Air Quality Model Guideline
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Air Policy
Alberta Environment and Parks
Main floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Preface

The Alberta Environment and Parks (AEP) Air Quality Model Guideline (Guideline) is intended for operations and proposed operations that require an *Environmental Protection and Enhancement Act* (EPEA) approval, that operate under a Code of Practice for emissions to the atmosphere, or as required by other regulatory agencies within Alberta.

AEP has developed the Guideline to ensure consistency in the use of dispersion models for regulatory applications in Alberta. The practices recommended within this Guideline are a means to ensure that these objectives are met.

The Guideline outlines AEP’s air quality modelling (also commonly referred to as dispersion modelling or air dispersion modelling) requirements and methods. Although some specific information on models is given, the user should refer to user guides and reference materials for the model of interest for further information on air quality modelling. The Guideline will be reviewed regularly to ensure that the best and most practical available tools are being used to predict air quality.

Additional information relevant to dispersion models can be located at these web pages:

http://www.epa.gov/scram
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1.0 Introduction

This Guideline provides detailed guidance on suitable methods and approaches that should be used to assess air quality from emission sources. It sets out:

- the statutory authority;
- an overview of the approach;
- guidance on appropriate technical methods, and
- the information required to demonstrate that a source maintains air quality below the Alberta Ambient Air Quality Objectives (AAAQOs)\(^1\).

It is not intended to provide a technical description of the theory behind air quality modelling - such information is widely available in other published documents, and references are provided within the text.

Detailed advice on the types and uses of air quality models is provided in Sections 2.0 to 3.0. Section 4.0 provides information on the preparation of source information as input to modelling assessments. Section 5.0 provides guidance on the treatment of terrain and buildings within a modelling domain. Section 6.0 provides information on the appropriate meteorological data to be used in an assessment. Section 7.0 provides guidance on the content and preparation of information to be reported in an assessment. Section 8.0 provides links to related air modelling information and resources. Section 9.0 provides guidance for regional modelling. Appendix A lists the contents of screening assessments. Appendix B lists the expected contents of refined and advanced assessments. Appendix C summarizes the expected technical skills and competencies required to perform air quality modelling. Appendix D lists the allowed model options for refined/alternate models. Appendix E provides a list of acceptable ozone values for modelling.

1.1 Purpose of the Air Quality Model Guideline

AEP has developed the Air Quality Model Guideline to ensure consistency in the use of air quality models in air quality assessments. The objectives are to:

- provide for uniform benchmarking;

\(^1\) Alberta regulatory modelling is not required to demonstrate compliance with the Canadian Ambient Air Quality Standards (CAAQS). These standards are intended for regional air quality management and comparison to monitored ambient air quality at designated monitoring stations.
provide a structured approach to the selection and application of models;
ensure appropriate and consistent model application;
ensure that there is a sound scientific basis for the use of alternatives, when alternatives are appropriate, and
detail the required content of assessments submitted to the department.

Sections 2.0 to 5.0 of the Guideline address only primary substances directly emitted from a source. Some substances are formed in the atmosphere as a result of the interaction of these primary substances with substances from either natural or industrial sources. These are known as secondary substances (e.g., secondary particulate, acid deposition and ozone). Concentrations and/or deposition of secondary substances, when required, must be estimated by means acceptable to AEP as described in Section 9.0.

1.2 Statutory Authority

This Guideline is issued by AEP, under Part 1, 14 (4), the Environmental Protection and Enhancement Act, 1992 (EPEA). This document replaces all previous versions of the Alberta Air Quality Model Guidelines. For the purposes of this document “Director” means, subject to Section 25 of EPEA, a person designated as a Director for the purposes of this Act by the Minister.

This guideline should be read in conjunction with “Using Ambient Air Quality Objectives in Industrial Plume Dispersion Modelling and Individual Industrial Site Monitoring” (AEP 2013, or as amended), the air monitoring directive (AEP 2016, or as amended) as well as the “EPEA Guide to Content for Industrial Approval Applications” (AEP 2014, or as amended).

1.3 Air Quality Models

AEP works with Albertans to protect and enhance the quality of the air through a regulatory management approach that includes:

- air quality models;
- ambient air quality objectives;
- air emission inventories;
- source emission standards;
- approvals;
- ambient air quality monitoring;
• source emission monitoring;
• environmental reporting;
• inspections/abatement, and enforcement, and
• research.

Information from emission inventories and source controls are utilized in air quality modelling to relate the resulting ambient air quality predictions to the ambient air quality objectives. Ambient monitoring is used to measure the actual air quality.

The purpose of an air quality model is to provide a means of calculating the estimated ambient ground-level concentrations of an emitted pollutant given information about the emissions and the nature of the atmosphere. The amount released can be determined from knowledge of the industrial process or actual measurements. However, predictive compliance with an ambient air quality objective is determined by the concentration of the pollutant at ground level. Air quality objectives refer to concentrations of pollutants in the ambient air, not at the emission source. In order to assess whether an emission meets the ambient air quality objective it is necessary to determine the ground-level concentrations that may arise at various directions and distances from the source. This is the function of the air quality model.

An air quality model is a set of mathematical relationships or physical models, based on scientific principles that relate emission rates of an air pollutant to the resulting ambient concentrations and deposition. Model predictions are useful in a wide variety of air quality decisions, including determining appropriateness of facility location, monitoring-network design, and stack design. Models also provide information on the areas most influenced by emissions from a source, the contribution of weather to observed trends, and the air quality expected under various scenarios. Dispersion modelling requires knowledge of the physical properties of sources, source emission rates and the local meteorology and topography.
2.0 Air Quality Modelling Protocol

An air quality dispersion model is a set of mathematical equations describing the dispersion and/or deposition of a substance from source to receptor. These models require: information on the emission characteristics of the source (Section 4.0); the selection of the appropriate modelling domain with consideration of local terrain and necessary receptor sampling (Section 5.0); the use of appropriate meteorology (Section 6.0); as well as consideration of the impact of non-modelled sources within the modelled study area by the addition of an appropriate baseline value (Section 7.0). Modelling is an important tool that provides insight into the impact of industrial development and can be used to predict future scenarios, short-term episodes, and long-term trends.

2.1 Modelling Decisions

All activities that emit substances into the atmosphere that are subject to an EPEA approval or operate under a Code of Practice, or as required by other regulatory agencies in Alberta, are required to undertake the appropriate air quality modelling to demonstrate the impact on air quality relative to the AAAQOs listed in “Ambient Air Quality Objectives and Guidelines Summary” (AEP 2019, or as amended). Additional modelling to demonstrate the impact on air quality for substances with ambient air quality guidelines (AAAQGs), listed in “Ambient Air Quality Objectives and Guidelines Summary” (AEP 2019, or as amended), may also be required in applications where it is reasonable to expect a local concern about these substances, e.g., dust fall from a mine.

When a renewal or an amendment is required for existing facilities that emit substances into the air, a new modelling assessment conducted in accordance with the current Alberta Air Quality Model Guideline must also be submitted as part of the application.

