.C. modelling guideline for such applications, it even though its use has been very limited to date. The limitation on its use to date is likely due to the expense of meteorological monitoring, and that limitation may be mitigated in the future as more experience and confidence is gained in using local meteorology derived from mesoscale models to drive dispersion models.

Currently, the AERMOD model does not have the capability to predict pollutant deposition and plume depletion. *The guidelines should state that proponents should use the CALPUFF model where deposition and plume depletion are important. For fugitive dust sources, the FDM model may be appropriate for use in some circumstances (e.g., time-varying emission rates) instead of CALPUFF.*

3.2.3 Best-Estimate Models

The CALPUFF model is the only best-estimate model recommended by the draft B.C. modelling guidelines. Although the model is applicable to most situations in the province, the guidance document suggests its use should be limited only to large-scale developments due to the complexity of required meteorological data inputs, the set up of files, and the high degree of technical skill required of the modeller. In response to similar concerns expressed in comments at the 7th modelling conference on air quality in Washington, D.C in 2000, the USEPA (2003) has stated that, although the processing steps for using the CALPUFF model are indeed numerous and complex, they can be managed by competent and experienced staff. As such, there should be no practical resource constraints to the use of the CALPUFF model.

One factor that has limited the widespread acceptance of the CALPUFF model by the MWLAP as a default model for regulatory applications has been the lack of published, peer-reviewed performance evaluations of the model for near-field applications in complex terrain. Because the results of modelling analyses are used by government regulators to aid in decisions that may have significant financial, environmental and societal implications, decision makers need to have a demonstrated level of confidence in the results of the models being used. Based on applied experience with the CALPUFF model (e.g., tritium releases in a complex terrain, coastal environment), SENES staff have acquired confidence in the capabilities of the CALPUFF model. The USEPA has stated its intention to establish a website listing investigations using CALPUFF for any cases involving complex winds as they become available, and to build a knowledge base from which determinations can be made on the use of CALPUFF for various complex wind situations.

Alternatively, prior to adopting modelling philosophy option #2 (i.e., CALPUFF as the preferred model for B.C.), the MWLAP may wish to consider conducting field evaluation studies of the CALPUFF model, or conducting a survey of other regulatory agencies to solicit information about the use of the CALPUFF model for evidence of model performance in near-field impacts in complex terrain. To this end, SENES can supply the MWLAP with a copy of the previously noted modelling analysis of tritium releases in Berkeley, CA[5].

The actual use of the CALPUFF model in B.C. has outstripped the draft guidance expectations, but the issues related to the proper use of the model identified in the draft guidelines remain a significant concern. Furthermore, the widespread use of the CALPUFF model in B.C. is limited due to the lack of on-site meteorological data collection. Although the model can be run with data from only one meteorological station (i.e., allowing the CALMET model to define the 3-dimensional air flow over complex terrain), the more complex the terrain, the more meteorological data sites are required. While mesoscale meteorological models such as MM5 and MC2 show much promise in being able to assist in developing meteorological input data to initialize the CALMET model runs, CALPUFF performance still depends on the density and quality of meteorological observations within the modelling domain.

The guidance document should acknowledge the desire to use this model in most applications. However, there is a need to develop an agreed-upon set of model inputs, grid resolutions, and switch settings for regulatory applications. Deviations from these requirements would be allowed, but only after consultation with the MWLAP.

3.3 COMPARISONS OF MODEL RESULTS

In comparisons between ISC3, AERMOD and CALPUFF, significant differences in maximum predicted concentrations have been noted in some cases for the same model inputs, depending on the type of source (point, area, volume), as well as steady versus non-steady atmospheric conditions. Inconsistent results have also been noted in some comparisons. In some jurisdictions, proponents have been required to run all 3 models, and use the most conservative estimate from any of the models.

[5] SENES Oak Ridge Inc. 2000. *Air Dispersion Modeling of Tritium Releases at the Lawrence Berkeley National Laboratory for 1998 Using a CALPUFF Complex Terrain Methodology.* Submitted to The University of California Ernest Orlando Lawrence Berkeley National Laboratory in partial fulfillment of contract W-7405-ENG-48.

At present, there is insufficient understanding of the different results that can be expected from using models such as ISC3, AERMOD and CALPUFF. *There is a need to define guidelines that prevent proponents from choosing the model that gives them the best (i.e., lowest) predicted impact, without going to the other extreme of choosing the most conservative model estimate after running all three models. It may be necessary for the MWLAP to commission a series of model comparisons for several physical settings to get a feel for what each of these models is likely to do with respect to point, line, area and volume sources. The results could then be incorporated into the modelling guidelines to assist in choosing which model to use. Alternatively, if the CALPUFF model is designated as the preferred model, proponents would have to demonstrate that using ISC3 or AERMOD would not result in significantly lower maximum predicted impacts.*

3.4 LONG-RANGE TRANSPORT AND SECONDARY PM FORMATION

The draft B.C. modelling guidelines recommend the CALPUFF model as an appropriate model for long-range transport applications. This is consistent with the recent approval of CALPUFF by the USEPA as a recommended model for long range transport application.

CALPUFF is suitable for modelling SO_4 and NO_3 formation and deposition over long range transport distances (e.g., 50-500 km), but significant (20-30%) underestimation of SO_4 deposition rates have been reported over these distances. Comments made by attendees to the 7th conference on air quality modelling in June 2000 noted that the chemical transformation algorithms in CALPUFF are out of date (i.e., the model underpredicts sulphate formation), and that the aqueous phase chemistry algorithms that have been recently installed in the model code are too new and untested to be trusted for applications involving air quality related values (AQRV). While these limitations are acknowledged by the USEPA, the latter agency has concluded that these limitations do not preclude the USEPA from recommending the use of CALPUFF for long range transport assessments of PSD increment consumption in Class I areas.

However, the CALPUFF model has also been used (inappropriately, in SENES's opinion) for modelling secondary particulate matter (PM) in the near field (<10 km) on one B.C. assessment. SENES is not aware of any models currently under development that would be suitable for modelling secondary particulate matter formation in the near field. SENES is also not aware of any validation studies on the accuracy of the CALPUFF model's ability to simulate sulphate and nitrate deposition at near field distances. *Consequently, SENES recommends that the PM formation algorithm in CALPUFF not be used for near-field applications. Instead, the PM emissions should be modelled as the total emission of filterable and condensable PM. The transformation of NO_x and SO_2 to sulphates and nitrates is unlikely to contribute much to ambient fine particle concentrations in the near-field, and the CALPUFF model should not be* *used to estimate the impact of NO_x and SO_2 emissions on secondary PM formation at distances less than 10 km from the source.*

The CMAQ model in MODELS3 would be suitable for O_3 and secondary particulate matter formation in regional scale modelling analyses. CMAQ is one of the models that the USEPA has mentioned for use in evaluating $PM_{2.5}$ impacts (the other model being REMSAD). The CMAQ model is currently being applied by RWDI West Inc. for Environment Canada in the Lower Fraser Valley, and is being used to estimate secondary PM formation for the data set obtained during the 12-day Pacific 2001 field study. However, the results are being produced on a 4 km grid resolution, consistent with the resolution of the MC2 meteorological input data and the emission inventory. While it would be technically feasible to run the CMAQ model on a finer grid resolution (e.g., 1 km), the validity of the results at that resolution scale would be questionable. Furthermore, it currently takes several days of model run-time to complete a single model simulation at the 4 km grid resolution for only the 12-day episode. It would require weeks of model run time to simulate a whole year at a 1 km grid resolution as part of a permit application. More complex numerical models such as AURAMS, which is under development at Environment Canada, are still several years away from completion, and are also designed to be run at the regional scale on an episodic basis only.

The USEPA has noted that simulation of secondary particulate matter formation is a multi-faceted and complex problem that requires models which can integrate chemical and physical processes that are important in the formation, decay and transport of fine particulate matter. While the USEPA encourages regulatory control agencies in the U.S. to use models such as CMAQ and REMSAD, the USEPA also acknowledges that any given modelling application requires a high degree of technical judgement and professional experience in the choice of models, the use of the models, the development of emission inventories and meteorological inputs to the models, and the selection of episodes to be modelled. Consequently, the USEPA has provided no specific guidance on how to address this issue in the most recent version of its modelling guidelines.

As such, there is currently no available model which could be used to estimate secondary particulate matter formation on a fine grid scale resolution for an entire year of meteorological input data, be it for a single source or all sources in a region. There is a need for specific guidance on what to do about secondary particulate matter for permitting applications in B.C..

3.5 FUMIGATION AND OFF-SHORE SOURCES

Sections 1.14, 5.1.7 and 10.7 of the draft B.C. modelling guideline provides only some general statements that: 1) fumigation is difficult to model, 2) uncertainties are large for its treatment in specific models, and 3) typically this phenomenon is not considered in air quality assessments even though it may be a primary cause of air quality episodes. The guidelines suggest that models which can be used for fumigation conditions include SCREEN3, CALPUFF & OCD.

No specific guidance is provided on which of the three models should be used in particular situations, or about mixing results of two different models for the same modelling analysis (e.g., CALPUFF for non-fumigation conditions and SCREEN3 for fumigation on the same source*). If SCREEN3 is limited to use on only relatively small sources, most permitting applications would be evaluated using either CALPUFF or the OCD model. There is a need to provide specific guidance on where and when to use either model.*

This confusion would be eliminated if CALPUFF was selected as the primary assessment model for B.C. The USEPA's recent revisions to the regulatory modelling guidelines specifically identifies the availability of the CALPUFF model for use in modelling fumigation in certain situations (on a case-by-case basis), but also includes the OCD model as a recommended model for offshore sources.

3.6 ROADWAY EMISSIONS

Modelling of vehicular emissions from roadways has not been addressed in the draft modelling guidelines. It is not clear to what extent roadway emissions are to be considered in any permitting application. In the proposed development of a bulk material transport and storage facility, would the permitting of the facility include evaluation of air quality impacts stemming from vehicular emissions from heavy duty trucks arriving/departing the facility or just the emissions from the facility itself? To what extent are proposed roadway developments or expansions required to conduct air quality impact assessments for vehicular emissions?

The recommended model should be CAL3QHCR. The model is specifically mentioned by the USEPA in the most recent version of the regulatory modelling guidelines as suitable for use in refined intersection modelling, on a case-by-case basis.

Alternatively, proponents could be directed to use either the ISC3, the AERMOD or the CALPUFF models for linear sources, after making appropriate adjustments for initial dispersion. The appropriate adjustment methodology would need to be described in the guidelines.

It may also be worth noting that an elongated area source in ISC3 or AERMOD may provide a good representation of some roadway emissions, in lieu of an explicit line source option in these models. A series of volume sources has historically by used in the U.S. with ISC3, and the two approaches should be comparable as long as receptors are not too close to the roadway. If receptors are located adjacent to the roadway, or even in the roadway, then the area source approach is considered preferable.

3.7 ACCIDENTAL RELEASES

Modelling of accidental releases is not addressed in the draft modelling guidelines. *A new section should be added to the guidelines recommending that heavier-than-air gases should be modelled using the ALOHA model for screening-level analyses, or the DEGADIS, SLAB, HG-SYSTEM, or SAIC Application models for refined modelling applications. Each model would need to be described with recommendations for which model is best used for specific applications.*

3.8 COMPLEX FLOW AROUND BUILDINGS

Air quality impacts due to complex flow around buildings are not discussed in the draft modelling guidelines. This is not the same as modelling building downwash effects for emissions from short stacks. Rather, this type of modelling could be used to evaluate the emissions from short stacks on the roof of a building on the air quality at the intake air vents of the same building or adjacent buildings, or to model the effect of a building acting as a barrier to the dispersion of fugitive dust from an area source. It may also be used to evaluate the impingement of an elevated plume on the face of a high rise residential building.

This type of assessment has traditionally been conducted using wind tunnels. However, advances in computer hardware have led to the development of models that can now accomplish the same results without having to use wind tunnels. Furthermore, whereas wind tunnels are restricted to evaluating dispersion under neutral stability conditions, Computational Fluid Dynamics (CFD) models can simulate dispersion over all stability classes. CFD models are receiving greater attention for environmental applications, but there has been insufficient experience in their application to date to recommend any particular model. *It is recommended that the B.C. modelling guidelines simply acknowledge the potential value in the use of such models for specific applications, and possibly list the available models. The onus would then be on the proponents to provide the justification for the use of any particular model for a specific application.*

3.9 PLUME VISIBILITY

Section 10.4 of the draft B.C. modelling guidelines addresses plume visibility effects associated with the primary effects of particulate matter, sulphates and nitrogen dioxide. Plume visibility due to water vapour releases is discussed in Section 10.9 and in Appendix 7 of the draft guideline.

3.9.1 Visibility Effects of PM, NO_2 and SO_4

The draft B.C. modelling guideline notes that there are currently no visibility standards in Canada as a whole, or for B.C. in particular. The guideline also states that the use of available models for plume visibility in complex terrain situations is uncertain, and that there is a lack of regional background visual range estimates against which modelled impacts can be compared.

The guidance document cites a 1988 USEPA reference describing a step-wise approach to visibility impact assessment using VISCREEN (Levels 1 & 2) or PLUVUE-II (Level 3). The specific USEPA reference is not provided in the draft guideline document. The use of the deciview scale in U.S. is also cited as an example of a method for determining ‘acceptable’ visibility impacts. The guidelines recommend that, where visibility impacts are critical for an impact assessment, detailed plans for monitoring/modelling should be developed in consultation with MWLAP staff.

The primary weakness in this section of the guidelines is that guidance document sets out modelling options based on plume visibility modelling in other jurisdictions, but does not provide specific guidance for applications in B.C. *In order to ensure consistency of applications across regions of the province, the guidelines should either provide guidance on which method to use in B.C. based on other jurisdictions, or develop a B.C.-specific policy on plume visibility impacts.* By allowing the use of methods sanctioned in other jurisdictions without adopting a B.C. specific policy, MWLAP is establishing a *de facto* policy on a case-by-case basis.

3.9.2 Visibility Effects of Water Vapour

The draft guideline recommends assessing plume visibility from water vapour releases (e.g., cooling towers) using screening techniques for estimating visible plume length. Suitable models recommended by the guidelines include ISC-PRIME or AERMOD. The ATCOOL model is recommended in the guideline as the ‘best estimate’ technique for estimating visible plume length for large cooling towers. The guidance document notes two examples of the successful application of the ATCOOL model in B.C. However, it is unlikely that screening techniques will be necessary if the use of screening-level models is restricted to relatively small sources, as stated elsewhere in the modelling guidelines.

The SACTI model is suggested as an appropriate model for estimating plume length, drift deposition, fogging, icing and shadowing impacts for a whole range of meteorological conditions due to vapour releases from large cooling towers located in complex terrain. However, the guidance document notes that there is no experience with the application of SACTI in B.C. The SACTI model meteorological input data requirements include seasonal and annual average wind speed and direction, dry and wet bulb temperature, the extent and height of cloud cover, as well as mixing height. Data on cloud cover is often difficult to obtain for many locations in B.C. Consequently, with the exception of a few locations where such data are readily available, applications of the SACTI model would require the establishment of an on-site meteorological monitoring program using automated cloud cover and ceiling height monitors, or the use of a full weather prediction model.

Plume visibility and fogging potential have recently also been estimated for the proposed power plant at Duke Point near Nanaimo using the FOG model, as part of the CALPUFF analysis. FOG uses ISC3-formatted wind speed, direction, stability class, mixing height and relative humidity.

The B.C. modelling guideline should note that there is insufficient data and experience with any of these models to justify recommending a particular model at this time. The guideline could simply list and the available models, much as the USEPA used to do in Appendix B of the USEPA modelling guidelines, without any explicit recommendations.

3.10 NO_X CONVERSION TO NO_2

Section 10.1 of the draft B.C. modelling guidelines sets out a 3-tiered approach for estimating annual average NO_2 concentrations:

Tier 1 – assume that all NO_x converts to NO_2 and, if the ambient air quality objective for NO_2 is exceeded, the guidelines recommend using the Tier 2 method;

Tier 2 – use the ozone limiting method (OLM) for single plumes by running the ISC3-OLM version of the ISC3 model, and if the ambient air quality objective for NO_2 is still exceeded, the guidelines recommend using the Tier 3 method; and,

Tier 3 – use the ISC3-OLM model with sequential, 1-hour average O_3 concentrations.

The guidance document suggests that the Tier 2 analysis is unlikely to exceed ambient air quality objectives in B.C. Consequently, the Tier 3 method is unlikely to ever be applied in this province.

Alternatively, the guidelines recommend using the Plume Volume Molar Ratio Method (PVMRM), and running the AERMOD/PVMRM method when this version of the AERMOD model becomes available in about 2-3 years. However, in it's response to comments made at the 7th conference on air quality modelling in 2000, the USEPA (2003) has stated that the PVMRM method has not been standardized and is not available in a form for distribution in the public domain. Testing of the model has been limited, and it needs to be considered for a greater variety of NO_x sources.