Further air quality modelling as part of the assessment process may also be required at the discretion of the Director, including:

- the original modelling did not comply with the current Air Quality Model Guideline;
- there are proposed changes made to the emission sources for the proposed project not included in the original modelling;
- there are emission sources in the study area not properly accounted for in the original modelling;
- there are sensitive receptors in the area not properly accounted for in the original modelling, or
• there are other situations deemed necessary to be considered by the Director.

2.2 The Tiered Modelling Approach

The choice of dispersion model depends on a number of factors. There is a wide range of models available, and it is important that the modeller selects the model that fits the demands of the task. A hierarchy of commonly used dispersion models has been established, categorizing the models according to how they might be used within the assessment process. Generally, there are four levels of assessment:

1) A screening assessment is a simple and quick way to estimate a “worst-case” predicted concentration of project impacts. They may be used as an initial assessment, with the use of more refined models only being necessary if the screening model is predicting an exceedance of an AAAQO.

2) A refined assessment, because of its higher level of sophistication, more closely estimates actual air quality impacts. Refined modelling will form the basis of most air quality assessments. These assessments will make use of settings for approved regulatory models as specified in this document (see Appendix D).

3) An advanced assessment builds on a refined assessment but allows the use of alternate settings other than the prescribed settings specified in a refined assessment. When considering an advanced assessment there are two additional requirements:

   a) Permission to submit an advanced assessment must be obtained in writing from the Director before modelling is undertaken. It must be clear from the application why a refined assessment will not be sufficient and how the selected alternate configuration will meet these needs.

   b) The proponent must submit a companion refined assessment using the specified default AEP settings (see Appendix D) along with the advanced assessment to demonstrate that the advanced assessment was in fact an improvement over the default refined assessment while still being conservative, i.e., the advanced assessment does not exceed any AAAQOs for the designated emissions averaging periods.

Note: Submission of an advanced assessment does not automatically guarantee its acceptance over the companion refined assessment but will be evaluated on a case-by-case basis.
4) An alternate assessment makes use of alternate model other than the approved regulatory models. As such, they are only to be used in exceptional circumstances and require a considerable amount of effort to demonstrate their fit for purpose. When considering an alternate assessment there are several additional requirements:

a) The alternate assessment must use an air quality model that is open source and current. Models that are proprietary in nature that cannot be run by AEP or any other interested third party are not acceptable. Models that have been superseded by more current regulatory models are not acceptable.

b) Use of meteorology other than the AEP regulatory prognostic meteorology supplemented with local meteorology as specified in Section 5 is not acceptable.

c) Permission to submit an alternate assessment must be obtained in writing from the Director and AEP before modelling is undertaken. It must be clear from the application why a refined assessment will not be sufficient and how the alternate assessment will meet these needs. The Director will have to review this request and grant permission to the proponent before an alternate assessment may proceed. The proponent should be prepared that this may significantly delay processing the application.

d) The proponent must submit the most suitable companion refined assessment using default AEP settings (see Appendix D) along with the alternate assessment to demonstrate that the alternate assessment was in fact an improvement over the refined assessment while still being conservative i.e., the advanced assessment does not exceed any AAAQOs for the designated averaging periods.

Note: Submission of an alternate assessment does not automatically guarantee its acceptance over the companion refined assessment but will be evaluated on a case-by-case basis.

In all modelling assessment reports the version of all the models used and the model options (if applicable) must be explicitly provided. The AEP allowed non-default and/or alternate model option switches are provided in Appendix D.

The flow chart for the selection of the appropriate modelling assessment is shown in Figure 1.
Figure 1  Flow chart describing the decision making process to choose the appropriate air quality model for an assessment
3.0 Approved Regulatory Air Quality Models

A tiered air quality modelling approach is expedient, as the aim is to progressively reduce uncertainty by moving from simple and cautious models to complex and more representative ones, as circumstances warrant. One screening model (AERSCREEN) and two refined/advanced models (AERMOD/CALPUFF) are recommended by AEP.

All the approved regulatory models discussed in this guideline are considered short-range. That means that only air quality within 50 km of the source is predicted reliably, except for CALPUFF, which can be used up to about 200 km.

AERSCREEN and AERMOD rely upon a plume splitting algorithm based upon the divided streamline of the plume to estimate the amount of plume that will be transported over complex terrain. The plume that is trapped on the windward side is dispersed assuming a horizontal dispersion coefficient that is symmetric and may not be representative of the stagnation that is occurring resulting in artificially high ground level concentrations of a pollutant. The simple acknowledgement of this in the assessment is not sufficient as the effects of the dispersion of the windward component of the plume may not be properly accounted for. Hence, for projects in complex terrain CALPUFF is the preferred model.

The criteria for determining whether terrain is complex or simple is given by (Rowe 1982):

- Simple terrain (parallel air flow) - terrain whose elevation does not exceed 2/3 of the plume height (plume rise + stack height) at stability category F with a wind speed of 1 m/s and a flow rate of Qmax/2.
- Complex terrain – topography where elevations are greater than those used to define simple terrain.

The maximum elevated terrain within the modelling domain allowed above the base of a stack to be considered simple terrain in a modelling domain can be calculated using spreadsheet found at


Figure 2 summarizes the logic for determining whether or not complex terrain modelling should be undertaken.
Figure 2: Flow chart for simple and complex terrain determination for air quality modelling

1. Identify pollution source

2. Calculate plume rise at 1 m/s for stability class F and Qmax/2

3. Is terrain height > 2/3 plume height?
   - Yes: Complex terrain modelling is required
   - No: Simple terrain modelling is required
3.1 Screening Model

The first tier of modelling assessment involves evaluating the impact of a single source by employing a screening method such as AERSCREEN. The screening model results serve as a benchmark for each type of source and for comparison against other sources.

3.1.1 AERSCREEN

AERSCREEN is the U.S. EPA recommended screening model used to produce estimates of worst-case scenarios. AERSCREEN interfaces with the AERMOD model and performs modelling runs in the AERMOD screening mode. AERSCREEN generates a site-specific matrix of worst-case scenario meteorological conditions with MAKEMET, the default MAKEMET options should be used. The PRIME downwash algorithms (see Section 5.2 for additional information on the use of this option) and AERMAP terrain processors are incorporated.

AERSCREEN is only able to model a single point, capped stack, horizontal stack, rectangular area, circular area, flare, or volume source (U.S EPA 2011b). When considering more than one source each source must be run separately and the maximum ground level concentrations from each run must be summed, regardless of location, to provide the maximum modelled ground level concentration.

In very limited circumstances multiple point sources may be merged, if appropriate (see Section 4.3), into one point source in preparation for a screening assessment.

The results of the AERSCREEN assessment must include the addition of a representative baseline concentration (that is derived in accordance with Section 7.2). If the maximum modelled assessment ground level concentration plus the baseline concentration are below the AAAQO, it may not be necessary to undertake further modelling, except as specified (See Section 2.1).

3.1.1.1 AERSCREEN Averaging Periods

AERSCREEN produces hourly averages and includes time factors for 3-hr, 8-hr, 24-hr and annual averages, which should be used when available. For any other averaging periods, where there is no pre-determined value generated by the model, apply the following formula:

\[ Impact \ parameter = 1.1233 \times (\text{averaging period in hours})^{-0.2906} \]  

(1)
Multiply the calculated impact parameter (appropriate for the averaging period in question) by the maximum predicted 1-hour concentration to obtain the relevant average.