The draft B.C. guidance document is very specific about using the ISC3-OLM method. The OLM has been added as a Tier 3 screening-level approach in the latest version of the USEPA modelling guidelines, to be used on a case-by-case basis. However, no guidance is provided in either set of guidelines as to the implications of mixing results from CALPUFF and ISC3-OLM in a single analysis. Since CALPUFF can result in significantly different predictions of maximum 1-hour average NO_x concentrations than results from ISC3, mixing of results from CALPUFF and ISC3-OLM model to calculate maximum 1-hour NO_2 can lead to some uncertainty about whether or not predicted impacts will exceed ambient air quality objective levels. *If CALPUFF is chosen as the preferred model for B.C., the ISC3-OLM model should not be used in order to avoid mixing results from two different models. Similarly, if the chosen modelling philosophy for B.C. is to follow the USEPA, then the AERMOD/PVMRM method should be used in conjunction with the AERMOD model for other air quality impacts, whenever the AERMOD is adopted by the USEPA as the recommended regulatory model.*

It is also worth noting that for short-term (e.g., 1-hour average) concentrations of NO_2 impacts due to emissions from vehicular traffic beside major roadways, it would be appropriate to assume that 90-95% of the NO_x emitted from the vehicles is NO. *As such, over short distances of a few hundred metres, 1-hour average NO_2 impacts from such sources can be conservatively assumed to be equivalent to 10% of the NO_x impacts as derived from the dispersion model analysis.* This would be a less conservative approach than assuming that all of the NO_x converts to NO_2 instantly upon being released from the emission source.

3.11 ODOURS

Section 10.2 of the draft modelling guideline states that no single dispersion model is recommended for modelling odour impacts. The guidance document states that short time-averaging concentrations can be derived from puff type dispersion coefficients in Gaussian models, or from concentration fluctuation theory to derive probability estimates for how often concentrations may exceed odour threshold levels. If odours are determined to be a critical component of an air quality assessment, the proposed assessment approach must be detailed in a monitoring and modelling plan in consultation with the MWLAP staff.

Although the ISC3 model has been used successfully in odour modelling applications, the preferred model at present is CALPUFF due to its puff formulation. Furthermore, one-to-two order of magnitude differences in predicted odour concentrations have been reported for area sources using AERMOD, compared with ISC3 and CALPUFF.[6] *Therefore, the B.C. modelling guidelines should recommend the use of the CALPUFF model for odour impact assessments.*

3.12 CONTAMINANT DEPOSITION

Section 10.3 of the draft B.C. modelling guidelines recommends using the CALPUFF model for gaseous contaminant deposition, and the ISC-PRIME for particulate matter deposition. *However, it should also be noted in the modelling guidelines that the CALPUFF model can be used for both particulate matter and gaseous pollutant depositions.* Because of differences in predicted concentrations between CALPUFF and ISC-PRIME, it would be inconsistent, and therefore inappropriate, to conduct deposition modelling of gaseous emissions using the CALPUFF model, while modelling the particulate matter deposition using the ISC-PRIME model.

If the decision is made to maintain consistency with the USEPA on modelling recommendations, the ISC-PRIME model would be used for both gaseous and particulate matter deposition rates following the protocols developed by USEPA Region 6[7] *for human health and ecological risk assessments. Note, however, that the USEPA Region 6 guidance only addresses wet deposition of gaseous pollutants, as well as both wet and dry deposition from particle phase pollutants. The guidelines should recommend switching to the AERMOD model when a version of the model is available that incorporates a deposition algorithm.*

On the other hand, if the decision is made to designate CALPUFF as the preferred model in B.C., all modelling requiring estimates of both wet and dry phase gaseous and particulate matter deposition rates (e.g., for human health and/or ecological risk assessments) must be conducted using the CALPUFF model.

With respect to wet deposition modelling using CALPUFF, the model requires hourly precipitation intensity (mm/hr) data, which is generally not available from most meteorological monitoring stations in B.C. *In such circumstances, it is recommended that 'present weather data' records be obtained from local airport monitoring stations and used to evenly distribute the total daily precipitation amount among all hours of the day for which the 'present weather data' records indicate that precipitation occurred.* The 'present weather data' records contain

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[6] Doisey, P.G., Hess, M.E. and L. Farrell 2002. *Modeling of Odors and Air Toxics: A Comparison of the ISCST3, AERMOD, and CALPUFF Models.* Proceedings of the WEF Specialty Conference on Odors and Toxic Air Emissions 2002, Alburquerque, NM, April 28 – May 1, 2002.

[7] U.S. Environmental Protection Agency (USEPA) 1998. *Human Health Risk Assessment Protocol for hazardous Waste Combustion Facilities.* EPA Region 6.

information on whether the precipitation occurred in liquid or frozen form, a factor that must also be specified for the CALPUFF model.

The guidance document also notes that the FDM model is no longer recommended by the USEPA for fugitive dust sources. However, based on applied experience at SENES, it is worth noting that the FDM model is better than either ISC-PRIME or CALPUFF for modelling in situations of variable emissions rates (e.g., wind erosion due to variable wind speeds). *Therefore, it is recommended that the modelling guidelines retain the FDM model as being recommended for use in special situations of time-varying emission rates from large area sources.*

3.13 GOOD ENGINEERING PRACTICE

Section 4.8 of Chapter 4 in the draft B.C. modelling guidelines discusses Good Engineering Practice (GEP) with respect to stack emissions. The guidelines state that, although not bound by the rules for GEP in the U.S.[8], the MWLAP has used these rules to discourage the use of tall stacks as a means of remedying air quality problems and to ensure that the adverse situation of downwash is avoided, or at least accounted for, in modelling assessments. However, it is emphasized in the draft guidelines that the guidance does not limit the maximum height allowed in modelling assessments to 65 m, as is the case for modelling in the U.S. The draft B.C. guidelines indicate that the USEPA rules for GEP are incorporated into the BPIP utility program, which is used in the ISC-PRIME model.

As noted previously, the building downwash algorithm in earlier versions of the CALPUFF model was not the same as the PRIME algorithm in ISC-PRIME or AERMOD-PRIME, and may not produce the equivalent results. However, as noted in Section 3.2.2 above, Earth Tech has committed to installing the PRIME algorithm in CALPUFF to support the USEPA's recent decision to designate the CALPUFF model as a preferred model for near-field air quality impacts on a case-by-case basis.

3.14 MODELLING ACCURACY AND UNCERTAINTY

In common with other environmental analyses, air quality impact assessments must, of necessity, rely heavily on assumptions about operational parameters which affect estimated emission rates and the use of mathematical models to extrapolate information beyond what can be determined

[8] U.S. Environmental Protection Agency (USEPA) 1985. *Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) (Revised).* Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-450/4-80-023R.

through direct monitoring methods. However, no matter how sophisticated the analytical techniques being used, it is always necessary to question the reliability of the results.

When the objective of the assessment is the derivation of a "best estimate" predicted impact for an emission source, the associated uncertainty of the estimate must be quantified and disclosed. The quantification of the uncertainty could include upper and lower bound estimates, confidence interval, probability frequency distributions or other error bounds of the estimate.

Section 9.0 of the draft B.C. modelling guidelines provides a good overall discussion of the *reducible* and *inherent* uncertainty in dispersion model predictions. The guideline attempts to provide some perspective on the issue of the reliability of modelling results. While the discussion of these issues in the guidelines is informative, there is no guidance provided on what to do about uncertainty in predicted results for specific modelling situations. Although the sources of uncertainty discussed in this section of the draft modelling guideline are generally recognized, it has not been common practice for modelling analyses to explicitly consider uncertainty in permitting decisions. For example, the USEPA modelling guidelines provide no specific guidance on the quantification of model uncertainty for use in decision-making, and consider it acceptable practice to use the “best-estimate” of predicted concentrations for most pollutants (the exceptions being ozone, $PM_{2.5}$ and regional haze impact assessment). This may be due, in part, to the fact that uncertainty in model predictions is considered during the evaluation stage of model performance, before the model is accepted for use in regulatory applications. In addition, there may be a desire for simplicity in the interpretation of modelling results on the part of industry, regulatory and public stakeholders.

Nevertheless, the issue of uncertainty in model predicted concentrations has been raised repeatedly in public hearings on the permitting of proposed new emission sources in B.C. *Reducible uncertainty can be addressed through clear guidelines on model inputs. For example, the guideline should provide some direction on how to deal with reducible error through sensitivity and/or uncertainty analyses of the model input data (e.g., upper and lower uncertainty bounds for emission rates, use of multi-year meteorological data sets to account for year-to-year variability, sensitivity to differing methods of in-filling for missing wind data, etc.).*

For particularly sensitive air quality assessments, model output can also be evaluated within a probabilistic framework. Uncertainties in such parameters as emission rates, particle size distributions, and meteorological variables such as mixing heights can be probabilistically sampled to develop an ensemble prediction of the probability distribution within which impacts on air quality concentrations or deposition rates are likely to occur. The decision on the acceptability of the impacts can then be based on the 90^{th} or 95^{th} percentile of predicted impacts. Such techniques have been employed by SENES in Canada and the United States for such diverse assessments as an accidental release of scrubber solution from a petroleum refinery, permitted releases of trace metals from copper and zinc smelters and refineries, and dose reconstruction of radioactive releases from nuclear weapons development programs. Such analyses may be too onerous for typical permitting applications, but the B.C. modelling guideline should, at a minimum, recognize the availability of this type of uncertainty analysis as acceptable practice for assessments in special circumstances.

The guideline should also require dispersion modelling assessments to explicitly acknowledge the *inherent* uncertainty in modelling results, in order to ensure that the results are not represented to the public as absolutely accurate. The uncertainty can then be factored into any decision on permitting the facility. For example, the draft guidelines state that an error of $\pm$40% or less in the predicted 1-hour average concentrations from a properly run model could be interpreted as a relative mean absolute deviation of ensemble averages or probable error in the model prediction of the ensemble average. That being the case, would it be feasible to incorporate that uncertainty into the interpretation of the acceptability of the predicted impacts on air quality? If the decision point on the permit is based on the maximum predicted concentration, the results are open to the criticism that the maximum predicted concentration may be underestimated by up to a factor of two or more. However, if the decision point on impacts is based on say the 95th or the 99th percentile values of predicted concentrations, it may be feasible to add an inherent uncertainty factor of 40% for the ensemble forecast on top of the 99th percentile predicted concentration for comparison with the ambient air quality objectives (see Section 4.5.2 and 4.5.3 for a discussion of the frequency distributions of observed pollutant concentrations).

Ultimately, the need to consider quantitative uncertainty in a modelling analysis depends on:

1. whether an erroneous result in the predicted impact may lead to large or unacceptable consequences (e.g., exceeding the ambient air quality objectives, or an established health risk criterion);

2. whether a realistic, rather than a conservative, estimate of impact is required; or,

3. a need to identify priorities for the assessment components for which additional information will likely lead to improved confidence in the estimate of the predicted air quality impact.

A quantitative uncertainty analysis may be unnecessary under the following circumstances:

1. If conservatively-biased screening model analysis indicates that the risk from potential air quality impacts is clearly below regulatory or health risk levels of concern, and factoring in the additional uncertainty would not change any conclusions about the acceptability of

the predicted impacts. Conservative screening calculations are designed to provide a risk estimate that is highly unlikely to underestimate the true impact (e.g., ambient PM_{10} concentration) or health risk. Therefore, a more detailed modelling analysis is likely to demonstrate that the true impacts are even lower.

2. If the cost of an action required to reduce the impacts is low, a quantitative uncertainty analysis on the predicted impacts and/or health risk assessment might not be warranted. For example, if the cost of reducing the emissions of PM_{10} is lower than the cost of conducting an uncertainty analysis.

3. If data for characterizing the nature and extent of air quality impacts (e.g., PM_{10} emission rates) are inadequate to permit even a bounding estimate (i.e., an upper and lower estimate of the expected emission rates), a meaningful quantitative uncertainty analysis cannot be performed. In such a case, ambient monitoring may be the only alternative method of resolving the uncertainty about potential impacts.

These concepts could be formally incorporated in the B.C. modelling guidelines to help clarify the issue of how to address the uncertainty in a quantitative manner. *However, such an approach to dealing with model uncertainty would require a policy decision by the MWLAP.*

3.15 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

The draft B.C. modelling guideline does not discuss what types of measures are to be followed to ensure that the modelling analyses are technically valid.

The use of computer models is an activity that requires an extremely high degree of quality assurance/quality control and the guidance document should specify the types of QA/QC procedures that should be followed. Modelling input data for QA/QC and output data for comparison against ambient air quality objectives, standards or guidelines should be streamlined to reduce review time while ensuring that the simulation is valid. *This could involve creating a post-processing program that would do quality assurance checks on the model output file including such simple things as:*

- *plotting model topography vs. real topography;*
- *analysis of meteorological inputs vs. standardized regional datasets;*
- *order of magnitude analyses of concentrations vs. emissions;*
- *others methods.*

3.16 DOCUMENTATION REQUIREMENTS

The level of documentation to be submitted to the MWLAP in support of each modelling analysis (e.g., complete description of emission data and sources, model input/output files, QA/QC analyses, quantitative uncertainty and/or sensitivity analyses, and a statement about the confidence in the accuracy of the predicted results, etc.) is not specified in the existing draft B.C. guidelines. *A list of the minimum documentation that should be provided in support of a regulatory modelling analysis should be developed and added to the guideline document.* This would assist the Ministry staff to ensure that all information is provided for review during the permit approval process, as well as for any subsequent permit appeals.

4.0 MODEL INPUT REQUIREMENTS

4.1 METEOROLOGICAL DATA

Meteorological data input requirements for modelling are discussed in Section 7.0 of the draft B.C. modelling guideline. Specific topics are addressed in the following subsections:

7.3	duration of data record required for modelling
7.1 & 7.2	representative data
7.4.3	on-site data collection programs
7.4	alternative meteorological station data sources
B.18	use of mesoscale meteorological models
7.4.6	acoustic Doppler radar (SODAR)
7.4.7	balloon profiling techniques
7.5	atmospheric stability classification
7.6	mixing heights
7.7	preparing data for model use
7.7.4	regulatory completeness requirements for missing data
7.7.5	treatment of light wind conditions
10.5 & 10.6	stagnation conditions
7.7.6 to 7.7.10	meteorological data input requirements for ISC-PRIME, RTDM, CTDMPLUS, AERMOD and CALPUFF.

An important topic not addressed in the draft guideline is the issue of the level of meteorological data documentation that must be provided to the MWLAP in support of the modelling analysis, as well as the requirement of making that information available to interveners during permit appeals. Each of these issues is discussed below.

4.1.1 Duration of Data Record

Consistent with the general practice for regulatory modelling, the draft B.C. modelling guideline states that the minimum duration of meteorological data for modelling purposes is one year, to a maximum of 5 years. However, the guideline does not explicitly state that a minimum of one year of data is a requirement, or what proponents are to do if even one year of data is not available. The guideline suggests that proponents may look to available data from nearby meteorological stations (e.g., airport stations) if it can be demonstrated that such data are representative of conditions for the area to be modelled.

The guideline should state that, at a minimum, one year of representative on-site data, or 5 years of local airport data, will be required for permitting purposes. Furthermore, for modelling applications that require comparisons to the Canada-Wide Standards for $PM_{2.5}$ and ozone, recent CCME guidance suggests that a minimum of two years of meteorological data would be required to determine compliance with these standards.

A related issue for the use of refined or 'best-estimate' models such as CALPUFF is the time required to run the model using even one year of meteorological data. This is especially true if the analysis is conducted using mesoscale meteorological models to initialize the CALMET model. A requirement to run more than one year of data would impose considerable extra costs and time on proponents. Nevertheless, the recent revisions to the USEPA regulatory modelling protocols state that, when using the CALPUFF model for long range transport or complex wind situations based on NWS station data if merged with available mesoscale meteorological fields, proponents will be allowed to run the model with less than 5 years of data, but must use at least 3 years of assimilated meteorological data. The 3 years do not have be consecutive years in the data record. Based on SENES's experience in running the CALPUFF model, it is likely that the requirement to use at least 3 years of meteorological data is likely to prove to be impractical for the near future, until computer processing technology can substantially reduce the model run time for such a large data set.

On the other hand, as illustrated in the discussion of contaminant monitoring data in Section 4.5 below, one year of meteorological data may be sufficient to provide a representative set of predicted air pollutant concentrations up to a certain percentile value with some degree of confidence, but would have only a one-in-five probability of capturing the peak concentrations that might be expected to occur over a 5-year period. Therefore, if the decision criterion for the acceptability of air quality impacts is based on some lower percentile value such as the 95th, 98th or 99th percentile, then a modelling analysis based on one or two years of meteorological data may be equivalent to the impacts that would be expected to occur if the analysis were based on a 5-year data record. On the other hand, if the decision criterion is based on the 100th percentile value (i.e., maximum impact), then a one or two-year data record may not be sufficient to account for the year-to-year variability in the peak concentration.