3.2 Refined/Advanced Models

The second tier or refined assessments using refined/advanced regulatory model are required to address the impacts of single or multiple sources within the modelling domain, if any of the following conditions apply:

- The screening assessment predicts exceedances of an AAAQO;
- The area is environmentally sensitive (e.g., a national park), and/or
- Public concerns need to be addressed (e.g., sensitive receptors).

Brief descriptions of the regulatory refined models are presented below.

3.2.1 AERMOD-PRIME

AERMOD was developed by the U.S. EPA (2004), in collaboration with the American Meteorological Society. This is a multi-source steady-state plume model. In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both the vertical and horizontal planes. In the convective boundary layer (CBL), the horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). Additionally, in the CBL, AERMOD treats “plume lofting,” whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate.

AERMOD should be run using the most current U.S. EPA regulatory default options with some exceptions allowed (see Appendix D). Deviation from the model options listed in Appendix D is deemed to be an advanced assessment. As such, the requirements for this type of assessment listed in Section 2.2 must be met.
3.2.2  CALPUFF

The CALPUFF model is a multi-layer, multi-species, non-steady-state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on substance transport, transformation, and removal. CALPUFF can use the three-dimensional meteorological fields developed by the CALMET model, or simple, single-station winds in a format consistent with the meteorological files used to derive steady-state Gaussian models. Particular attention should be paid to setting up a (nested) CALMET meteorological grid that will properly account for terrain effects. As a rule of thumb, the spacing of the CALMET grid in the region being studied should be of the order of 1/10th of the dimension of the feature, e.g., a valley, being resolved.

The default model options from the current developers of the CALPUFF modelling system or EPA designated agent’s distribution of the CALPUFF modelling system serve as the basic set of model options to be used for CALPUFF modelling applications. AEP recommended deviations from these options are provided in Appendix D. Hence, the AEP default model options are a blend of released model options and AEP recommended alternate options. Deviation from the model options listed in Appendix D is deemed to be an advanced assessment. As such, the requirements for this type of assessment listed in Section 2.2 must be met.

If the U.S. EPA releases a more current version of CALPUFF modelling system than posted on the CALPUFF developers site the U.S. EPA release will be preferred.

3.3  Alternate Models

When proposing an alternate assessment with an alternate model, details of the project must be discussed with AEP and the Director and accepted by both AEP and the Director prior to commencing the modelling. In some cases the particular circumstances of topography, climate, source configuration, emissions characteristics, sensitivity of receptors, local concerns, or other unusual features will require the selection of a non-recommended air quality model better suited to the situation.

The use of an alternate air quality model must be supported by at least one of the following:

- a detailed observational study (field, wind tunnel, or water channel);
- theory supported by comparisons in literature, and/or
- theory supported by comparison with on-site data.
Alternate air quality models must demonstrate that they perform better than the recommended advanced model while still being conservative. In general, a performance evaluation consists of the following (U.S. EPA, 1992a):

- accuracy of peak predicted concentrations (against site-specific air quality data),
- a correlation analysis;
- visual presentation and interpretation of appropriate isopleths showing predicted concentration patterns;
- test of model precision, and/or
- test of model bias.

Table 1 provides a list of dispersion models recommended by the department for use in Alberta and the appropriate assessment level. The specific situations under which they can be applied are also outlined in Table 1.
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<th>Approved Air Quality Model</th>
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<td></td>
<td>Model Domain</td>
<td>Meteorology</td>
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<tr>
<td>Screening</td>
<td>AERSCREEN</td>
<td>≤ 50 km</td>
<td>MAKEMET</td>
</tr>
<tr>
<td>Refined</td>
<td>AERMOD</td>
<td>Appendix D</td>
<td>≤ 50 km</td>
</tr>
<tr>
<td></td>
<td>CALPUFF</td>
<td>Appendix D</td>
<td>≤ 200 km</td>
</tr>
<tr>
<td>Advanced</td>
<td>AERMOD</td>
<td>Written approval of Director before modelling; side by side comparison with Refined model required</td>
<td>≤ 50 km</td>
</tr>
<tr>
<td></td>
<td>CALPUFF</td>
<td>Written approval of Director before modelling; side by side comparison with Refined model required</td>
<td>≤ 200 km</td>
</tr>
<tr>
<td>Alternate</td>
<td>Other</td>
<td>Written approval of Director and AEP before modelling; side by side comparison with Refined model required</td>
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Note: Non-model specific control parameters, e.g., formatting of input/output files, etc., may be set to suit the needs of the particular project. These administrative settings do not influence the level of the assessment.
4.0 Source Input Data

All air quality dispersion models require some form of input data that describe how much of a pollutant is being emitted, details on how the pollutant is being emitted, and the environment into which the emission occurs. Where the model assumes that the emissions are not chemically transformed in the atmosphere, the predicted concentration is directly proportional to the emission rate, i.e., if the emission rate is doubled, the predicted ground level concentration also doubles. Given this dependence, it is important that emission values input into the model are representative of the situation. The use of outdated or unrealistic emission limits for approved sources may lead to unrealistic or frequent exceedances not attributable to regulatory model conservatism but rather to the choice of emission limits.

Note: In all assessments, a table listing the source parameters, emission rates and emission quantification methods for all sources must be included.

4.1 Source Types

Emission sources can be categorized into four types based on geometrical shape: point, line, area, and volume sources. All of the dispersion models listed in Section 3.0 can be used for point, line, area, and volume source types; however, with AERSCREEN, there are limitations for multiple source situations. The different source types are defined as follows:

- **Point sources** are discrete sources that are stationary and emitting pollutants into the atmosphere from a specific point of origin such as stacks or flares. The source parameters normally required for point sources include the UTM or grid coordinates, emission release height (i.e., stack height), exit velocity, stack diameter, exit temperature and mass emission rates of the substance of concern.

- **Line Sources** are sources where emissions are in linear form, distributed over a line such as roads, rail lines and conveyor belts. Parameters normally required for line sources include the dimensions of the line and the mass emission rates. Some models may not treat line sources explicitly – in this case, sources of this type can be handled as area sources (long, thin rectangles) or as a string of volume sources.

- **Area sources** are clusters of point or line sources (e.g., fugitive emissions from industrial processes). Parameters normally required for area sources include the coordinates of the
area perimeter, the emission release height, and the mass emission flux rate of the substance of concern (i.e., mass emission rate per unit of area, g/s.m²). Examples of area sources include lagoons and retaining ponds, open pit mines, mine fleets, aggregated point sources.

* **Volume sources** are three-dimensional sources such as area sources distributed with a vertical height, for example, dust emissions from an aggregate storage pile, emissions from tanks. Parameters normally required for volume sources include the coordinates of the volume dimensions and the mass emission rates.

### 4.2 Source Emission Rates

The selection of emission rates for input into the model depends on the type of model and the purpose for which the model is being used. Air quality modelling undertaken to support an approval must clearly demonstrate the expected impacts of the approved activity in a representative manner. Figure 3 provides the logic flow for decision making as to which emission scenarios will be required as part of an assessment. Within this context there are two possible variations – new sources (Section 4.2.1), and renewal of existing/amendment of existing sources (Section 4.2.2).
Figure 3  Generic logic for the selection of emission scenarios required for a modelling assessment. The logic is applicable to new, renewal and amendment applications (see text below for details)
4.2.1 New Sources

In the case of new sources, maximum emission rates and typical emission rates would be the proposed rates. Emission parameters can be determined or derived from, in order of preference:

1) Design and engineering estimates, or
2) Emission factor estimates from published sources (manufacturer specifications or AP-42, (U.S. EPA 1995a)).

For modelling purposes, a proposed maximum emission rate would be considered different from a proposed typical emission rate if the proposed maximum emission rate exceeds the proposed typical emission rate by more than 10%. When these proposed emission rates do not differ, modelling of the proposed maximum emission rate for the project sources is required and sufficient (Branch 1 of Figure 3). Modelling must also include all non-project sources at their maximum emission rate and the addition of the appropriate baseline to capture the contribution from non-modelled sources (see Section 7.0 for a complete description of these sources).

When these proposed maximum and typical emissions rates do differ (Branch 2 of Figure 3) the modeller must further consider whether or not the proposed maximum emissions are due to an infrequent event (e.g., start up, shut down, maintenance, upsets – Branch 3 of Figure 3) or otherwise (Branch 4 of Figure 3).

If the proposed maximum emission rate is due to infrequent events (branch 3 of Figure 3) then the modelling assessment must include two modelling scenarios. The first to assess the impact of the infrequent events, the second to assess the impact of typical operating conditions. In particular, these scenarios should include:

A modelling scenario demonstrating compliance for infrequent events where the proposed maximum emissions from the infrequent events are modelled in conjunction with all other sources in the modelling domain operating at their maximum emissions as well as the addition of the appropriate baseline. Results from this scenario should be interpreted as per the guidance provided in "Using Ambient Air Quality Objectives in Industrial Plume Dispersion Modelling and Individual Industrial Site Monitoring", (AEP 2013).

A modelling scenario demonstrating the impact the facility will have on air quality during typical operations. This requires modelling all project sources using proposed typical emissions. Modelling must also include all non-project sources at their maximum and the addition of the appropriate baseline value (see Section 7.0 for a complete description of these sources).
If the proposed maximum emission rate is not due to infrequent events (Branch 4 of Figure 3) then the assessment must still include two modelling scenarios to properly capture the impact of operating at the proposed maximum emission rates and the proposed typical emission rates.

The first modelling scenario should set all project sources operating at their proposed maximum emission rates with non-project sources operating at their maximum rates. This scenario must also include the appropriate baseline to capture the contribution from non-modelled sources (see Section 7 for a complete description of these sources).

The second modelling scenario will be similar to the one immediately above but with all projects operating at their proposed emission rates.

4.2.2 Approval Renewals or Amendments

In the case of an approval renewal or amendment, the modeller should follow the same logic for determining what modelling is necessary in an assessment as for a new source but the maximum emissions rate should now be the approved maximum emission rate and the typical emission rates should be based on the average of the last three years of typical emissions from the project source. Stack emission parameters for renewal/amendment scenarios can be determined or derived from, in order of preference:

1) Approval limits;
2) Continuous emission monitoring conducted according to the Continuous Emission Monitoring System (CEMS) Code (AEP 1998, or as amended);
3) Manual stack surveys conducted according to the Alberta Stack Sampling Code (AEP 1995, or as amended);
4) Site specific source measurements;
5) Design and engineering estimates, or
6) Emission factor estimates from published sources (manufacturer specifications or AP-42 (U.S. EPA 1995a)).

Emission limits for authorized emission sources specified in EPEA approvals may be tied to specific process and control technology that may or may not include a specific mass/particle/other emission rate per unit time directly usable in an air quality model. The assessment must, in all cases, clearly state the emission rates for all sources in the appropriate units that may be directly used in an authorization as well as in units of mass/particle/other emission rate per unit time. The
conversion method used to derive the modelling ready emission rates must also be included in the assessment.

If sources operate only during specified hours, the modelling analysis can be restricted to those hours of operation. If this type of assessment is selected, special approval conditions may apply to restrict the operation of the facility to the time periods that were considered in the assessment.

### 4.3 Merged Sources: Stacks

The emissions from a facility can come from a number of different types of sources, locations, and characteristics. If the plumes from nearby similar stacks are close enough to merge, the plume rise can be enhanced. None of the recommended models account explicitly for the merged plume rise situation although modelling the sources as separate sources is generally a conservative assumption since the modelled plume rise in this situation will be lower than in reality.

Sources that emit the same pollutant from several stacks with similar parameters that are within 100 m of each other may be modelled by treating all of the emissions as coming from a single “representative” stack (U.S. EPA 1992b, Section 2.2). For each stack compute the parameter M:

$$M = \frac{h_s V_s T_s}{Q_s}$$

where:

- $M =$ merged stack parameter which accounts for the relative influence of stack height, plume rise, and mass emission rates on ground level concentrations,
- $h_s =$ stack height (m),
- $V_s =$ stack volumetric flow rate (m$^3$/s) $= (\pi/4) d_s^2 v_s$,
- $d_s =$ stack inside diameter (m),
- $v_s =$ stack gas exit velocity (m/s),
- $T_s =$ stack gas exit temperature (K), and
- $Q_s =$ stack pollutant mass emission rate (g/s).
The stack that has the lowest value of M is used as the "representative" stack. The emission from all of the merged stacks is then assumed to be emitted from the representative stack with the total pollutant mass emission rate, $Q_T$, given by:

$$Q_T = Q_1 + Q_2 + \ldots + Q_n.$$  

Note: If sources are located more than 100 m apart, or if they differ in their stack heights, volumetric flow rates, or exit gas temperature by more than 20% then they must be treated as separate sources.

### 4.4 Fugitive Emission Sources

Fugitive emission sources are often difficult to characterize since their emissions may vary with wind speed, temperature and time of day or process changes. Compounding this is the control efficiency of mitigation measures applied to reduce emissions, which may only be crudely estimated. If no better emission information, e.g., from a monitoring program, is available AP-42 emission factors (US EPA 1995) may be used to estimate fugitive emissions.

When modelling fugitive emissions care should be given to the choice of appropriate source type, i.e., the choice of an area source or volume source to best represent the nature of the emissions. Consideration should also be given to seasonal variability of the emissions from these sources where appropriate.

### 4.5 Flaring

Continuous and non-routine flares should always be designed in conformance with the most current guidelines and standards recommended by AEP or the Alberta Energy Regulator (AER), as appropriate.

Non-routine flares typically represent sub-hourly events and should be modelled and assessed using guidance from the most current version of the “Non-Routine Flaring Management: Modelling Guidance”, (AEP 2014, or as amended). The AER provides tools for flaring calculations, posted on their website, which are acceptable modelling tools for the intended purposes of non-routine flaring or incinerating.
Continuous flares should be modelled as continuous sources (consideration of their continuous rates and typical rates as per Figure 3) and should not use the risk-based approach developed to assess non-routine flaring. Pseudo-parameters for a continuous flare must be created using the AER non-routine flaring tool. In all flaring modelling make sure to use the no stick downwash (NOSTD) option as well as turn off the flaring option in AERSCREEN and the EPA flaring parameters as these are already accounted for in the AER non-routine flaring tool.