Consequently, the question of the duration of meteorological data record required for modelling purposes is related to the question of the basis that the MWLAP will use for determining compliance with ambient air quality objectives (see discussion in Section 5.1 below). If the source is expected to meet the objective level all of the time (i.e., at the 100th percentile level), then one year of data may not be enough. If the source emissions (plus background concentrations) are only expected to be below the objective level at the 99th percentile, for example, then one year of meteorological data may be perfectly adequate. This is a philosophical decision that MWLAP needs to address.

4.1.2 Representative Data

The draft B.C. guideline states that on-site meteorological data are preferred, but the need for on-site data must be balanced against the use of alternate station data by cost, level of effort and time constraints for obtaining on-site data. The guidelines provide a good general discussion of factors to be considered in determining whether alternate site data is representative for the location of interest. Reference is made to a 1995 USEPA guidance on characterizing the area of the alternate collection program in comparison to the area of interest for modelling for determining whether the alternate site data are representative for the area of interest. The specific USEPA reference is not provided in the draft guideline.

As currently defined in the guidelines, the decision on whether alternate site data is suitable for the modelling application is left to the subjective judgement and experience of the MWLAP and proponent's staff. Experience and professional judgement of qualified individuals is an integral part of the decision making process in evaluating whether available meteorological data are representative of the area of interest. At present, there is no mechanism identified in the guidance document for resolving differences of opinion between qualified individuals. In this respect, it is worth noting that the recent revisions to the USEPA modelling guidelines allow flexibility and the use of professional judgement in determining the representativeness of available meteorological data, supplemented with technical guidance on determining representative data[9].

However, in our opinion, it should be clearly indicated that one-year of on-site data is the default, first choice option for regulatory modelling purposes, and that proponents must justify their reasons for using alternative site data on the basis that such data are equally suitable for the purpose. As currently defined in the guidelines, the tendency would most likely be to first look to the available data as the first choice option before considering an on-site monitoring program. The distinction between the two approaches may appear subtle, but in practice it has been SENES's experience that proponents will tend to opt for the use of the available alternative site data first, resisting establishment of an on-site monitoring program. This leaves the MWLAP staff in the position of having to justify why the alternative site data is not suitable, when the onus should properly be on proponents to justify their decision that an on-site data program is not necessary.

[9] U.S. Environmental Protection Agency (USEPA) 2000. *Meteorological Monitoring Guidance for Regulatory Modeling Applications.* Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-99-005.

4.1.3 On-site Data Collection

The draft B.C. modelling guideline notes that representative meteorological data is often not readily available from alternate sources due to B.C.'s mountainous topography. The guideline sets out the minimum number of meteorological parameters that must be included in an on-site monitoring program, siting requirements and QA/QC procedures for on-site monitoring which is consistent with USEPA guidance. Note, however, that there have been frequent examples where data from poorly sited stations have been used for regulatory modelling purposes in B.C. over the past 5-8 years.

The guidance states that the use of on-site meteorological data is 'ideal', but does not state that it is a 'requirement'. As discussed above in Section 4.1.2, this leaves the door open for proponents to look to alternate data sources as a first choice, only considering on-site data collection if alternate station data cannot be obtained. The absence of an explicit requirement for on-site data provides incentive for proponents to argue that alternate data sources are adequately representative for modelling purposes, putting Ministry staff in the position of arguing why it may not be representative.

Wherever possible, on-site meteorological monitoring should be the standard a priori requirement. Instrument siting criteria should be consistent with World Meteorological Organization (WMO) recommendations.

If proponents choose to rely on alternate or local airport data, the onus must be on proponents to demonstrate that alternate data is adequately representative. Any resulting uncertainty in predicted air quality impacts from the use of such data must be factored into the permitting decision. For example, permits may be issued on a conditional basis until the permittee can validate predicted modelling results either through the collection of on-site meteorological data and re-modelling of air quality impacts, or through ambient air quality monitoring, after the conditional permit has been issued. The latter is consistent with the draft B.C. guidance provided in Section 7.4.4 which states that ***"…an approval can be granted based on a commitment to do a proper monitoring program and assessment at a later date and, if needed, to agree to a remedial control program."*** Such guidance is also consistent with several decisions rendered by the B.C. Environmental Appeal Board for existing and proposed facilities, for example in Dawson Creek and Prince George.

It should also be noted that, in its most recent meteorological monitoring guidance document and in the Guideline on Air Quality Models, the USEPA has shifted to the use of "site-specific" as the qualifier for representativeness of data instead of "on-site" in recognition of the fact that location of a meteorological tower within the property boundaries of a facility is neither a requirement for, nor a guarantee of, the representativeness of the data for site specific applications. It is suggested that the MWLAP also adopt this new language convention.

4.1.4 Alternate Meteorological Station Data Sources

The draft guideline provides a good general discussion of data available from Environment Canada, and existing monitoring site data from stations operated by the MWLAP. However, there is no discussion of the differences between automatic station and airport station observations of cloud cover and wind speed/direction. Comparisons between these types of stations suggest that average wind speeds from automatic stations are one-half those reported by nearby airport stations which rely on observations made 10 minutes before the hour, rather than on measured hourly averaged data. Differences can also be expected between airport cloud cover observation data and automatic cloud cover station data. The recent revisions to the USEPA modelling guidelines state that discretion based on professional judgement should be used in determining whether or not to use cloud cover data from automatic recording stations for regulatory modelling applications.

The potential consequences to dispersion modelling results of relying on airport data should be clearly spelled out in the modelling guidelines. In this regard, it is worth noting that the USEPA guidance[10] on meteorological monitoring for regulatory modelling applications states that airport station data generally do not meet the guidance requirements defined for regulatory modelling in the U.S. with respect to instrument threshold, wind direction precision, and averaging period. However, the USEPA also notes that, while data meeting its guidance requirements are preferred, airport data continue to be considered acceptable for use in regulatory dispersion modelling applications.

It is also worth noting that there can be significant difficulties in using data from Canadian airport monitoring stations or on-site meteorological monitoring programs for input to dispersion models due to the need to transform the data into formats compatible with the input requirements of models such as ISC-PRIME, AERMOD or CALPUFF. A certain degree of computer programming skill is required of modellers to format such data. The MPRM program can be used to format data compatible with ISC-PRIME, MPRM cannot be used for CALPUFF, and AERMET is used to process data for AERMOD.

Data from Canadian airport stations can be purchased from the U.S. National Climate Data Center (NCDC) in DATSAV3 (TD9956) format which is not compatible with the CD144 format

[10] U.S. Environmental Protection Agency (USEPA) 2000. *Meteorological Monitoring Guidance for Regulatory Modeling Applications.* Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-99-005.

required for CALPUFF. However, NCDC will provide data in the CD144 format upon request and payment of fees for the reformatting of the data. Both the TD996 and CD144 formats must be reformatted using utility programs available from the CALPUFF model's developer, Earth Tech.

Meteorological data from on-site meteorological monitoring programs pose an even greater challenge in that data storage modules differ in the formats used to record data, depending on the meteorological parameters being recorded, the equipment's manufacturers, and the sampling and averaging times chosen for data collection. There are no standard utility programs available to assist in the transformation of the monitoring data to model-compatible formats. *In order to ensure consistency and quality of input data to models, it is recommended that the MWLAP consider developing standardized utility programs that can be used for this purpose.*

4.1.5 Use of Mesoscale Meteorological Models

The draft guideline provides a good general discussion of the option for using the existing 1995 MM5 database for B.C. and Alberta as input to the CALMET model. However, the guidance relies on the subjective judgement of the modeller to decide whether the resultant wind fields in CALMET are acceptable. Furthermore, there is no discussion of QA/QC procedures required to verify whether the use of MM5 data in CALMET results in 'reasonable' estimates of wind fields in the horizontal and vertical dimensions.

Similarly there is no discussion of using forecast models such as ETA to generate a complete 1-year data set of wind fields, temperature, precipitation and cloud cover for remote locations lacking representative meteorological data observations. It is worth noting, however, that a recent report by RWDI West Inc.[11] prepared for MWLAP recommended against using a relatively coarse resolution prognostic model run in combination with a finer scale diagnostic model run (e.g., using MM5 in combination with CALMET) in complex terrain, unless observational data from a significant number of observing sites are incorporated into the simulation. However, it is likely that future analyses will continue to rely on such data, especially after their use in two permitting projects for power plants in B.C. and in Watcom County, WA.

Therefore, there is a need to define where the use of regional meteorological data sets is appropriate, and the conditions and limitations on the use of such data. The guidelines should also specify the types of analyses that must be performed to validate wind fields resulting from the use of mesoscale models such as MM5, MC2, RAMS or the ETA models. If forecast models *are used in lieu of surface observational data for permitting purposes, the modelling guidelines need to clearly define requirements to conduct a quantitative uncertainty analysis as part of any subsequent air quality impact assessment and factor that uncertainty into any subsequent permitting decisions (e.g., issuing conditional permits, with additional requirements for monitoring/modelling validation studies).*

4.1.6 Acoustic Doppler Radar (SODAR)

Section 7.4.6 of the draft B.C. modelling guideline provides a brief discussion of the issues related to obtaining vertical profiles of wind and turbulence, and notes that the use of such methods must be developed in consultation with, and approved by, MWLAP staff. However, it should be noted that practical experience with this type of instrumentation is limited in B.C., and SENES's experience with using this type of data elsewhere as input to modelling analyses suggests that the data may not necessarily improve modelling results.

As implied in the draft guidelines, the decision on the use of SODAR should be made on case-by-case basis. Additional cautionary statements are required in the guidance document about some of the difficulties in using SODAR data, as well as some specifics on where and when it should be used.

4.1.7 Balloon Profiling

Section 7.4.7 of the draft B.C. modelling guideline provides a brief discussion of the issues related to obtaining vertical profiles of wind and temperature for estimating mixing heights. No specific guidance is provided on how to integrate data from short-term, intensive field studies using balloon profiling techniques into a meteorological data file to be used for regulatory modelling.

The use of such data has been relatively infrequent in B.C. Consequently, specific guidance can be developed on a case-by-case basis, where appropriate. No further elaboration of guidance is required.

4.1.8 Atmospheric Stability Classification

Section 7.5 of the draft B.C. modelling guideline discusses the various methods that can be used to develop atmospheric stability data from surface meteorological observations. The guidance

[11] Rowan Williams Davies & Irwin Inc. (RWDI) 2002. *Using Mesoscale Models to Support Regulatory Dispersion Modelling.* Submitted to the Water, Air and Climate Change Branch, British Columbia Ministry of Water, Land and Air Protection, Victoria, BC.

identifies the Turner method as the most frequently used approach, but cites the lack of hourly cloud cover data in many parts of B.C. as a significant limitation to many applications. The guidelines also discuss alternative methods using solar radiation and temperature gradient (SRDT), and turbulence fluctuations (σ_A and σ_E). The draft guidance document recommends using the Turner method if data are available, and states that poorer performance in stability classification can be expected for the alternate methods, unless the performance of these methods is checked and appropriate adjustments are made.

The guidance document also states that the need to define atmospheric stability class using the various methods is expected to pass with newer approaches to modelling which rely on direct measures of turbulence such as used in the AERMOD model. AERMOD still requires cloud cover data, but future updates to AERMET are expected to be able to use the SRDT method.

The draft guidance document does not indicate that on-site meteorological stations should be equipped with automatic cloud cover and ceiling monitors. These instruments are being used more frequently in standard meteorological monitoring applications and the costs are no longer prohibitive. Alternatively, cloud cover data can be derived from archived meteorological forecast model results. *A requirement for automatic cloud cover and ceiling height monitors should be added to the guidelines to be used for on-site monitoring stations, unless the emission source of interest is not particularly sensitive to atmospheric stability (e.g., fugitive dust from areas sources).*

4.1.9 Mixing Heights

Approaches to determining mixing heights for use in dispersion modelling analyses are discussed in Section 7.6 of the draft guideline. The low density of upper air stations in B.C. is identified as a significant limitation to defining mixing heights in this province, unless the proponent's area of interest is close to one of these stations. In such cases, the guidance options include: 1) conducting profiling studies using minisonde or tethersonde balloons, 2) installing a SODAR monitor following EPA (1995) guidance, 3) calculating the screening-level mixing heights using MWLAP's program MIXH.

However, mixing heights can also be derived from the CALMET model. A discussion of the methods used to derive mixing heights using the CALPUFF model is provided in a report on the mixing height climatology of North America.[12] *The latter report can be used to provide an overview of this issue for the B.C. modelling guidelines. If the overall philosophy of the B.C. modelling approach is based on the use of the CALPUFF model, there will be a need to provide*

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[12] SENES Consultants limited (SENES) 1997. *A Mixing Height Climatology for North America (1987-1991).* Prepared for Environment Canada, Ontario Ministry of Environment and Energy, and Alberta Environment.

very specific guidance on how to apply the CALMET/CALPUFF modelling system, including the derivation of mixing heights.

4.1.10 Preparing Data for Model Use

Section 7.7 of the draft B.C. modelling guideline recommends using the PCRAMMET or MPRM programs when relying on airport data, and the MPRM program when using on-site meteorological data. Note however that these programs are only useful when preparing data from a single point surface station for use in models such as ISC3 and AERMOD. This guidance is inadequate for modelling applications that rely on regional meteorological data sets from mesoscale models. *Some additional, specific guidance will need to be added to the guidelines addressing the procedures to be followed when using data from models such as MC2, MM5 or ETA.*

4.1.11 Regulatory Completeness Requirement for Missing Data

Section 7.7.4 of the draft guideline states that the basic requirement is for 90% completeness in the data record over a 12-month monitoring period. Missing data can be filled in by using either: 1) data from another level on the meteorological tower, 2) linear interpolation for 1-2 hours of missing data (except at sunrise & sunset), or 3) by in-filling data using alternate site data where it is deemed appropriate. However, the requirement for 90% completeness in a 12-month period could mean that there may be significant data gaps in any one season if all of the missing data falls in one period. Significant air quality impacts could be missed if this is the case. *Consequently, it is recommended that the basic requirement for completeness incorporate some limits for how much missing data would be considered acceptable in any season (e.g., 90% over 12 months and at least 75% completeness in every season). There could also be a requirement to run sensitivity tests on the dispersion modelling outcomes when in-filling data from alternate sites.*

4.1.12 Treatment of Light Wind Conditions

Section 7.7.5 of the draft guideline provides a discussion on how different models such as ISC-PRIME, RTDM and AERMOD treat ‘calms’. Specific guidance on modelling is presented in Sections 10.5 & 10.6. The overall discussion provides some useful information, but fails to provide guidance on what to do in specific situations. There is also no discussion on handling randomization of wind direction or the treatment of calms. *It is recommended that Sections 7.7.5, 10.5 and 10.6 be merged into one section, and that the guidelines provide more specific instructions on the treatment of light winds or calms.*

4.1.13 Stagnation Conditions

If the frequency of wind speeds less than 0.5 m/s is low, Sections 10.5 and 10.6 of the draft guidelines recommend using AERMOD. Alternatively, proponents are directed to use a box model or WYNDvalley in special circumstances, but only after consultation with MWLAP staff. Otherwise proponents should use the CALPUFF model, again after consultation with Ministry. However, the guidelines fail to quantitatively define how 'frequent' winds must be below 0.5 m/s before a decision is made to use models other than ISC3, ISC-PRIME, RTDM, etc. What is meant by the term 'low' in the recommendation to use AERMOD? How many consecutive hours of calm conditions must occur to be defined as a stagnation episode? The guidelines also do not specify who decides on which models to use when, or what criteria are to be used in making such a decision.

The WYNDvalley model has been deleted from the USEPA modelling guidelines, and is effectively replaced with the CALPUFF model. *SENES recommends that the B.C. guideline also reduce the choice of models that can be used for calm conditions to CALPUFF as the recommended model.*

4.1.14 Meteorological Data Input Requirements for Specific Models

Sections 7.7.6 through 7.7.10 of the draft modelling guideline provides a useful listing of meteorological data input requirements for the ISC-PRIME, RTDM, CTDMPLUS, AERMOD and CALPUFF models. *It is suggested that the discussion of data input requirements for RTDM and CTDMPLUS should be deleted, consistent with the recommendation to de-emphasize these models for general use in B.C.*

4.1.15 Documentation Requirements

The level of documentation to be submitted to MWLAP in support of each modelling analysis (e.g., geophysical data, meteorological station siting parameters, wind roses, description of missing data-filling, treatment of calms, mixing heights, stability classes, QA/QC analyses, copy of input/output files, etc.) is not specified in the existing draft B.C. guidelines. When using data from automatic meteorological stations, it is particularly important to perform QA/QC on the time recorded for each data record (i.e., local standard time or GMT). *For QA/QC purposes, SENES recommends that the MWLAP require proponents to supply not only the meteorological data files used for the modelling, but also a portion of the raw data record prior to its transformation to model-compatible format.*

A list of the minimum documentation that is required to be provided in support of a regulatory modelling analysis should be developed and added to the guideline document. This would assist the Ministry staff in ensuring that all information is provided for review during the permit approval process, as well as for any subsequent permit appeals.