Note: Flares must be modelled as per the purpose to which they will be used. For example, if a flare stack designated for use in non-routine operations but is also used as a continuous flare then the impact of both flaring modes must be clearly demonstrated in the assessment.

4.6 Non-vertical Releases and Stacks with Rain Caps

Model non-vertical releases and stacks with caps using the appropriate options provided in AERSCREEN, AERMOD and CALPUFF.

If there are horizontal stacks or rain caps on a point source stack, there is effectively no vertical velocity of the effluent although the plume may still rise due to buoyancy if the effluent is warmer than the ambient air. In the case of a rain cap, the exit velocity may even be negative (i.e., downward oriented) and the plume will start to rise from a lower point than the actual stack exit.

4.7 Local Buildings and Downwash

To take account of local building effects, models generally require information related to the dimensions and location of the structures with respect to the stack. If the stack is located on the top of a building, or adjacent to a tall building, it may be necessary to consider the size of these buildings. As a general guide, building downwash problems may occur if the height of the top of the stack is less than 2 ½ times the height of the building upon which it sits. It may be necessary to consider adjacent buildings if they are within a distance of 5 times the lesser of the width or peak height from the stack (5L). This distance is commonly referred to as the building's region of influence. If the source is located near more than one building, assess each building and stack configuration separately. If a building's projected width is used to determine 5L, determine the apparent width of the building. The apparent width is the width as seen from the source looking towards either the wind direction or the direction of interest. The stack height calculation does not
dictate a minimum stack height; it determines whether building sizes need to be considered to account for possible building downwash conditions.

For example, the models require the apparent building widths (and heights) for every 10 degrees of azimuth around each source. Due to the complexity of building downwash guidance, the U.S. EPA has developed a computer program for calculating downwash parameters. The U.S. EPA Building Profile Input Program (BPIP) is designed to calculate building heights (BH’s) and the apparent width (U.S. EPA 1995b), and it is available from the U.S. EPA SCRAM web site. Building downwash should not be analyzed for area or volume sources.

The Plume Rise Model Enhancement (PRIME) algorithm that is integrated into AERMOD and CALPUFF is the preferred method used in the models to account for building downwash. AERSCREEN also uses all the advantages of the PRIME algorithm and uses BPIP to calculate building information to run the model. However, it is also known that PRIME was developed using a limited set of building profiles that can lead to unreasonable estimates of ground level concentrations under certain circumstances. This is an ongoing area of research and it is expected this will be corrected by the U.S. EPA in the near future.

In the interim, if modelling is conducted using PRIME and high downwash values are predicted that the modeller judges to be excessive there are several options available to them:

a. The modeller may use the ISCST3 downwash algorithm if either of the following conditions are met (Schulman and Scire 2012):

   Wide Buildings: Width > 4 x Height of Good Engineering Practice (GEP) stack
   or
   Long Buildings: Length > 4 x Height of Good Engineering Practice (GEP) stack

   Use of the ISCST3 algorithm (not the ISCST3 model) under these circumstances does not constitute the use of an alternate model but its use must be noted in the assessment.

b. The modeller may use either ORD (Monbureau et al. 2018) or PRIME 2/AWMA (Petersen et al. 2017, Petersen and Guerra 2018) alpha options as described under AERMOD system. Use of these downwash options would constitute an alternate model and must follow the protocol defined in Section 3.3. Note: If U.S EPA accepts either of these options as a beta or regulatory option then the accepted option may be used without the additional requirements required for using alternate models.
### 4.8 Particulate Emissions from Stack Surveys

Stack surveys will typically report the total suspended particulate (TSP) in the effluent stream. TSP may be comprised of fine particulate matter smaller than 2.5 $\mu$m ($<\text{PM}_{2.5}$), coarser matter smaller than 10 $\mu$m ($<\text{PM}_{10}$) or coarser matter still ($>\text{PM}_{10}$). In order to properly model the impact of particulate (both $\text{PM}_{2.5}$ and TSP) it is necessary to first determine the particle size distribution ($<\text{PM}_{2.5}$, $<\text{PM}_{10}$, $>\text{PM}_{10}$) and then the aerodynamic properties of the particles for the source.

To determine the particle size distribution use actual measured data if available, otherwise use the manufacturer’s specifications or emission factors. To determine the aerodynamic profiling by mass use the following (Lawrence 2012):

Let $\text{PM}_{2.5}$ (mass) = (P1 + P2 + P3 + P4) (mass) with
- P1 (mean particle diameter) = 0.625 $\mu$m
- P2 (mean particle diameter) = 0.875 $\mu$m
- P3 (mean particle diameter) = 1.125 $\mu$m
- P4 (mean particle diameter) = 1.875 $\mu$m

Let $\text{PM}_{10}$ (mass) = $\text{PM}_{2.5}$ (mass) + (P5 + P6) (mass) with
- P5 (mean particle diameter) = 4.25 $\mu$m
- P6 (mean particle diameter) = 8 $\mu$m

Let $>\text{PM}_{10}$ (mass) = P10 (mass) + P7 (mass) with
- $>\text{PM}_{10}$ (mean particle radius) = 20 $\mu$m

Example:
Create the appropriate input to model TSP and $\text{PM}_{2.5}$ from a pulp and paper source that is emitting 10 g/s of TSP. From the AEIR Standard (Alberta Environment and Parks, 2018) a pulp and paper source has ($\text{PM}_{2.5}$/TSP) = 0.560 and ($\text{PM}_{10}$/TSP) = 0.737 (recall that $\text{PM}_{10}$ is cumulative and includes the $\text{PM}_{2.5}$ mass fraction).

**AERMOD Solution:**

To set up AERMOD it is necessary to first define the mass fraction. For this problem a table of input values for particulate deposition modelling is as follows:
<table>
<thead>
<tr>
<th>PM Species</th>
<th>Mean Particle Diameter (µm)</th>
<th>Mass Fraction*</th>
<th>Particle Density (g/cm³)</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (PM₂₅)</td>
<td>0.625</td>
<td>0.1400</td>
<td>1</td>
<td>1.400</td>
</tr>
<tr>
<td>P2 (PM₂₅)</td>
<td>0.875</td>
<td>0.1400</td>
<td>1</td>
<td>1.400</td>
</tr>
<tr>
<td>P3 (PM₂₅)</td>
<td>1.125</td>
<td>0.1400</td>
<td>1</td>
<td>1.400</td>
</tr>
<tr>
<td>P4 (PM₂₅)</td>
<td>1.875</td>
<td>0.1400</td>
<td>1</td>
<td>1.400</td>
</tr>
<tr>
<td>P5 (PM₁₀)</td>
<td>4.250</td>
<td>0.0885</td>
<td>1</td>
<td>0.885</td>
</tr>
<tr>
<td>P6 (PM₁₀)</td>
<td>8.000</td>
<td>0.0885</td>
<td>1</td>
<td>0.885</td>
</tr>
<tr>
<td>&gt;PM₁₀</td>
<td>20.000</td>
<td>0.2630</td>
<td>1</td>
<td>2.630</td>
</tr>
</tbody>
</table>

* The mass fraction is assumed to be distributed uniformly amongst the different diameter bins associated with a particular PM species.