4.2 GEOPHYSICAL DATA

While digital terrain data have been used in the ISC3 model in the past, the correct specification of terrain elevations, land/water boundaries and land use is of critical importance to more technically advanced models such as AERMOD and CALPUFF.

Section C.20.5 of the draft B.C. modelling guideline discusses the availability and use of geophysical data with respect to the CALPUFF model. It is noted that the CALMET land use processor CTGPROG requires land use data that is available from the U.S. Geological Service (USGS) and uses land use designation codes which are specific to the USGS data. Alternative sources of geophysical data for B.C. are given as:

1. land use data from the Geographic Data BC (BTM – Baseline Thematic Mapping):
    a. format not compatible with requirements of CTGPROG and requires a translation matrix to convert land use classifications to USGS designations;

2. land use data (in polygon format) from the 'non-productive Forest Data base available from the Ministry of Forests Relational Data Dictionary:
    a. polygonized data can be translated to raster images to provide data in CTGPROG-suitable format, and would require additional manipulation by a utility program to provide a format suitable for the GEO.DAT requirements in CALMET;

3. digitizing 1:50,000 scale contour maps or BTM land use maps:
    a. time consuming but may require less time to provide data compatible with CALMET data requirements.

Although not mentioned in the draft B.C. modelling guidelines, it should be noted that the Greater Vancouver Regional District (GVRD) also maintains an Arcview geographic database. Digital Composite Theme Grid (CTG) Land Use and Land Cover (LULC) data can be derived from the GVRD's database. However, because the GVRD database uses a classification system consisting of only 16 land use categories, the GVRD's land use categories must be converted into the 52 category LULC category system required for input to the CALMET model.

The guideline document should also states that 3 arc-second digital elevation maps (DEMs) can be used for modelling at a fine grid resolution of about 100 x 100 metres. These are available from Geomatics Canada. The CALMET/CALPUFF terrain-processing program TERREL can be used to process this data into the formats required by the ISCST3 and CALMET. The AERMAP pre-processor can directly read this format and prepare terrain data for AERMOD. The data can be obtained from the Geogratis (NRC Web page). This data is then converted to the USGS land classification through a program that SENES has developed internally. SENES could provide a copy of this program to the MWLAP. *For the AERMOD-PRIME model, SENES would propose to use a variation of the existing USEPA scheme for characterizing land use in a particular study area. If 50% of the land use within a 3 km radius from the source is urban, then SENES would suggest using urban dispersion coefficients. If 50% of the land use within the 3 km radius is not urban, SENES would suggest using rural dispersion coefficients.*

SENES is also aware of an interference problem with AERMOD with respect to surface roughness which will need to be resolved or flagged for the modelling guidelines.

The guidelines should recommend that proponents do some basic QA/QC on their geophysical data before running any dispersion model. The simplest form of QA/QC is to take the model output terrain and compare it to a map. It should be a basic requirement of the guidelines that the documentation supplied in support of the modelling analysis include such a comparison.

4.3 SOURCE DATA

Source data input requirements are only briefly discussed in Section 8.0 of the existing draft B.C. modelling guidelines. The guideline emphasizes that determining the emission rates to be used in any modelling analysis is not a trivial matter, and states that emission data can be obtained from theoretical calculations, stack sampling or from emission factors.

4.3.1 Emission Rates

The draft guideline states that source data should reflect emissions at maximum capacity or production (e.g., maximum permitted in-stack concentration multiplied by the total gas volume at normal operating conditions). Since maximum air quality impacts may not occur at maximum operating conditions, the guideline states that the modelling should also be done for 75% and 50% capacity in screening mode for intermediate and complex terrain situations. In addition, citing the precautionary principle, the guideline states that worst-case scenarios for abnormal or upset operating conditions should also be evaluated.

However, there is insufficient discussion of key issues related to sources of emission data in the existing draft guidelines. Specifically, the guideline does not address:

1. How representative of normal operating conditions are periodic (i.e., annual, bi-annual, or quarterly) stack sampling results?

2. What are the limitations of using emission factors or theoretical calculations over stack sampling data?
3. When is it not appropriate to rely on emission factors?
4. What level of uncertainty in emission estimates is considered acceptable for a permitting application?
5. How should uncertainty in source data be determined?

The guidance document appears to preclude the use of maximum design capacity if the maximum normal operating conditions are below maximum design capacity. Furthermore, the guidance suggesting the use of screening-level analysis for 75% and 50% capacity in intermediate and complex terrain appears to contradict the guidance on the use of screening-level analysis defined in Section 3.1 that screening models are typically used for small sources. There also appears to be a contradiction in logic with regard to the use of the precautionary principle. If the precautionary principle dictates that modelling should be conducted for abnormal or upset operating conditions, why is this principle also not used to require the evaluation of facility emissions at the maximum design capacity? As well, it is not clearly stated whether the terms 'abnormal' or 'upset' operating conditions include emissions during plant startup, shutdown, or normal maintenance.

There is a need to define the priority of data sources to be used for modelling analyses and their associated degree of acceptable uncertainty. Many large existing sources in B.C. still are not required to regularly monitor PM_{10} and $PM_{2.5}$ emissions. The modelling guidance needs to make clear whether these data must be obtained through stack sampling for a regulatory model application, or if they can rely on emission factors and/or theoretical calculations based on an assumed control efficiency. *While there may be no other alternative to the use of emission factors and assumed control efficiencies for proposed new facilities, the guidelines should make clear whether this is also acceptable for existing sources, and/or under what circumstances it would not be acceptable.*

Similarly, many large existing sources are also not required by permit to monitor common pollutants such as NO_x or SO_2. *The guidelines need to make clear under what circumstances 'grandfathering' of industrial facilities will no longer be considered acceptable for permit modelling applications, such that stack sampling will be required. If a source is evaluated based on theoretical calculations and/or emission factors, what degree of uncertainty should be applied to the estimated emissions, and how should that uncertainty be factored into a permitting decision?*

The guidance document also needs to be clear on when a source should be evaluated at its maximum design capacity. If operations at 75% and 50% capacity are going to be a concern, the modelling will have to be conducted using either the ISC3 or AERMOD models for *intermediate terrain, or using CALPUFF in complex terrain, for consistency with other modelling guidance. Furthermore, for consistency with the application of the precautionary principle with regard to modelling emissions from abnormal or upset operations, the guidelines should make clear that the upper bound estimate of emission rates derived from emission factors or theoretical calculations should be used rather than the mid-range estimate.* For example, the Alberta modelling guidelines state that maximum emission rates should be used when running models for stack design, but that typical emission rates can be used for estimating annual average concentrations.

4.3.2 Condensable and Filterable Particulate Matter

The draft modelling guideline provides no guidance on how to address secondary particulate matter formation from condensable particulate matter emissions. Section 1.11 of Chapter 4 in the guideline briefly discusses the fact that modelling secondary contaminants involves complex transformation chemistry, which in turn requires far more inputs (i.e., precursor gases, reaction mechanisms and rates, sunlight, humidity, etc.) than is required for modelling primary contaminant emissions. The guideline states that the uncertainty associated with model estimates of secondary contaminant is not well understood.

Recent experience in B.C. has included the use of filterable particulate matter (PM) in dispersion modelling, coupled with (in SENES's opinion, inappropriate) calculation of secondary particulate matter formation using the CALPUFF model for near-field (<10 km) PM impacts. *There needs to be clearly defined guidance on whether to include all condensable PM as total PM emission (filterable + condensable), or to model secondary PM formation.*

At present, there are no models available that can be used to calculate secondary PM formation in the near-field on a fine grid scale resolution for an entire year of meteorological input data (see Section 3.4 of this report for a discussion of secondary PM formation modelling). *SENES recommends that, for the time being, all condensable PM be included with filterable PM for total PM emissions.* This approach would be consistent with the precautionary principle being applied to estimated emission rates.

4.3.3 Averaging Stack Sampling Data

The current draft modelling guideline does not address the issue of how to treat non-continuous stack sampling data for modelling applications related to different averaging times. The current lack of guidance leaves the issue open to widely varying interpretations. *The guidelines could state that a sensitivity analysis or quantitative uncertainty analysis must constitute an integral part of the modelling study whenever there is variability in emission rates.*

Since many sources in B.C. are required to conduct stack sampling on an annual or quarterly basis, *there needs to be some guidance on how to incorporate the variability among emission tests into the uncertainty of the model predicted impacts.* For example, if two stack tests show ±50% difference in measured emission rates for the same plant production rate, *the guidance document should make clear when it is appropriate to average the results (e.g., for calculating annual average concentrations), and when it is necessary to use the highest measured emission rate (e.g., for estimating 1-h, 24-h average concentrations).*

4.3.4 Fugitive Sources

Fugitive sources are not discussed in the draft B.C. modelling guideline. Such sources can play an important role in local air quality, and have been a contentious issue on some recent projects in the province (e.g., coal dust from in-transit coal cars, bulk material transport terminals, cement batch plants, odours from sewage treatment plants).

Such sources are often very difficult to characterize (e.g., emission estimates depend on average emission factors; emissions vary by wind speed and time of day; the control efficiency of mitigation measures applied to reduce emissions may not be known, and are not constant) and are not easily incorporated into standard regulatory models. Often, what is modelled is the average emission rate on a monthly or seasonal basis, and not the temporally-varying fluctuations in emission rates which affect short-term concentrations. Furthermore, the predicted impacts are highly dependent on the particle size distribution defined for the modelling analysis, as well as the plume depletion algorithm being used in the model. None of the plume depletion algorithms will account for the reduction of emissions through interception by obstacles (perimeter walls, trees), and there is no simple way to incorporate re-suspension of deposited material (Note: The re-suspension of toxic compounds has been a component of modelling work conducted by SENES for emissions from a hazardous waste incinerator).

Currently, either the ISC3, CALPUFF or FDM models are suitable for modelling fugitive emissions, but it is recognized that significantly different results can be derived for the same input data to the ISC3 and CALPUFF models for both gaseous and particulate emissions from areas sources, as well as for particulate emissions using the CALPUFF and FDM models. The CALPUFF model is fairly sensitive to the specification of particle size distribution by particle size class. AERMOD is expected to have a deposition algorithm in future versions of the model, but comparisons of dispersion modelling results from area sources using the current version of AERMOD versus ISC3 and CALPUFF suggest that differences of 1-2 orders of magnitude can be expected with the current version of the AERMOD model. In cases of wind erosion from stockpiles, models such as ISC3, AERMOD and CALPUFF are awkward for incorporating fluctuations in emission rates based on variable hourly wind speeds. Devising hourly varying emission input files is time consuming and often impractical. Use of a single emission rate often leads to overprediction of impacts on air quality. The FDM model is better suited to these types of applications than ISC3 or CALPUFF. However, in complex facilities involving a mixture of source types, combining model outputs from FDM and other models in post-processing can be very difficult.

Due to the limitations of existing models for fugitive emission sources, the B.C. guidelines could state that regulatory applications involving fugitive sources must be verified through monitoring. For a proposed facility, this could mean establishing a monitoring program after the permit is granted to confirm the accuracy of the modelling assessment for the permit application, as well as to demonstrate compliance with ambient air quality objectives.

Furthermore, it would be helpful if the modelling guidelines could include a definition of what constitutes 'fugitive emissions'. For example, the USEPA defines "fugitive emissions" in the regulations promulgated under Title V of the Clean Air Act as ***"those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally-equivalent opening"***. This definition is identical to the definition of "fugitive emissions" adopted by the USEPA in the regulations implementing the New Source Review (NSR) program. The USEPA considers emissions which pass through a stack, chimney, vent, or other functionally-equivalent opening are not fugitive, whether they are collected or not. However, where emissions are not actually collected at a particular site, the question of whether the emissions are fugitive or non-fugitive may be based on case-by-case determinations made by the permitting authority. SENES has encountered this issue with regard to (so-called) fugitive emissions from copper and zinc smelters and refineries in Canada, and the confusion stemmed precisely from the lack of a proper definition of what constitutes a fugitive emission source. *To avoid similar confusion in B.C., SENES recommends that the MWLAP develop a definition of fugitive emissions for the modelling guideline.*

4.3.5 Odour Emissions

Although the draft modelling guideline notes that odour modelling may be required on some projects, the guideline does not address issues related to obtaining reliable odour emission data for modelling purposes. At present, there is no reliable odour panel in B.C.

Modelling specific odorous compounds is feasible in B.C. using standard GC/MS laboratory techniques to obtain compound concentrations in emission streams, but modelling mixtures of compounds that must be evaluated by odour panels is currently impractical due to the lack of proper odour panel capabilities. *The guidance document should discuss the issues surrounding sampling and analysis of odorous gases, and the use of quantitative uncertainty in odour modelling applications.* SENES has addressed many of the issues related to the assessment of odour emissions using dispersion modelling techniques (specifically CALPUFF) in work completed in 2002 for the Greater Vancouver Regional District. *Some of that material could be incorporated into the B.C. modelling guideline and expanded upon to provide more general guidance on how to treat odour emissions. The important point is that the modelling guideline cannot talk about which models to use for odour modelling without addressing the issue of source data to be used in such modelling.*

4.4 RECEPTOR GRID & DISCRETE RECEPTOR LOCATIONS

Table 1.1 in Section 3.2 of the draft B.C. modelling guideline states that, as part of the development of a modelling plan, proponents must: 1) define a grid resolution sufficient to ensure that terrain features and concentration gradients will be adequately resolved, 2) specify all relevant receptors (locations, ground level and flag pole), and 3) identify any special receptors considered to be environmentally sensitive. However, the guidelines provide no specific instruction (or examples) for grid resolutions to be used in modelling. There are also no definitions of what constitutes a 'relevant' or 'environmentally sensitive' receptor.

While it is recognized that the selection of grid spacing often represents a balance between accurately identifying the maximum predicted impacts and computer processing time for the model, some specific guidance is required for minimum level grid resolution to ensure that maximum impacts are not grossly underestimated. This is particularly important in situations involving terrain-induced flows due to complex topography and land/water boundaries. While it would be unreasonable to impose a minimum grid resolution of 50-100 m for impact assessments covering large areas, a minimum requirement for grid resolution in the order of 200-250 metres would be appropriate for most applications. The guidance could also encourage the use of nested grids of variable resolution, with finer resolution in the areas closest to the source where maximum impacts are expected, and larger grid spacing with distance from the source. Since elevated plumes can impact on distant hills giving maximum concentrations well away from the source, some care is required in the use of nested grids due to the unique situation of topography in B.C.

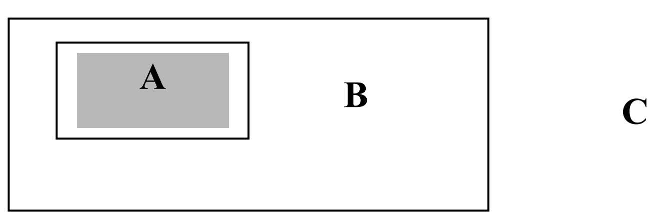
Some questions that the guidance document might address could include:

1. *What is the density of grid points required for identifying accurate maximum concentrations for different time periods (e.g., 1-h, 8-h, 24-h averages)?*
2. *What are the advantages/disadvantages of different types of receptor grids (Cartesian versus polar coordinates) for different types of sources (point, area, volume, line)?*
3. *Should the proponents be required to demonstrate that the maximum predicted impacts would not change with increasing resolution as part of an impact assessment?*

Guidance on grid resolution is also required when using coarse grid mesoscale meteorological models to drive fine-scale grid refined models such as CALMET/CALPUFF. Using a finer grid resolution for the dispersion model does not compensate for the use of a coarse grid resolution for the meteorological fields. The grid resolution of the meteorological model must be sufficient to properly capture the effects of topographic features (hills, land/water boundaries) on air flow in order for the dispersion model to accurately predict pollutant concentrations. *The guidance document would benefit from a more detailed discussion and recommendations on grid resolution for use in models such as CALPUFF and AERMOD.*

Another critical issue for modelling in B.C. involves the definition of what is important in the selection of off-site receptor locations. Specifically, if the assessment results are to be compared to ambient air quality objectives, it would be beneficial to have a definition of what constitutes 'ambient air'. The definition is important to answering the following questions:

1. Is the assessment of pollutants such as CO, NO_2, SO_2 and PM_{10} to be evaluated at all off-site receptor points in the modelling grid, or only at the locations where people live, work or play, consistent with the CCME's recent guidance for determining achievement of CWS for $PM_{2.5}$ and ozone?
2. Is the closest residential property, even if it only constitutes one individual, to be considered as a location for a discrete receptor, or are proponents only to consider impacts that affect the larger community, again consistent with the recent CCME guidance for CWS?
3. If an industrial source purchases a large amount of property around the source, should that area be masked out of the modelling results as representative of on-site impacts, even if there is no fence surrounding the property?
4. What if the property is enclosed by a fence?
5. Does it matter if a public road runs through the property?
6. If one industry leases property inside the property of another, are off-site impacts from emissions on the leased property to be considered as applying to areas beyond the lease, but including areas inside the property line of the property owners, or only those areas beyond the property line of the owners? To illustrate, if industry A leases land from industry B, does the definition of off-site ambient impacts from industry A include areas inside the property line of industry B, or does the definition of ambient air only apply to areas outside the property line (i.e., in C) of industry B?