**CALPUFF Solution:**

The CALPUFF modelling system also models TSP in analogous way to AERMOD with an initial distribution PM species (P1, P2, etc.) by mass that is summed at each receptor using CALSUM or other appropriate tool. For this problem, the input table for TSP would be:

<table>
<thead>
<tr>
<th>PM Species</th>
<th>Size Range (µm)</th>
<th>Mean Diameter (µm)</th>
<th>Geometric sigma*</th>
<th>Associated Mass Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PM2.5</td>
</tr>
<tr>
<td>P1 (PM₂₅)</td>
<td>0.50 – 0.75</td>
<td>0.625</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>P2 (PM₂₅)</td>
<td>0.75 – 1.00</td>
<td>0.875</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>P3 (PM₂₅)</td>
<td>1.00 – 1.25</td>
<td>1.125</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>P4 (PM₂₅)</td>
<td>1.25 – 2.50</td>
<td>1.875</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>P5 (PM₁₀)</td>
<td>2.50 – 6.00</td>
<td>4.250</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>P6 (PM₁₀)</td>
<td>6.00 – 10.00</td>
<td>8.000</td>
<td>0.000</td>
<td>X</td>
</tr>
<tr>
<td>&gt;PM₁₀</td>
<td>&gt; 10.00</td>
<td>20.000</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

* The mass fraction is again assumed to be distributed uniformly amongst the different diameter bins associated with a particular PM species.

Note: Both AERMOD and CALPUFF by default assume a particle density of 1g/cm³. This should not be changed unless the proponent is modelling a source where the particle density is known to be considerably denser than the default value (e.g., a hard rock mining operation). In this case, the proponent should consult the Newfoundland guidance document “Guideline for Plume Dispersion Modelling” (Lawrence 2012) to determine the appropriate change in mean particle diameter.
4.9 Modelling TRS

If TRS (reduced species of Sulphur, e.g., H$_2$S, CS$_2$, COS, C$_2$H$_6$S, CH$_4$S, C$_2$H$_6$S$_2$, and others) emissions rates are measured or estimated as such these should be input into the model as is. If individual species of TRS are measured or estimated separately then TRS should be formed as the simple mass sum of these species.
5.0 Terrain, Receptors and Modelling Domain

Dispersion models require digital elevation information, as terrain can have a significant impact on the flow of pollutants. It is also important to model an adequate study area to ensure the possible expanse of pollutant impacts are captured.

5.1 Terrain Situation

Modellers should choose the best available sources of terrain data suitable for AERMOD and/or CALPUFF from the following:

1) Natural Resources Canada’s Canadian Digital Elevation Data (CDED) provides terrain data in USGS DEM type data for a 1:50,000 and a 1:250,000 scale maps (NAD83). It is available to download from the appropriate subdirectory under:


   For this data note the following:

   o The 1:50,000 map scale data has a grid resolution range of 0.75 to 3 arc-seconds. For data south of 68° N latitude, the grid resolution is roughly 20 m, depending on latitude.
   o The 250,000 map scale data has a grid resolution range of 3 to 12 arc-seconds, depending on latitude. For data south of 68° N latitude, the grid resolution is roughly 90 m, depending on latitude.

2) The distribution of Provincial Digital Base Map Data to the public is provided by AltaLIS Ltd. The data can be ordered from the AltaLIS website at:

   https://www.altalis.com

Note: The web links provided are only guaranteed to be current at time of publication of this document. If these sites are no longer available, it is the responsibility of the proponent to update this information. The proponent should always use the best information available.
5.2 Selecting Receptor Grid

The user needs to define the locations at which ground-level concentrations are to be predicted. These locations are termed 'receptor' locations. In selecting receptor locations, it is important to identify all sensitive receptors in the study area and adequately sample the receptor grid at these locations to ensure the predicted maximum ground level concentrations at these locations are properly captured. Sensitive receptors include, but are not limited to, individual residences, residential areas, schools, hospitals, fire halls, commercial day care and seniors’ centres, campgrounds, parks, recreational areas and facilities, and sensitive ecosystems.

All modelling assessments should use a Cartesian receptor grid, which can be regularly or irregularly spaced. Since the number of allowed receptors is limited, they should be more densely located where maximum impacts are expected. To ensure the maximum concentrations are obtained, the model should be run with the following set of receptors, at a minimum:

- 20 m receptor spacing in the general area of maximum impact and the property boundary;
- 50 m receptor spacing within 0.5 km from the source;
- 250 m receptor spacing within 2 km from the sources of interest;
- 500 m spacing within 5 km from the sources of interest, and
- 1000 m spacing beyond 5 km.

For each scenario in the assessment the model should be run at least twice. Firstly, with a coarse grid to determine the areas of high impact and/or concern. Secondly, with the finer grid in the vicinity of the impacted area to obtain the maximums. Additional modelling may be required if there is a need to further refine the ground level predictions. Only the scenarios with the final receptor configuration, not the intermediate receptor configurations, need to be included in the assessment.

In areas with many industrial sources, or for large buoyant sources (100 m tall stacks, high exit temperature), a larger 250 m grid, and a coarse grid out to a distance of 20 km may be necessary to find the area of maximum impacts. In some cases, an even larger grid may be necessary.

The model domain for any assessment should not exceed the limitations of the model. If it is necessary to model at points beyond the model limitations, the results should be interpreted with extreme caution.
Note: The only allowed exception to the 20 m receptor spacing rule at the property boundary is for very large area sources, i.e., the project boundary perimeter is larger than 50 km, where sampling at this rate will require excessive computing resources. If there are any sensitive receptors affected by waiving the 20 m receptor spacing requirement then the requirement for high resolution sampling around the sensitive receptor takes precedence. All other spacing rules still apply.

### 5.3 Facility Boundary

Models are typically used to predict ambient concentrations for comparison with the Alberta Ambient Air Quality Objectives (AAAQOs) or Alberta Ambient Air Quality Guidelines (AAAQGs). The areas of applicability of the AAAQOs and AAAQGs are not simply defined by the facility boundary but must take into account areas beyond the facility boundary where it is reasonable to expect public access. The facility boundary is determined by the facility fence line and/or the perimeter of disturbed area that defines where public access is normally restricted. As an example, if a public access road passes through the facility, the facility boundary along this feature is defined by the road allowance.

### 5.4 Modelling Domain

The modelling domain must encompass the project impacts on the surrounding environment in a cumulative manner. The modelling domain must:

1) Include all predicted ground-level concentrations of pollutants from the project at or above 10% of their respective AAAQO. Be sure to include this contour on all plots of predictions. When modelling more than one pollutant ensure the modelling domain is based on the most spatially extensive AAAQO predictions.

2) The project facility should be in the centre of the study area.

3) Ensure that the assessment takes into account all industrial sources within the modelling domain. If there are other industrial sources outside of the modelling domain that will contribute to the modelled ground level concentration of pollutants from the project then the modelling domain must be expanded to include the additional source(s). See Section 5.4.1 for additional details.
4) A representative baseline value must always be added to all predicted concentrations for all assessment scenarios for all averaging periods. See Section 7.2 for guidance on creating appropriate baselines.

5.4.1 Cumulative Effects Assessment of Nearby Sources

All industrial emission sources within 5 km of the project boundary must be included in the modelling assessment. In cases where there are additional industrial sources outside of this 5 km catchment that are contributing (additively) to the ground level concentrations of pollutants from the project under assessment these additional sources must also be included in the emissions inventory and modelling assessment. Determination of which sources outside of this 5 km catchment may be impacting a project can be made using a screening model. The threshold criterion for including these additional sources is if they contribute an additional 5% to the pollutant isopleth defining the modelling domain for the same pollutant for the same averaging period (See Section 5.4 above for definition of Modelling Domain). Particular care should be taken to include all relevant sources in industrialized regions, e.g., the industrial heartland, to ensure a realistic assessment of the cumulative impacts are presented. Failure to do so may require additional modelling to complete the cumulative effects assessment.

When conducting a cumulative assessment emission estimates for non-project industrial emissions should be based on the following in order of preference:

1) Approval limits;
2) Manufacturer’s emission data;
3) Emission factors, or
4) If none of the aforementioned values are available emissions can be estimated by any method authorized by the department such as manual stack surveys or continuous emission monitoring.

It is the responsibility of the project proponent to obtain the best available representative emissions data from non-project industrial sources.
Figure 4  Illustration showing industrial emission sources to be included in an assessment. Sources A and B must be included as they fall within the 5 km catchment of the project. Source C does not need to be included, as it does not overlap in a significant way with the project. Source D must be included even though it is beyond the 5 km catchment as it does impact the project.
6.0 Meteorological Input Data

AERSCREEN is able to generate a site-specific worst-case meteorological data set, the input of meteorological data is not required into the AERSCREEN model.

For refined or advanced assessments more representative meteorological data, both temporally and spatially, for the modelling domain should be used. Meteorological data can come from two sources: ground meteorology or modelled meteorology (or a combination of the two) depending upon the application. Within this context, AEP allows the following:

1) Applications for which there is on-site (within facility boundary, not modelled) meteorology available, that is judged to be representative of the modelling domain, may use the on-site meteorology in an air quality modelling assessment provided it meets the following criteria:

   a) There is a minimum of one year of hourly on-site meteorology available. On-site meteorology must be related to the longer term (seasonal or annual) meteorology by statistical methods. Relating on-site meteorology to data from climate or meteorological stations having longer collection periods ensures that on-site data are temporally representative of meteorology for the entire modelling domain. An on-site meteorological data set should not be used if fewer than 90% of the annual data are available. When missing data values arise, they should be handled in one of the ways listed below (U.S. EPA 2000), in the following order of preference:

      i) If there are other on-site data, e.g., temperature measurements at another height, they may be used when the primary data are missing and corrections based on established vertical profiles should be made. Site-specific vertical profiles based on historical on-site data may also be appropriate to use after consultation with AEP.

      ii) If there are only one or two missing hours, linear interpolation of missing data may be acceptable. Caution should be exercised when the missing hour(s) occur(s) during day/night transition periods.

      iii) If representative off-site data exist, they may be used, only for missing data values. In many cases, this approach is acceptable for cloud cover, ceiling height, mixing height, and temperature. An assessment to determine whether this data is adequately representative will involve an examination of the surrounding terrain, surface characteristics, and the height of the source versus the height of the measurements. Meteorological data should be considered representative only when the monitoring site and the facility site are in climatologically similar regimes (U.S. EPA 2000).
The upper air sounding data should be taken from the most representative or closest upper air monitoring station or the current AEP meteorological data set (provided the AEP data and on-site data temporally coincide) available on the AEP website:


2) For all other applications, five years of modelling must be undertaken with data taken from the AEP meteorological data set serving as the basic meteorological data set to be used (in CALPUFF applications this would be the initial guess field) to be supplemented by ground based meteorology, where appropriate. In summary:
   a) The AEP meteorological data set supplemented with meteorology from all readily available (publically accessible) ground meteorology within the modelling domain whose meteorology temporally coincides with the five years provided in the AEP data set. Missing meteorological data from these stations should be treated as per the instructions for similarly treating missing data for on-site meteorology (outlined above). Complete information on which stations were used and the extent to which any of their data were treated must be provided as part of the reporting process.
   b) When there are no available ground meteorology in the modelling domain, or the ground meteorology does not temporally coincide with the AEP meteorological data set, or the ground meteorology is incomplete then the AEP meteorological data set should be used by itself.

No other meteorological data sets are acceptable.

6.1 Surface Characteristics

Surface characteristics determine the degree of ground turbulence caused by the passage of winds across surface structures.

In CALMET surface characteristics are determined by the terrain data input into the model. Refer to the most recent CALMET user guide for default settings for surface characteristics.

For AERMOD assessments, the following method is to be used for selecting the rural or urban surface roughness categories.
Classify the land use within a 3-km radius of the source. If more than 50% of the land use falls within the following categories—heavy or light industrial, commercial, and compact residential (two-story dwellings, limited lawn sizes)—it is considered to be urban. Otherwise, use the rural coefficients by selecting rural roughness, except for forests, which are treated as urban locations.

Note: When modelling includes flaring the modeller may use the AER non-routine flaring tool to generate these land use values.

The input for the AERMET meteorological processor of AERMOD requires surface roughness, Bowen ratio and albedo parameters. Although there are default values for surface roughness, the monthly values should be used if available. When monthly data is unavailable, a representative value can be selected based on the land use type as a function of season within a 3 km radius of the input meteorological data (Table 3).

The EPA released AERSURFACE in 2008, a utility to obtain realistic and reproducible surface characteristics using United States land cover datasets. Unfortunately, these datasets do not cover Canada. Tables 2 through 4 are AEP’s recommended settings for Alberta. However, if in the professional opinion of the air quality modeller they think they can develop more realistic surface characteristics using AERSURFACE as per the AERMOD Implementation Guide (USEPA 2008) they may do so provided justification in writing is provided to the department as part of their assessment.
### Table 2  Surface Roughness Length (m) for Land Use and Seasons (Paine, 1987)

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (fresh water and sea water)</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>1.00</td>
<td>1.30</td>
<td>0.80</td>
<td>0.50</td>
</tr>
<tr>
<td>Coniferous Forest</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>Swamp</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>Cultivated Land</td>
<td>0.03</td>
<td>0.20</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.05</td>
<td>0.10</td>
<td>0.01</td>
<td>0.001</td>
</tr>
<tr>
<td>Urban</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Desert Shrubland</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Definition of Seasons:
- "Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1–2 months after the last killing frost in spring.
- "Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.
- "Autumn" refers to a period when freezing conditions are common, deciduous trees are leafless, crops are not yet planted or are already harvested (bare soil exposed), grass surfaces are brown, and no snow is present.
- "Winter" conditions apply for snow-covered surfaces and subfreezing temperatures.

Albedo and Bowen Ratio values can also be chosen to appropriately represent particular site conditions. Table 3 and Table 4 provide Albedo and Bowen Ratio values as a function of land use and season (Paine 1987).