7. What is the appropriate method to be used in evaluating the impact of pollutants on high-rise residential properties? Balconies?

With regard to the last question, occasionally impacts need to be evaluated from a plume impinging on the side of a building, rather than at ground level. SENES is of the opinion that the use of 'flagpole' receptors is not the appropriate method to be used as it does not take into account the effect of the building structure on the pollutant concentrations. Flagpole receptors assume that the plume passes through the building as if it were not there, because the available Gaussian plume models were not designed to be used for this type of impact.

SENES has encountered these types of dilemmas in previous air quality impact assessments, in B.C., as well as in other parts of Canada and the United States. In some circumstances, a CFD model can provide a more appropriate method of evaluating such impacts. *It would be worthwhile if the B.C. modelling guideline could provide some clarification of MWLAP's position on these issues to ensure consistency of treatment for future assessments in B.C.*

4.5 BACKGROUND CONCENTRATIONS

Consistent with other modelling guidelines, the draft BC guideline document acknowledges the critical importance of considering existing air quality (from both natural and anthropogenic sources) in determining the acceptability of air quality impacts from new sources. The draft guideline states that, ideally, background air quality should be determined through long-term air quality monitoring. Because of time constraints for development schedules, the guideline acknowledges that this is not always possible, and that alternative methods must be considered. These may include conducting a short-term, pre-construction monitoring program or modelling emissions from existing sources. *Regardless of which method is used, however, there needs to be some specific guidance on how to interpret the resulting data, and on this issue the draft guidelines are not sufficiently clear.*

It is worth noting that, in SENES's experience, there has been little-to-no consistency in the practice of defining a background concentration in B.C, or elsewhere across Canada. The GVRD has verbally indicated to SENES that the decision on what constitutes background air quality is made on a case-by-case basis, depending on the source and the circumstances that exist for each assessment. In some cases, the GVRD will consider the annual average concentration of a pollutant as representative of the background air quality. At other times, the GVRD may choose to regard the maximum observed concentration as the background level on top of which a proponent must add the maximum predicted concentrations. SENES has noted similar inconsistencies in defining the background level across the province for various projects. *This is* *one section of the modelling guideline that requires more specific guidance in order to ensure a level playing field for all sources of emission.*

4.5.1 Using Existing Ambient Monitoring Data

The draft B.C. modelling guideline states that if the available air quality monitoring site is not in the vicinity of the source under consideration, proponents must conduct a careful review of the monitoring site in order to determine whether the data can be considered representative of background conditions in the vicinity of the proposed new source. Factors to be considered include:

- differences in geophysical characteristics;
- differences in nearby emission types;
- changes in emission over time; and
- instrumentation & data collection protocols.

At times, the issue of defining the levels of existing air quality has been contentious on permit reviews before the B.C. Environmental Appeal Board. However, no specific guidance is provided on how to determine the representativeness of monitoring station data. The decision is left to the subjective, professional judgement of proponents and/or MWLAP staff. No mechanism is identified for dealing with alternative interpretations by other stakeholders who might get involved in any public review of the permit, and SENES has no suggestions on any possible mechanisms for resolving these disputes.

4.5.2 Choosing Appropriate Background Level

The draft guideline states that, if acceptable air quality monitoring data are available and representative of background air quality, proponents are required to use a minimum of one year (the most recent data) to establish a single background level for each time average of interest (e.g., 1-h, 3-h, 24-h, annual average) by choosing the highest value from the data record (i.e., the 100^{th} percentile). However, the guideline also states that, in order to avoid making overly conservative assumptions about existing air quality, proponents may exclude periods of unusually high values from the monitoring record where local, intermittent sources have an influence on the monitoring site. Proponents must then choose the 100^{th} percentile from the screened data set. If there is more than one representative monitoring site, the guideline indicates that the background level should be based on the arithmetic average of the corresponding 100^{th} percentile from each site. For existing sources that may impact a monitoring site, proponents are directed to exclude data from the monitoring record during periods when the monitor is within a 90^0 arc downwind of the source.

There are a number of issues that can be raised with regard to this guidance:

1. While the requirement for a minimum of one year of monitoring data is appropriate, the B.C. guidance should define a maximum period of record as well. For example, *the guideline could define a maximum of the most recent 3-5 years of monitoring data be used, assuming that anything over 5 years is no longer representative of current emissions in the area.*

2. There is no guidance on data completeness for the monitoring record. *The guideline could, for example, adopt the requirements set out by the CCME for determining achievement of $PM_{2.5}$ and ozone CWS (e.g., 75% complete data record in each quarter of the year, and at least 18 hours in each daily period [midnight-to-midnight] for continuous monitors).*

3. Some jurisdictions in the United States use the highest value recorded in the past 3 years, as opposed to the highest value in one year required by the draft BC. guidelines. Thus, unless the one year of data being used happens to contain an anomalously high set of observed pollutant concentrations, the B.C. guideline would be somewhat less stringent than the requirements of some American jurisdictions.

4. Averaging the 100^{th} percentile values between available monitoring sites could result in an underestimation of background levels. *Perhaps, the guidelines should limit the use of averaging among monitoring sites to those situations where the maximum values do not differ by more than a certain percentage (e.g., not more than 75%).*

5. It may be difficult to define "unusual" peak values that are to be excluded from consideration. The decision could be subject to misinterpretation and/or abuse. As an alternative, B.C. could follow Alberta's example and arbitrarily discard the top eight highest observed values from consideration, but there is no scientifically defensible rationale for choosing to discard the top eight values, as opposed to say the top 3, 5, or 10 highest values.

   As an alternative to Alberta's approach, B.C. could also consider using some percentile value of the observed data record (e.g., 99.5^{th}, 99^{th}, 98^{th}, 95^{th},etc.). Some modelling assessments already assume the 50^{th} percentile value (i.e., the annual mean concentration) as being representative of background concentrations. This is not, however, a conservative approach to air quality management, and is inconsistent with the precautionary principle adopted by the draft B.C. guidelines for evaluating worst-case scenarios for abnormal and upset operating conditions (see Section 8.0 of the draft guidelines). Why would one adopt the precautionary principle for modelling emission scenarios, but rely on the much less stringent annual average concentration for defining the background air quality?

Figures 4.1 and 4.2 provide some examples of the relationship between the 100th, 99th, 95th and 50th percentile values of observed pollutant concentrations in the Capital Regional District (CRD) in 2001. The 95th percentile value for some pollutants is from one-third to one-half of the maximum observed concentration. It would be feasible to define the background level based on some value between the 95th and 99th percentile concentration and still be able to exclude the anomalously high values that may occur in any given year. It may also be preferable to define a different percentile concentration for different averaging times (e.g., the 99th percentile for 1-hour average background concentrations, and the 95th percentile for 24 hour average concentrations).

Figure 4.1

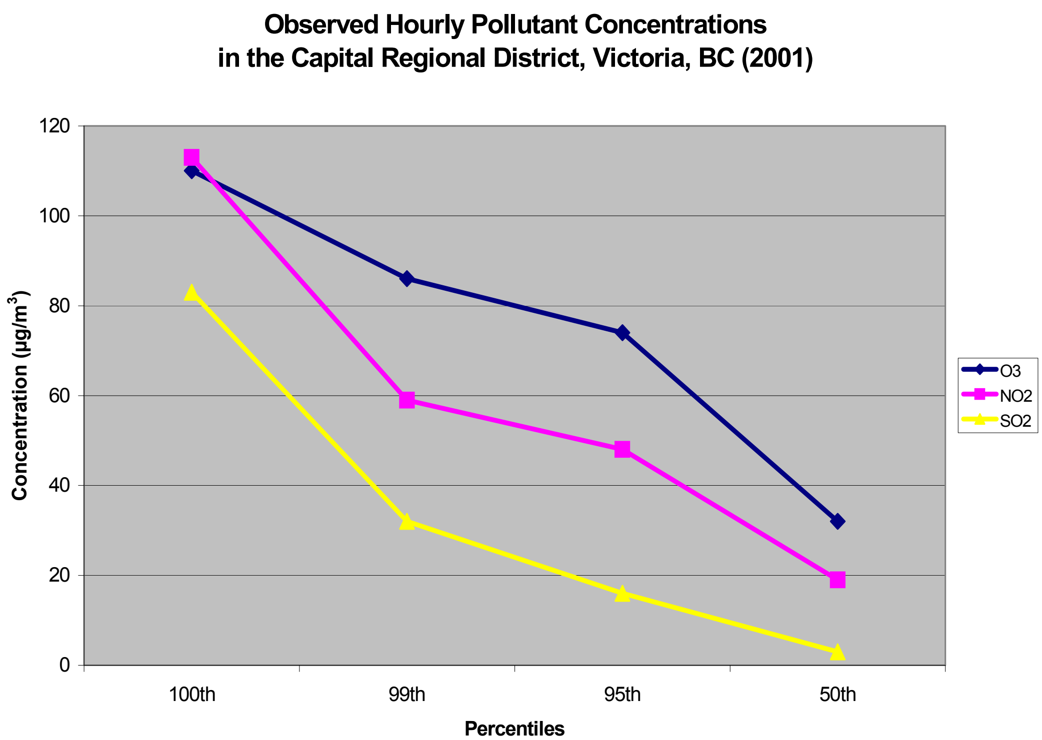
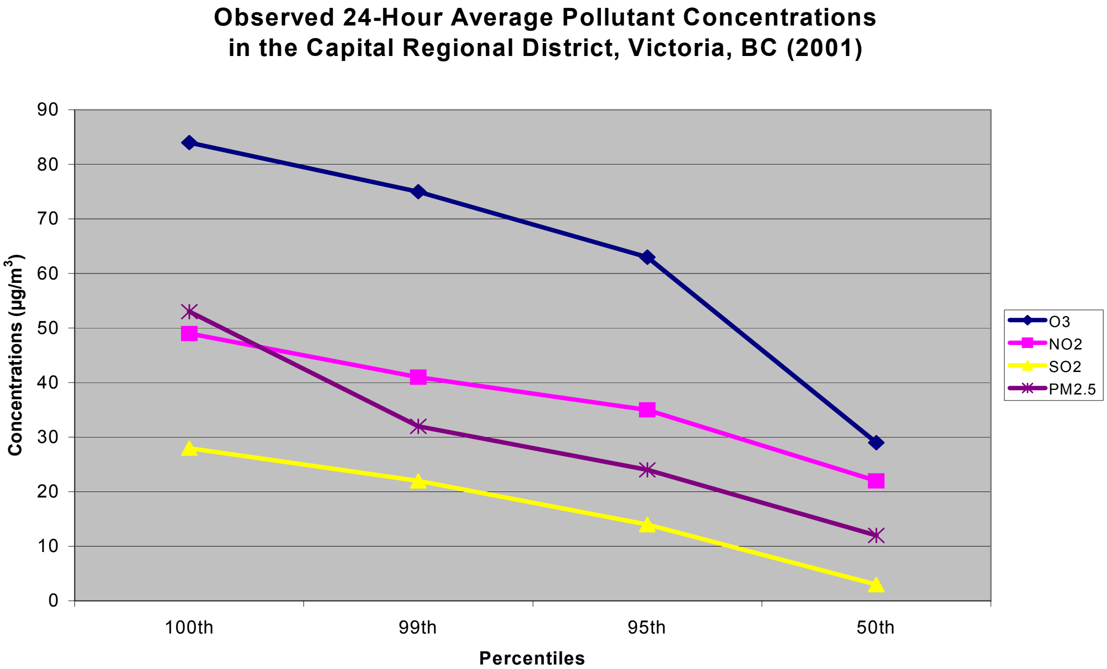


Figure 4.2



6. For existing sources that impact on a monitoring site, the exclusion of monitoring data from the monitoring record during periods when the monitor is within a 90^0 arc downwind of the source may be too loose. *Perhaps the guideline could consider limiting the downwind data to a 45^0 arc ($\pm 22.5^0$ downwind from the source). In addition, the guideline needs to be more specific about how to treat ambient monitoring data recorded during periods of low winds speeds (~1 m/s or less) when the wind direction may no longer provide a representative measure of the direction from which the pollutants were transported.* In complex terrain, with frequent calms, it may be very difficult to determine when a monitoring site is not being influenced by a nearby source at low wind speeds. For this reason also, choosing the 90th or 95th percentile from the observed data record may be less subjective for determining background concentrations.

4.5.3 Pre-construction Monitoring

Pre-construction air quality monitoring is addressed in Section 6.3 of the draft B.C. modelling guideline. The guideline states that, in areas where there is no air quality monitoring data available, one full year of baseline monitoring may be required. The monitoring program would include the need to monitor meteorological parameters in addition to air contaminants. However, the draft guideline does not state that a monitoring program shall be required when no monitoring data are available to establish background air quality, only that such a program may be required.

The guidance document could be revised to state that pre-construction monitoring is a requirement, unless the expected impacts are below specified 'significance' levels, as is currently done in the U.S. The guideline could also provide an option to limit monitoring for a shorter time period (e.g., 4 months), if it can be demonstrated that the monitoring period will encompass the period when background levels are likely to be highest.

However, it must be understood that there are limitations on the accuracy with which even a 1-year monitoring program can be used to provide a representative data set for background concentrations. For example, Figures 4.3 to 4.11 illustrate the differences in observed pollutant concentration levels at the air quality monitoring station in Chilliwack (Station T12 in the GVRD monitoring network) that can arise between a single year of monitoring data versus a 5-year data set (1998-2002).

Figure 4.3 depicts the probability frequency distributions for 1-hour averaged carbon monoxide (CO) concentrations. It can be seen that there is little difference in observed levels for 4 out of the five years in observed concentrations up to the 99th percentile level, and even the 5th year (2002) does not differ that much (i.e., by <10%) from the 5-year data record at the 99th percentile. The major differences between the observed values arise in the observed maximum concentrations. Therefore, any single year of monitoring data would be sufficient to provide a representative data set for 1-hour CO concentrations up to the 99th percentile, but could significantly underestimate the maximum observed concentration in 3-out-of-5 years (1998, 1999 & 2001). The same data set shows that the 8-hour averaged CO concentrations were also within 10% of the 5-year concentration up to the 99th percentile level (Figure 4.4), but that monitoring in 3-out-of-5 years would have underestimated the maximum 8-hour concentration by more than 10%.

Therefore, for CO, one full year of monitoring data provides a representative data set comparable to that of a 5-year data set up to the 99th percentile level. If the background concentration level is based on the maximum observed concentration, then one full year of monitoring would be insufficient to accurately define the maximum background concentration. On the other hand, if the background level is based on the 95th or even the 99th percentile, then one full year, or maybe even less, of monitoring data is sufficient to establish a representative data set for background concentrations.

Figures 4.5 through 4.11 provide similar examples of probability frequency distributions for 1-year versus 5-year data sets for other pollutants monitored at the Chilliwack station (NO_2, O_3 PM_{10} and $PM_{2.5}$). Using a difference of either 10% or 20% between the 5-year data set distribution and the 1-year distribution in any year as a criterion for distinguishing significant differences, one year of monitoring data appears to be sufficient to establish a representative data set up to the percentile levels listed in Table 4.1.

The data indicate that, for the Chilliwack monitoring station, one year of monitoring data is sufficient to establish representative data sets (i.e., within 10% of the 5-year data set) up to the 99th percentile for CO, but only the 95th percentile for $PM_{2.5}$. One year of data would only be sufficient to establish a representative data set up to the 90th percentile for 1-hour averaged O_3 and PM_{10}, but only to the 75th percentile for 8-hour averaged ozone. For 1 year of 24-hour averaged PM_{10} concentrations and 1-hour averaged NO_2 concentrations, differences between the 1-year and 5-year data sets are greater than 10% for all five years above the 50th percentile level.

If the criterion for representative data from one year is lowered to $\pm$20% of the 5-year data set, one year of data would be sufficient to provide a representative data set for all five pollutants to the 99th percentile for 1-hour and 8-hour averaging periods, but only to the 98th percentile for 24-hour averaged PM_{10} and the 95th percentile for $PM_{2.5}$ concentrations.

Table 4.1
Comparison Between 1-Year and 5-Year Probability Frequency Distributions For Air Quality in Chilliwack, BC (1998-2002)

Pollutant	Percentile Above Which Observed Levels in Any Year Differ from the 5-Year Data Set by >10%		
	1-hour Average	8-hour Average	24-hour Average
CO	99th	99th	-
NO_2	50th	-	-
O_3	90th	75th	
PM_{10}	90th	-	50th
$PM_{2.5}$	95th	-	95th

Pollutant	Percentile Above Which Observed Levels in Any Year Differ from the 5-Year Data Set by >20%		
	1-hour Average	8-hour Average	24-hour Average
CO	99th	99th	-
NO_2	99th	-	-
O_3	99th	99th	
PM_{10}	99th	-	98th
$PM_{2.5}$	99th	-	95th

Figure 4.3
Probability Distributions for Observed 1-Hour CO Concentrations
Chilliwack, BC (Station T12)

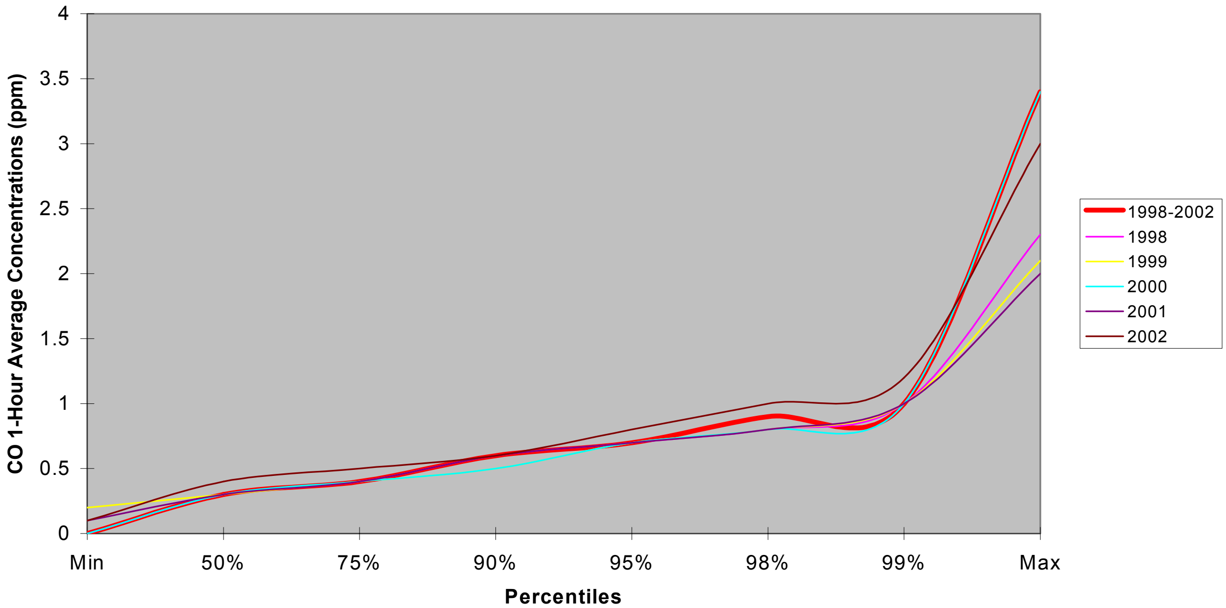


Figure 4.4
Probability Distributions for Observed 8-Hour CO Concentrations
Chilliwack, BC (Station T12)

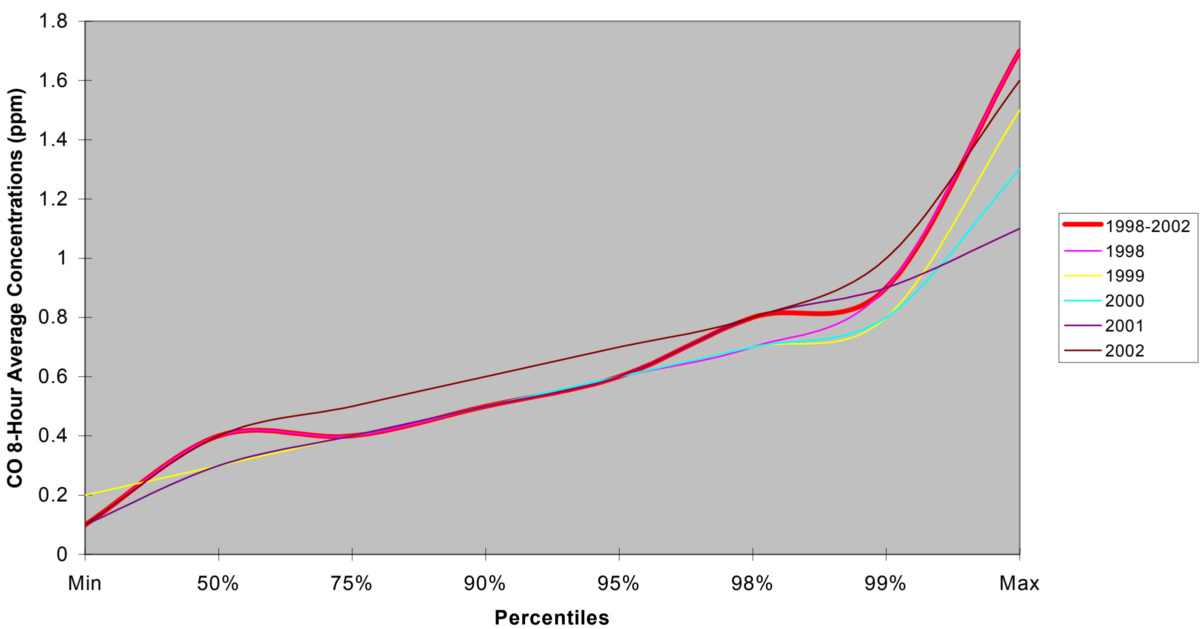


Figure 4.5
Probability Distributions for Observed 1-Hour NO_2 Concentrations
Chilliwack, BC (Station T12)

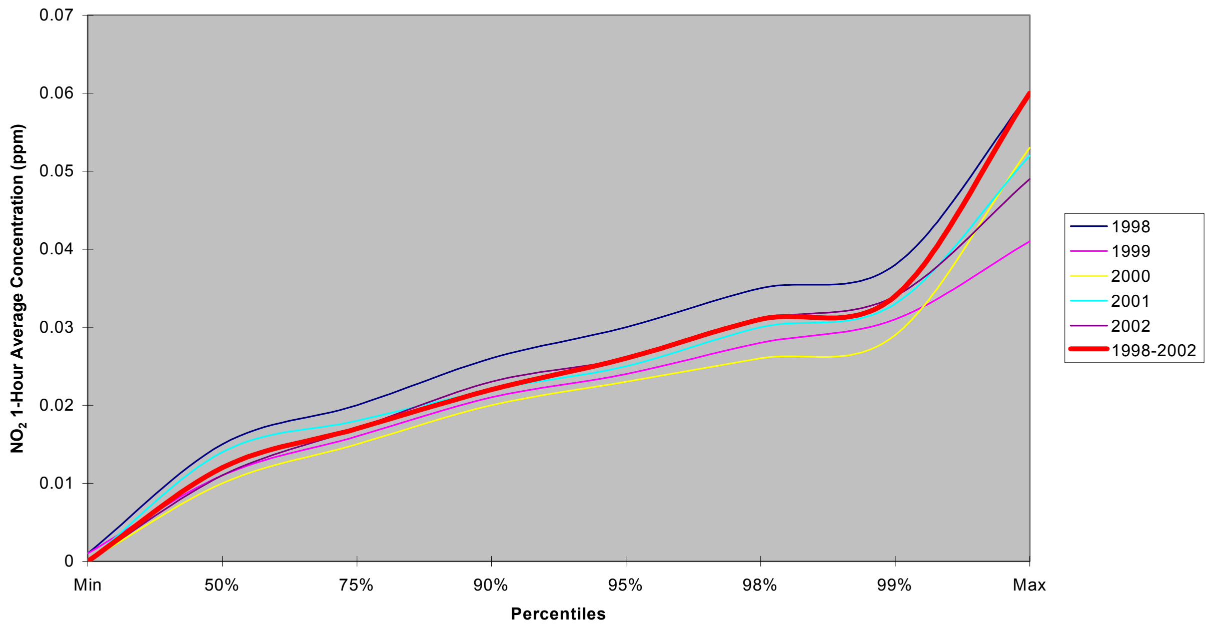


Figure 4.6
Probability Distributions for Observed 1-Hour O_3 Concentrations
Chilliwack, BC (Station T12)

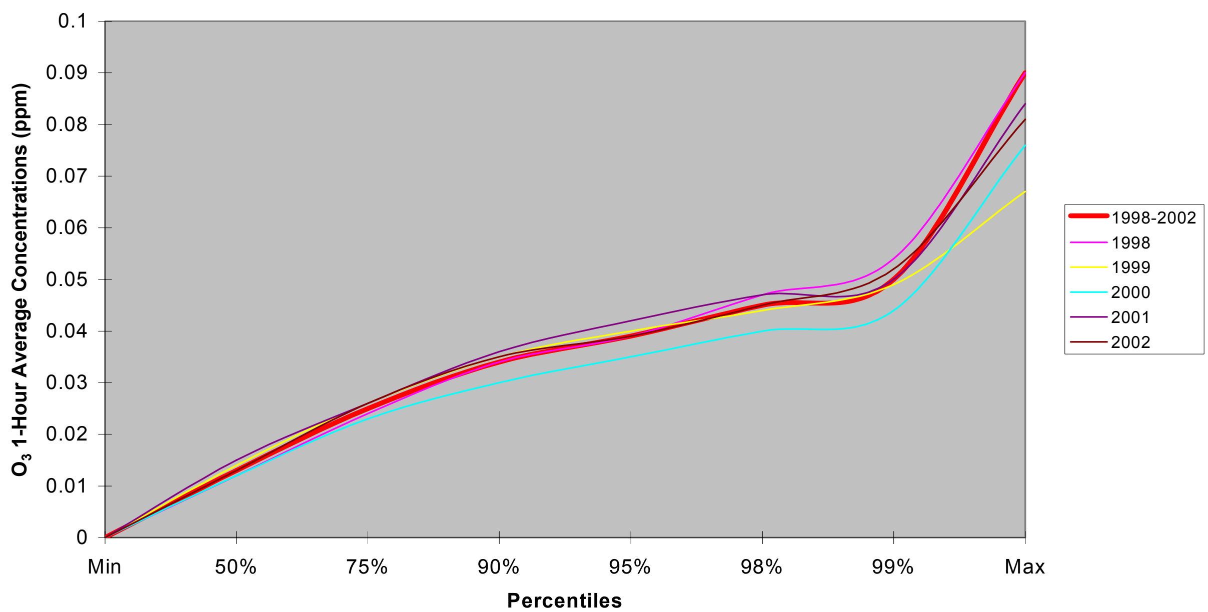


Figure 4.7
Probability Distributions for Observed 8-Hour O_3 Concentrations
Chilliwack, BC (Station T12)

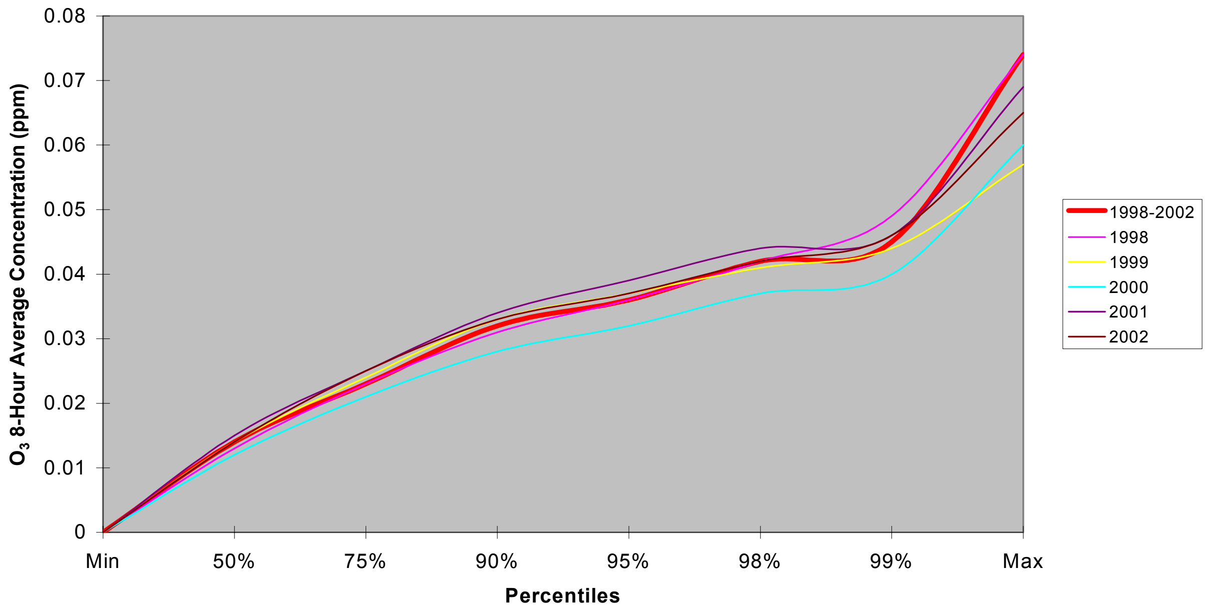


Figure 4.8
Probability Distributions for Observed 1-Hour PM_{10} Concentrations
Chilliwack, BC (Station T12)

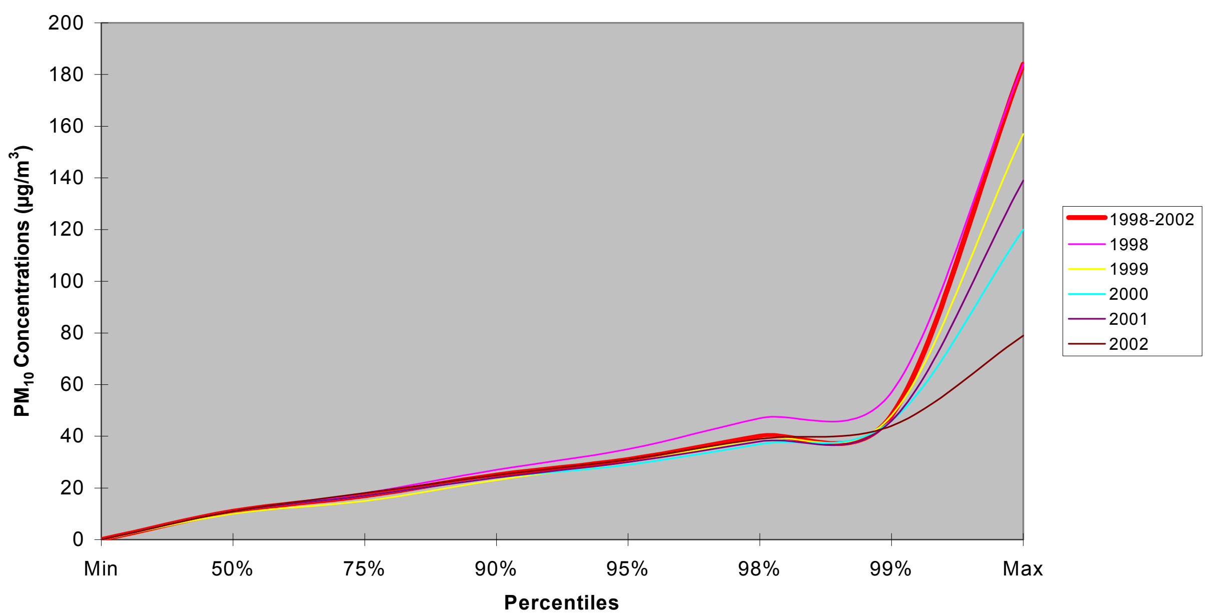


Figure 4.9
Probability Distributions for Observed 24-Hour PM_{10} Concentrations
Chilliwack, BC (Station T12)

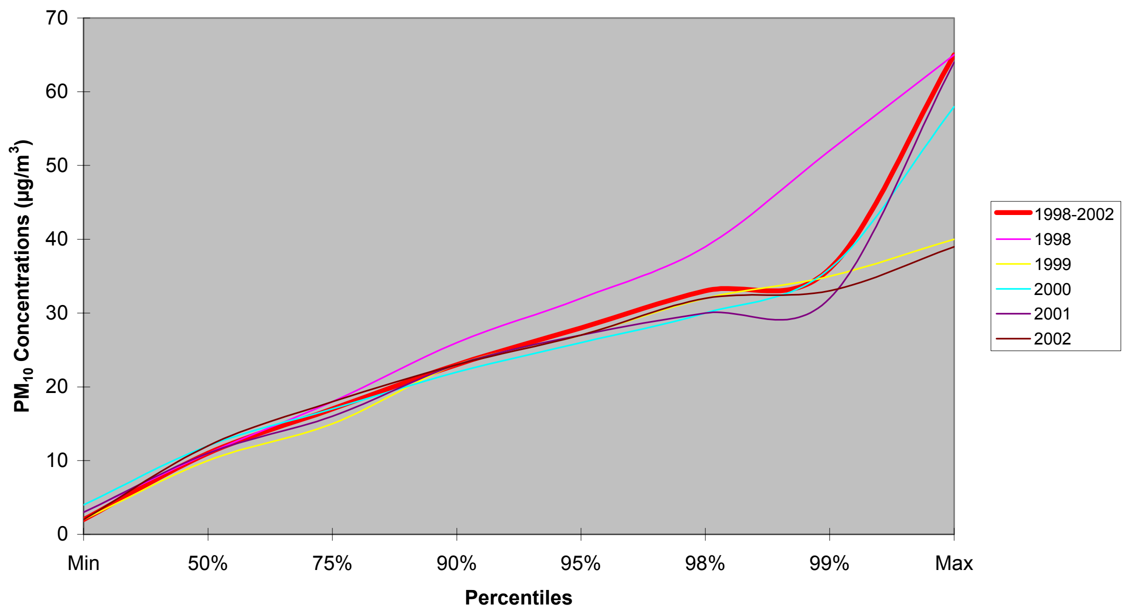


Figure 4.10
Probability Distributions for Observed 1-Hour $PM_{2.5}$ Concentrations
Chilliwack, BC (Station T12)

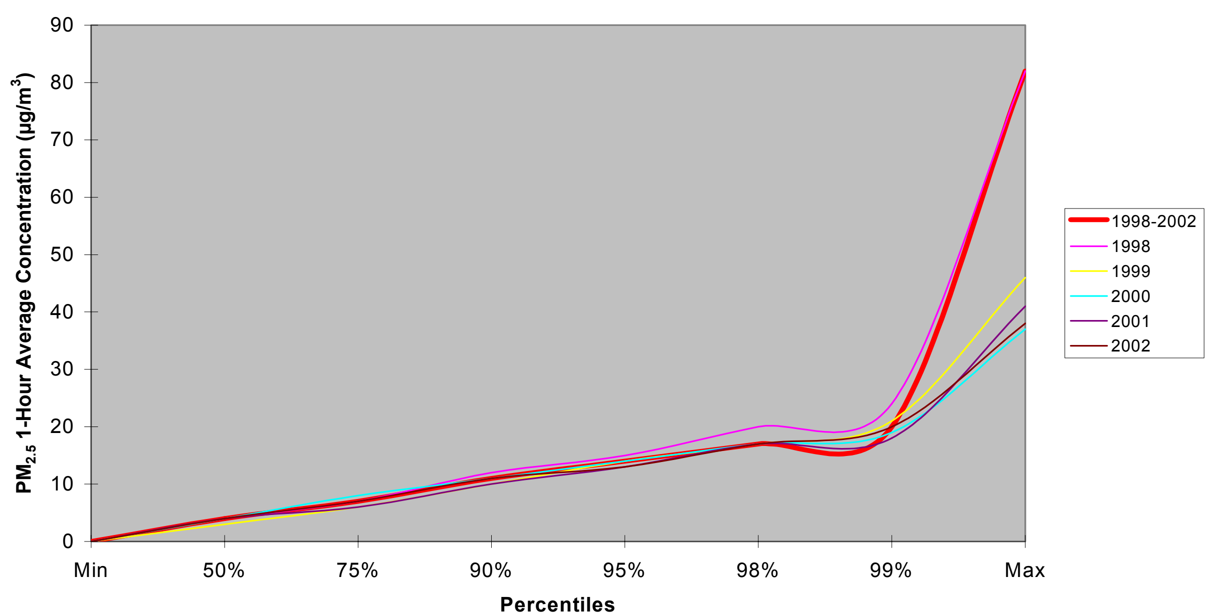
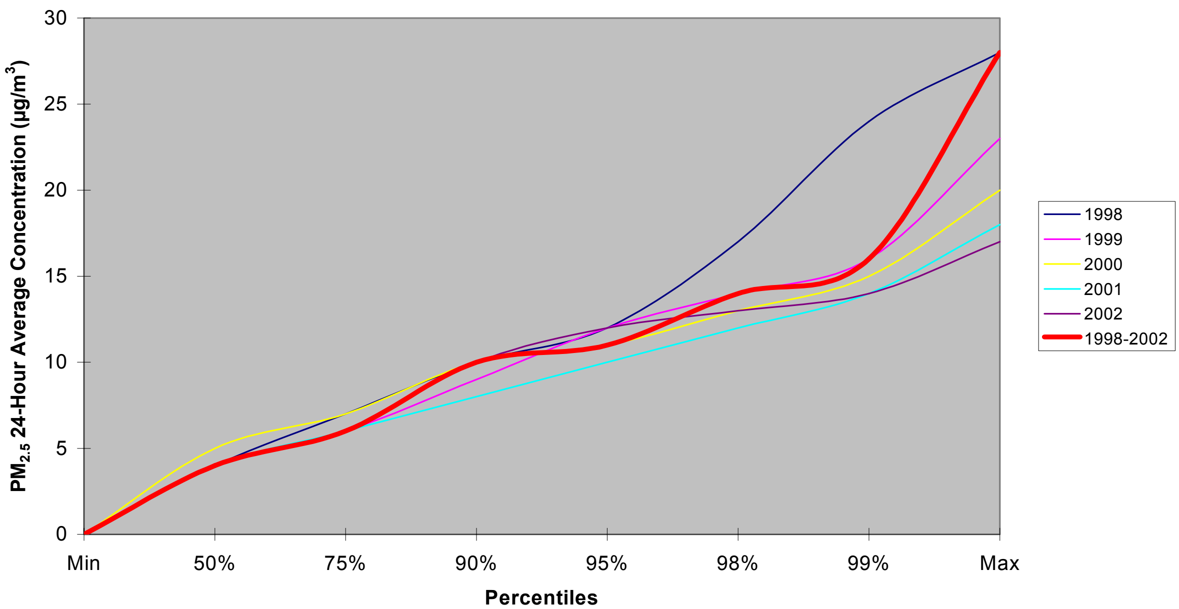


Figure 4.11
Probability Distributions for Observed 24-Hour $PM_{2.5}$ Concentrations
Chilliwack, BC (Station T12)



It would be necessary to conduct similar analyses on monitoring data from stations in other settings to confirm the range of variation that might exist between stations in other parts of the province. The point in presenting the data in Figures 4.3 to 4.11 is to reinforce the idea that one-full year of pre-construction monitoring does not necessarily provide an adequate measure of the background concentration if the background level is based on the 100th percentile, as suggested in the draft B.C. modelling guideline.

On the other hand, it is feasible to base the background level with a greater degree of confidence at some lower percentile from a 1-year monitoring program. However, that level will vary by pollutant, as well as by averaging time, and depends on the degree of accuracy expected from the 1-year data set (i.e., within $\pm$10% versus $\pm$20%). *If background levels are to be determined based on one-year of pre-construction monitoring data, it may be feasible to consider using a value such as the 95th or 99th percentile concentrations from the available monitoring data, plus an uncertainty factor of 20% in order to account for year-to-year variability.* This would allow the background level to be established with some confidence based on only one year of data, without the need to establish what the maximum observed concentration might be for that area.

Such an approach would be less stringent than basing the background level on the 100th percentile value observed in one year of monitoring at a particular location, but would provide a more stable estimate of background concentration for the community as a whole. It would also eliminate the need for subjective judgement in deciding on which ‘unusual’ high values should be discarded from the data set as representative of extreme or rare events.

However, it must also be recognized that the actual location chosen for a pre-construction monitoring program may not be ideally suited for sampling the highest air pollutant concentrations in the area. For practical reasons of access and security for monitoring equipment that must be considered when choosing a location for an air quality monitor, the location of a background air quality monitor may not provide an accurate measure of the highest air pollutant concentrations in the area of interest even if the monitoring program is carried out over a 5-year period. If pre-construction monitoring is based on only one sampling location, it may actually be more appropriate, from a precautionary principle perspective, to use the 99.9th or 100th percentile value observed in the 1-year data record because the maximum concentration observed at that background monitoring site may not represent the maximum concentration that occurs in the impacted area as a whole.

4.5.4 Modelling Emissions from Existing Sources

Section 6.5 of the draft BC modelling guideline suggests that, in the absence of any monitoring data to establish background air quality, it may be possible in some instances to determine background levels through modelling of major sources of emission in the area. This guidance is consistent with the USEPA modelling guidelines.

The draft B.C. guideline states that this method for defining background levels is not recommended for particulate matter emissions, but is allowable for other pollutants such as SO_2. The guideline also states that the choice of which sources to exclude/include in the modelling requires judgement, and can be assisted by using the SCREEN3 model to determine whether the impacts from a source are likely to be significant enough to warrant more detailed consideration.

Alberta Environment also allows modelled emissions from existing sources to be used to define background concentrations, based on average emission rates from the sources. In contrast, the B.C. guideline does not address the issue of how to treat emissions from existing sources that are being modelled. For example, should average emissions be used to define background levels for all averaging times? Should the emission rates from large industrial sources be based on the maximum permitted emission rate or on the average actual emission rate? Is it necessary to account for diurnal variability in emissions from area sources (e.g., space heating, vehicular emissions)?

In all fairness, the USEPA modelling guidelines are only slightly more specific in the definition of how to conduct multi-source modelling for background determination, while the Alberta guidelines do not discuss this issue at all. The draft guidelines from New Zealand also state that background levels can be determined through modelling other sources, but provide no guidance on how this should be done. However, the USEPA guidelines do at least state that point source emissions must be modelled at their maximum allowable emission rates, and that separate background concentrations must be established for each averaging time period. The New Zealand guidelines also allow use of ambient air quality monitoring data from similar type areas, as long as the area in question does not have significant large sources, or complex geographical or meteorological features. Alternatively, the New Zealand guideline permits proponents to assume a worst-case "guess" of the background levels.

At a minimum, the B.C. modelling guideline should state that maximum emission rates from major point sources may be critical for establishing short term peak background concentration levels. Therefore, if the background levels are to be based on the 100th percentile value (whether from monitoring data or modelling of existing sources), then it is only logical that any such modelling of existing major point sources should be based on the maximum allowable emission rates, and not on the average emission rates, as currently stated in the Alberta modelling guidelines. The use of the 100th percentile value may be critical to determining whether the predicted impacts from a new source in the area will result in ambient air quality levels that exceed the federal or provincial objectives. On the other hand, it would be entirely appropriate to assume average source emission rates in determining annual average ambient background concentration levels. *Therefore, the B.C. guideline needs to establish more specific rules on when to use average emission rates and when to use maximum emission rates in generating modelled background concentrations.*

5.0 INTERPRETATION OF MODELLING RESULTS

The existing draft B.C. modelling guidelines do not address the issue of how to interpret the results of an air dispersion modelling analysis with respect to national or provincial ambient air quality objectives, guidelines or standards. In practice, there appears to be no formal MWLAP policy regarding the interpretation of predicted impacts with respect to meeting provincial or federal ambient air quality criteria. It has been SENES's experience that decisions on what constitutes an acceptable or unacceptable impact from an emission source appear to be discretionary on the part of Ministry staff – varying from region-to-region, and project-to-project. While it is understandable and appropriate that some degree of discretion is a necessary component to permitting decisions, there is also a need to establish well-defined rules for the interpretation of results in order to promote consistency in such decisions and provide a level playing field for industry across all regions of the province.

British Columbia's ambient air quality objectives (AAQOs) and guidelines (there are no standards) are defined for two or three levels: A, B, and C, roughly comparable to the Federal Maximum Desirable, Maximum Acceptable, and Maximum Tolerable objective levels. Although the objectives were developed in the 1970's, there are no consistent or official definitions of the provincial Ambient Level A, B or C Objectives. According to a recent report by Caton and Bates[13], B.C.'s ambient air quality objectives essentially address ***"…acute exposures to pollutants for which detailed health impact criteria have been developed ('criteria pollutants'), rather than long-term or chronic cumulative exposures."*** The National Ambient Air Quality Objectives (NAAQOs) ***"…are also getting dated."*** Only the Canada-Wide Standards (CWS) for 8-hour averaged ozone and 24-hour averaged $PM_{2.5}$ have been based on up-to-date information on the human health and environmental effects of air pollutants.

In addition to the lack of specific guidance on the application of ambient air quality objectives, there has been considerable confusion in recent public reviews of ambient air quality impact assessments in B.C. in relation to the use of health-based 'Reference Levels'[14] for $PM_{2.5}$ and ozone, which were identified in 1999 as part of the CWS-setting process. The health-based 'Reference Levels' provide a useful benchmark to support area-wide air quality management goals and control strategies, but were never intended to be used in air permitting decisions. Nevertheless, the Reference Levels have been used in a number of recent air quality impact assessments in the province.

[13] Caton, R.B. and D.V. Bates 2002. *Updating BC Provincial Air Quality Objectives – An Options Discussion Paper*. Prepared for the BC Ministry of Water, Land and Air Protection, Victoria, BC.

[14] Reference Levels represent the lowest level at which statistically significant effects can be calculated for the available data. Reference Levels are not effects "thresholds", and the assumption is that damage may be occurring at pollutant concentrations below the health Reference Levels.

The lack of a defined policy on the application and interpretation of provincial and federal ambient air quality objectives, guidelines and standards currently represents a policy gap in B.C. SENES does not suggest that the B.C. modelling guidance document should be the place where these issues are debated. The issue is raised here because it is difficult to provide consistent, science-based and transparent guidance on the application of dispersion models in the absence of such policies.

The following provides a discussion of some of the issues that need to be addressed in the modelling guidance document.

5.1 APPLICATION OF AAQOS AND NAAQOS

It has been SENES's experience that, in practice, proponents try to demonstrate that the emissions from their proposed sources will meet the AAQOs and NAAQOs. If it cannot be demonstrated that the expected impacts will always be below the criteria levels, proponents will try to show that the frequency of exceedance is likely to be very low. It is then up to the regional MWLAP manager to decide whether or not the expected impacts are acceptable on a discretionary basis.

This approach differs significantly from that which is applied in the United States. The U.S. National Ambient Air Quality Standards (NAAQS) are defined in terms of how frequently they can be exceeded on an annual basis (e.g., once per year). Consequently, the dispersion models used in regulatory applications for the U.S. have been formulated to provide the highest and second highest predicted impacts for a given averaging period, and the interpretation of whether or not the predicted impacts are acceptable is obvious to all.

This is not the case in Canada, however. There are no legal or economic constraints for failure to achieve air quality objectives. As such, in B.C., there is no clearly-defined decision point in the spectrum of predicted air quality impacts that can be used to determine whether or not the impacts of emissions from a particular source are, or are not, acceptable. Regional MWLAP managers may be placed in a very difficult position with regard to permitting a source that a model predicts will occasionally exceed the AAQOs. *If the AAQOs are not to be used as a 'never-to-be-exceeded cap' for ambient air quality, the MWLAP needs to provide some degree of guidance on how frequently the AAQOs can be exceeded in an area.* Without such guidance, it is difficult to envisage how the MWLAP will be able to ensure that the modelling process is applied consistently across all regions of the province.

As examples of alternative approaches, B.C. could adopt one of several methods used in other jurisdictions:

- The Alberta modelling guidelines recommend that the eight highest maximum 1-hour predicted average concentrations in a single year should be considered as outliers representative of extreme, rare or transient meteorological conditions, and disregarded from permitting considerations. The guidelines provide no technical justification for the choice of the 9th highest value from the predicted concentrations for consideration as opposed to any other value. As there is also no guidance provided for longer term averaging periods (e.g., 8-hour, 24-hour), it must be assumed that the maximum predicted concentrations for all averaging periods greater than 1-hour cannot exceed the provincial ambient air quality guidelines. However, the Alberta guidelines do not specify whether the eight highest predicted values should be discarded at each point in the modelling grid, or only at the point of maximum impact. It is likely that, from a meteorological perspective, the eight highest values at one grid point will not be related in time to the eight highest values at another location.

- Ontario defines its regulatory impact criteria in terms of never-to-be-exceeded ½-hour averaged point-of-impingement (POI) concentrations. The fundamental assumption is made that meeting the ½-hour POI limits is consistent with meeting the NAAQOs, but there is currently no specific guidance in Ontario on how to interpret model results which demonstrate achievement of the POIs but, in conjunction with existing background concentrations, exceed the NAAQOs. Ontario is currently in the process of revising its modelling guidance.

- New Zealand's draft guidelines require reporting of the 99.9th percentile value of the predicted ground level concentration at the most highly impacted or most sensitive receptors. Proponents must also provide a number of other percentile values (e.g., maximum, 99.5th, 99th, etc.) and indicate the frequency of 'pollution events' that exceed the evaluation criteria being used. However, the term 'pollution event' is not defined and the guidance does not state which percentile value is to be used as a decision point for determining the acceptability of the impacts.

Because B.C., in common with all other provincial jurisdictions in Canada, is not constrained as to whether the air quality objectives can be exceeded, and if so, how often, it would be feasible to define a percentile value that could be used to judge the acceptability of impacts. *For example, the MWLAP could establish a policy which states that the 99th percentile (or 99.5th, 99.9th, etc.) of predicted air quality impacts from the proposed source, including existing background levels, will not exceed the provincial AAQOs. The percentile value may have to be set at a different level for different averaging times.* The advantage of such an approach is that it would provide a consistent and transparent methodology for evaluating source impacts. The disadvantage would be that it will limit the discretionary power of the regional managers in making permit approval decisions.

In effect, such a policy would mean that the current B.C. AAQOs are not to be interpreted as 'caps' on ambient air quality. Since the AAQOs are based on the knowledge of health-related air quality impacts from over 30 years ago, it may be more appropriate to review and revise the AAQOs first. Obviously, there are no easy answers to any of these questions. *They are policy-related matters that need to be resolved before they can be incorporated into the modelling guidelines.* However, it is worthwhile to consider the following question:

- What would be the point of defining explicit modelling guidance for using the best available, science-based models to provide the most accurate estimates of predicted impacts possible if there were no definition of how the impacts are to be interpreted?

5.2 APPLICATION OF CWS

As with the AAQOs and NAAQOs, there is no clear policy on how to interpret the results of modelling analyses with respect to the recently established CWS for $PM_{2.5}$ and ozone. Jurisdictions are required to report progress on the implementation of the CWS. If the standards cannot be met in a particular area, the only requirement for the regulators is that they demonstrate "best efforts" in trying to implement the standards.

Furthermore, the guidance document on achievement of the CWS from the Canadian Council of Ministers of the Environment (CCME)[15] indicates that reporting on CWS achievement is to be based solely on designated monitoring site data, and is only required for population centres over 100,000. Does this mean that proponents of new sources located in smaller population centres in B.C. do not have to consider 24-hour average $PM_{2.5}$ and 8-hour average ozone impacts in their dispersion modelling assessments? If demonstration of achievement for the $PM_{2.5}$ CWS is not required in smaller population centres, what level of $PM_{2.5}$ impact is to be considered acceptable in these smaller communities, or will sources not be required to evaluate $PM_{2.5}$ emission impacts at all?

The CCME guidance document for demonstrating achievement of the CWS (p.9) indicates that:

- ***"CWS achievement will be based on community-oriented monitoring (i.e. sites located where people live, work and play rather than at expected maximum impact points for specific emission sources).***

[15] Canadian Council of Ministers of the Environment (CCME) 2002. *Guidance Document on Achievement Determination. Canada-Wide Standards for Particulate Matter and Ozone.* Winnipeg. MB, ISBN: 1-896997-41-4.

- ***Rural (or background) sites will not be included for CWS achievement determination.***
- ***The Guidance Document will contain guidance on selecting community-oriented monitoring sites."***

Furthermore, if there is more than one designated monitoring site in a community, the CCME guidance document (p.12) indicates that ***"…the arithmetic average of valid daily values for all qualifying monitors should be calculated to provide the representative daily $PM_{2.5}$ concentration for the community for each day."***

This raises several other important questions about how to interpret emission impacts for sources of $PM_{2.5}$ in a modelling analysis, namely:

1. Should predicted $PM_{2.5}$ impacts only be evaluated at the designated sites for $PM_{2.5}$ monitoring instead of at all points in the modelling grid?
2. What if the point of maximum impact falls within the community, but not at one of the designated monitoring sites (e.g., sensitive receptors)?
3. Is there an upper limit on how many points in the modelling grid can be included in the determination of CWS achievement in order to prevent artificially lowering the arithmetic average $PM_{2.5}$ concentration across the entire community?
4. If impacts are only to be considered at locations where people live, work or play, how many people must be at a particular location for that location to be included for consideration?
5. Should areas designated for future residential or recreational development in municipal land use planning assessments be included, even if nobody lives there now?
6. In smaller communities where the boundaries between densely populated and sparsely populated areas may not be well-defined, where does one draw the line between which individual residences will be included in a community for evaluating $PM_{2.5}$ impacts and which are to be left out?
7. If maximum impacts in areas of 'moose pasture' (i.e., non-occupied land) do not count for achievement of CWS, does that guidance also apply to other pollutants not covered by the CWS?

In short, it would appear that the CCME guidance document on the achievement of CWS has failed to consider a number of issues related to the integration of dispersion modelling analyses with monitoring data used to demonstrate CWS achievement. The CCME guidance does countenance the use of atmospheric models to calculate transboundary transport of pollutants, as well as the influence of natural events (e.g., high $PM_{2.5}$ levels from long range transport, extreme wind events and forest fires) in the determination of CWS achievement, but specifically does not address the issue of evaluating $PM_{2.5}$ impacts for individual source permitting assessments.

Some additional questions to contemplate for the B.C. modelling guideline in relation to the CWS for $PM_{2.5}$ and ozone include:

8. Should the minimum number of years of meteorological data used for $PM_{2.5}$ and ozone impact modelling be raised to two years instead of one year, in order to be consistent with the minimum number of years required by CCME to demonstrate CWS achievement?
9. If the determination of the best scientifically defensible modelling approach to be used for determining transboundary transport contributions must be made in consultation with the province and the federal government, will the responsibility for conducting a transboundary transport analysis rest solely with the province and/or federal government, or will the proponents of a major new source located near the boundary also be required to conduct such an assessment as part of their permitting process?
10. How are the modelling results from individual new sources of $PM_{2.5}$ and ozone precursor emissions to be evaluated with respect to the CCME guidance for continuous air quality improvement and keeping-clean-areas-clean?

All of the questions raised above are policy-related matters, not technical issues related to dispersion modelling. However, it will be difficult to develop a modelling guideline in the presence of such policy gaps.

5.3 POLLUTANTS NOT COVERED BY AAQOS OR CWS

The draft B.C. modelling guideline does not address the interpretation of modelling results for non-criteria pollutants. Ontario has established ½-hour POI levels for numerous non-criteria pollutants, while Alberta recommends using the lesser value of either the Ontario POI criteria or the Texas Ambient Air Quality guideline concentrations. For pollutants not covered by either the Ontario POI or the Texas guidelines, Alberta recommends they be evaluated using risk assessment methods, but the guidance does not specify whether the risk assessment should include both human health and ecological impacts.

If the MWLAP chooses to rely on guidelines borrowed from other jurisdictions as Alberta has done, it would be establishing a set of *de facto* guidelines without going through a policy development process. On the other hand, remaining silent on this issue opens the door to inconsistent application of model interpretations across regions and projects in B.C. If risk assessment is used as an alternative approach to the interpretation of results, there need to be some rules established on what is considered an acceptable impact for both human and ecological receptors. *Therefore, one way or the other, the MWLAP must consider establishing policy guidance for the interpretation of results for such pollutants.*

For human health impacts, the risk assessment guidance for contaminated sites in B.C. uses a 1-in-100,000 risk level for determining adverse health impacts, and a similar criterion could be used for other air pollutants in order to maintain consistency with the contaminated sites legislation. But there are other health-related policy issues related to the criteria pollutants that also need to be considered. There is currently no defined policy stating who we are trying to protect through air quality impact assessments and human health risk assessment: 1) any individual in the modelling domain (i.e., the maximally exposed individual), 2) some subset of the total population (asthmatics, children, the elderly, First Nations), or 3) the larger community as a whole? The CCME guidance on CWS for $PM_{2.5}$ and ozone would suggest that the objective for these two pollutants is aimed at protecting the community as a whole, but not any specific individual or subset of the community. Should other pollutants be treated in the same manner to maintain consistency with the CWS, or be treated differently? Furthermore, how are impacts that exceed the $PM_{2.5}$ health-based Reference Levels to be interpreted from a health-risk perspective?

All of these are policy issues that need to be addressed before they can be incorporated into a modelling guidance document.

5.4 DEPOSITION OF POLLUTANTS

No guidance is currently provided on the interpretation of predicted pollutant deposition rates. Presumably, the recommended practice would be to conduct a risk assessment. Currently, only the ISCST3 and CALPUFF models provide the means for calculating both gaseous and particulate matter deposition rates, and each of these models will provide a different estimate of the amount of pollutant deposited. *Therefore, the MWLAP needs to provide guidance on which model to use in specific circumstances.*

Human health risk assessments would include inhalation as well as ingestion of deposited contaminants through food, water or soil. The USEPA[16] has defined precise guidelines on how to conduct air dispersion modelling analyses using the ISCST3 model for human health risk assessments related to hazardous waste combustion sources. *Should B.C. formally adopt a similar set of guidelines for health and ecological risk assessments using ISCST3, AERMOD or CALPUFF?*

Ecological risk assessments can be conducted following procedures that are consistent with guidelines outlined by various regulatory agencies including Environment Canada, CCME, and the U.S. Environmental Protection Agency. *For ecological risk assessments in fresh water*

[16] U.S. Environmental Protection Agency (USEPA) 1998. *Human Health Risk Assessment Protocol for hazardous Waste Combustion Facilities.* EPA Region 6.

aquatic environments, the MWLAP could use the B.C. water quality objectives[17]. *Therefore, deposition of air pollutants to aquatic environments could be evaluated using these objectives.* Specific pollutants considered in the water quality objectives are listed in Table 5.1

Table 5.1
List of Compounds Contained in Water Quality Objectives for B.C.

aldicarb	chlorophyll	lead	silica
aluminium	chlorothalonil	lithium	silver
aniline	chromium	magnesium	simazine
antimony	cobalt	manganese	sodium
arsenic	copper	mercury	sulphate
atrazine	cyanazine	methylene chloride	sulphide
barium	cyanide	metolachlor	tetrachloroethylene
beryllium	diazinon	metribuzin	thallium
boron	1,2-dichloroethane	molybdenum	titanium
cadmium	dimethoate	nickel	toluene
calcium	dinoseb	nitrogen (ammonia, nitrate, nitrite)	triallate
captan	ethylbenzene	phenols	tributyltin
carbon	fluoride	phthalic acid esters	1,1,1-trichloroethane
carbon tetrachloride	glycol	PCBs	trichloroethylene
carbofuran	glyphosate	PAHs	uranium
chloride	hexachloro-1,3-butadiene	potassium	vanadium
chlorophenols	iron	selenium	zinc

However, SENES is not aware of any other environmental guidelines defined for B.C. that could be used for assessing ecological impacts in this province. *Furthermore, it would be helpful if the B.C. modelling guideline could provide some criteria that are to be used in identifying ecologically sensitive receptors.*

5.5 ODOUR IMPACTS

Although the draft modelling guideline touches on odour modelling issues, there are no established provincial guidelines or objectives on acceptable odour impacts. *This is a policy issue that, once addressed, can be incorporated into the modelling guidance document.* SENES suggests that the modelling guideline define acceptable odour impacts as being in the range of not more than 5-10 dilutions-to-threshold (D/T) over a 10-minute average, or less.

[17] Ministry of Environment, Lands and Parks 1995. *Approved and Working Criteria for Water Quality – 1995.* Water Quality Branch, Victoria, BC.

5.6 VISIBILITY IMPACTS

As noted in the draft B.C. modelling guideline, there are no policies on how to evaluate plume visibility impacts in B.C. The modelling guideline provides information on methods used in other jurisdictions, but stops short of any recommendation of which method to use in this province. As such, there is currently no way to determine the acceptability of aesthetic impacts on visibility in a consistent manner in B.C. *Since the guidance document indicates that the deciview approach is gaining acceptance in the U.S., the MWLAP may wish to consider formulating a specific policy on adopting a similar approach for this province.*

6.0 CONCLUSIONS AND RECOMMENDATIONS

The most recent version of the B.C. draft modelling guideline provides much useful information on available dispersion models and recommended practices. The information provided is a mixture of theory and specific guidance, but guidance is not provided for each issue. In many cases, the issues are discussed from the perspective of common practices in other jurisdictions or options for how to treat the issue, but no specific guidelines are provided on what should actually be done in B.C. The information also largely reflects the state of modelling in 1998, not 2003. Much has changed in the ensuing 5-year period, which must be incorporated into any final version of the guideline, always recognizing that future developments will require constant updates to this guideline.

The principal weakness of the existing draft guideline is the lack of an overall modelling philosophy for regulatory applications in B.C. Although the province has traditionally followed the guidance on modelling provided by the USEPA, much of the latter agency's guidance has only recently been revised to reflect the increased use of the CALPUFF model throughout North America, and which has been increasingly used for permit applications in B.C. over the past 2-3 years. In the opinion of SENES staff, the MWLAP has two possible approaches that can be used to define a modelling philosophy that would greatly assist the MWLAP in completing a final version of the modelling guidelines. The two options are:

1. A tiered modelling approach following USEPA guidance and based on using the ISC-PRIME/AERMOD models for most applications, and occasionally CALPUFF for specific circumstances of complex wind situations.

2. A B.C.-appropriate modelling approach based on the CALPUFF model as the preferred model for most regulatory applications to fit the province's unique geophysical environment.

The first approach benefits from the credibility associated with using methods that are consistent with guidance recommended by a major regulatory agency such as the USEPA. With the deferral by the USEPA of any decision on the use of AERMOD, most modelling applications in B.C. would still rely on the ISC3 model, which itself is considered outdated. The basic drawback to this approach is that, in many cases, the CALPUFF model will be used simply because it is better suited to the mountainous terrain of this province. Consequently, there is a distinct advantage for B.C. to adopt the second modelling philosophy, with CALPUFF as the preferred model, allowing use of simpler modelling techniques such as ISC3 only where the scientific validity of the simpler models is not compromised. The primary disadvantage of the latter approach is that it would be somewhat out of step with the guidance provided by other regulatory agencies, possibly undermining public confidence in the analytical results. In addition, the CALPUFF model is more difficult to run properly, requiring a greater degree of direction and oversight on the part of MWLAP staff to ensure the reliability of modelling results. However, this is likely to be a temporary situation, whose significance would diminish with time and practical experience in its use. Adopting CALPUFF as the preferred model may also be more costly and time consuming for industry.

Whichever modelling philosophy is ultimately adopted, SENES is of the opinion that the development of a final version of the provincial modelling guidelines should stem from a well-considered philosophy on how the modelling should be conducted, and that it will not be feasible for the MWLAP to provide a transparent modelling process to government, industry and the public community in B.C. without first defining its modelling philosophy.

The development of the modelling guidelines would also be greatly assisted by the development of MWLAP policy on a number of issues related to the requirements for ambient air quality and meteorological monitoring, as well as the interpretation of modelling results. The policy gaps that need to be addressed include:

- defining the need for pre-construction monitoring and the length of the monitoring record for establishing background concentrations;
- defining how to evaluate existing monitoring data to determine appropriate background concentrations;
- interpretation of modelling results with respect to ambient air quality objectives, guidelines and Canada-Wide Standards;
- interpretation of modelling results for contaminants not covered by existing ambient air quality objectives, guidelines or standards;
- interpretation of modelling results with respect to human health impacts;
- defining acceptable endpoints for human health and ecological risk assessments;
- incorporating quantitative modelling uncertainty into permitting decisions;
- defining acceptable odour impacts, and
- defining acceptable plume visibility impacts.

Due to the broad scope and complexity of the issues involved in addressing these policy gaps, SENES recommends that they be resolved through a series of multi-stakeholder workshops, involving selected representatives from federal, provincial and municipal agencies, industry and the academic and consulting community. The objective of such workshops would be to identify and discuss the pros and cons of the various policy strategies that might be considered.

It is recommended that the policy decisions be incorporated into a separate overview document on air quality impact assessment. The modelling guidelines would be limited to specific guidance on technical matters related to which models to use, under what circumstances, and how they should be run. While it may be feasible to develop a purely technical modelling guideline without the resolution of the identified policy gaps, the resolution of these policy gaps is considered crucial to the application of models in a manner that is consistent with the goal of the MWLAP's Service Plan of providing an assessment process that is *"...clearly defined and transparent to government, industry, individuals and communities"*.

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