### Table 3  Albedo of Land Use Types and Seasons (Paine, 1987)

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (fresh water and sea water)</td>
<td>0.12</td>
<td>0.10</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.50</td>
</tr>
<tr>
<td>Coniferous Forest</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.35</td>
</tr>
<tr>
<td>Swamp</td>
<td>0.12</td>
<td>0.14</td>
<td>0.16</td>
<td>0.30</td>
</tr>
<tr>
<td>Cultivated Land</td>
<td>0.14</td>
<td>0.20</td>
<td>0.18</td>
<td>0.60</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.18</td>
<td>0.18</td>
<td>0.20</td>
<td>0.60</td>
</tr>
<tr>
<td>Urban</td>
<td>0.14</td>
<td>0.16</td>
<td>0.18</td>
<td>0.35</td>
</tr>
<tr>
<td>Desert Shrubland</td>
<td>0.30</td>
<td>0.28</td>
<td>0.28</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Table 4  Daytime Bowen Ratios for Land Use Types and Seasons (Average Moisture Conditions) (Paine 1987)

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (fresh water and sea water)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>1.5**</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>0.7</td>
<td>0.3</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Coniferous Forest</td>
<td>0.7</td>
<td>0.3</td>
<td>0.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Swamp</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Cultivated Land</td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.4</td>
<td>0.8</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Urban</td>
<td>1.0</td>
<td>2.0</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Desert Scrubland</td>
<td>3.0</td>
<td>4.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

* Winter Bowen ratios depend upon whether a snow cover is present. Bowen ratios range from the value listed for autumn for rare snow covers to the value listed for winter for a continuous snow cover.

** This value applies if water body is frozen over.

Definitions of the seasons are the same given in Table 1.
7.0 Model Output and Post Analysis

Model output is to be submitted to the director for review and acceptance as part of the assessment. The recommended information should include sufficient information such as all tables, figures, charts, input/output model control files, and all other specified information necessary to complete the assessment. Appendix A and Appendix B provide a complete listing of the required documentation to be included in an assessment. In particular, the model output should be sufficient to:

1) Demonstrate the objectives of the assessment have been met;

2) Clearly explain the methodology employed and other supporting information to prove that the model has been applied properly; and

3) Ensure the model output can be used effectively and efficiently to inform decision makers.

It is crucial that the submitted documentation includes sufficient detail so the reviewer can understand the assumptions and steps involved in the assessment. Failure to do so will certainly delay the processing time and may result in the assessment being rejected.

7.1 Model Outputs

7.1.1 Calculation of Hourly and Super-hourly Values for Comparison to AAAQOs and AAAQGs

The input to dispersion models consists essentially of emissions and meteorological data. The output from dispersion models consists of concentration values or deposition values. Predicted concentrations are expressed as micrograms per cubic metre (µg/m³) of air while deposition rates should be expressed in kilograms per square metre (kg/m²). Concentrations of gases may also be expressed as the ratio of the volume of the substance to the volume of air. In this case, concentrations are expressed as parts per million (ppm) or parts per billion (ppb). The following equation is recommended for converting the concentrations in µg/m³ to ppm at standard conditions (T_{std} = 25°C, P_{std} = 101.325 kPa):

\[
[\text{ppm}] \times 40.8862 \times \text{molecular weight} = [\mu\text{g/m}^3]
\]  (2)

\[ \]
The concentration of a substance will vary from second to second because of turbulence in the atmosphere. For practical use, concentrations are expressed as averages over specified time periods. AAAQOs and AAAQGs are usually stated for 1-hour averages, 24-hour averages, 30 day averages and annual arithmetic averages, although other time periods are used for some substances, e.g., 30 minute averaging for odour management (See Section 7.1.2).

Predicted concentrations at ground level can be high due to extreme, rare, and transient meteorological conditions and can be considered outliers. Therefore, hourly values above the 99.9\textsuperscript{th} percentile for each receptor in each year can be disregarded. For example, the highest eight 1-hour predicted average concentrations for each receptor in each single year should be disregarded. For all super-hourly averaging periods (averaging periods longer than one hour) the eight highest hourly predicted concentrations that were disregarded for the 1-hour averaging period must be included when calculating the 99.9\textsuperscript{th} percentile value, e.g., 8-hour averaging would remove the top 8-hour average, 24-hour averaging would not remove the top 24-hour average.

It should be clear from the assessment which modelled year(s) are being used for comparison to the AAAQOs and AAAQGs. In the case where two or more years are predicting exceedances more frequently than the allowed tolerance then relevant information (charts, isopleths, tables, etc.) for all years in violation of the allowed frequency of predicted exceedances should be included. For assessments where an exceedance is not predicted relevant information (charts, isopleths, tables, etc.) for the year with the maximum predicted value for a pollutant for the averaging period being reported should be included.

If a substance of concern does not have an associated AAAQO or AAAQG value, the lesser of Ontario Point-of-Impingement Values or Texas Commission of Environmental Quality Effects Screening Levels concentrations should be used. If neither Ontario nor Texas has a value for the substance of concern, a risk assessment should be conducted. Consult with AEP to determine the appropriate course of action before the risk assessment is commenced.

If maximum predicted concentrations exceed an AAAQO, the applicant must contact the Director to discuss the next steps to address the predicted exceedances. The same approach is required for any AAAQG the Director requires to be included in the assessment.

Further direction on the necessary actions required to meet AAAQOs is contained in “Using Ambient Air Quality Objectives in Industrial Plume Dispersion Modelling and Individual Industrial Site Monitoring” (AEP 2013, or as amended).
7.1.2 Calculation of Sub-hourly Values for Comparison to AAAQOs or AAAQGs

Air quality models usually consider hourly averaging periods as the minimum averaging period of concern. Hence, the use of hourly meteorological data for determining AAAQOs and AAAQGs is a standard practice. In cases where it is necessary to calculate a sub-hourly AAAQO or AAAQG based on hourly data the appropriate scaling factor must be used. For air quality modelling assessments this can be assumed to be (Ontario 2005):

\[ C_{\text{sub-hour}} = C_{\text{hour}} \times (\text{sub-hourly time/hour})^{-0.28} \]  

(3)

For example, for a 30-minute AAAQO or AAAQG, the modelled hourly value is scaled by a factor of 1.21 to determine the 30-minute value.

If a sub-hourly AAAQO or AAAQG for a pollutant is required for a particular assessment other than for odour management then the 99.9% tolerance should be applied.

When assessing sub-hourly AQQOs or AAAQGs for odour management, e.g., TRS, it is acceptable to eliminate the top 43 values (99.5% tolerance per 8760 independent hourly values per year at each receptor). Do not apply the tolerance allowed for infrequent events (See Section 4).

Note: If one year of on-site sub-hourly meteorology is available (see Section 6) and used in an odour assessment the 99.5% tolerance should be applied to this data as is.

7.2 Baseline Concentrations

Baseline air quality includes pollutants from anthropogenic and biogenic sources that are not directly included in the dispersion model. The correct choice of a representative baseline value requires considerable professional judgement. When selecting the appropriate ambient monitoring station to use to derive the baseline values it is important to consider the nature of the missing emissions that will be represented by the baseline values and the similarity of baseline monitor location to the project, i.e., similar topography, climate normals and air quality regime.
For example, if a modelling assessment is conducted for a project in a heavily industrialized area and the modelling domain is quite extensive then a monitoring station that operates under similar climatological conditions that also captures similar traffic and residential/commercial heating emissions as well as biogenic emissions in the area but not industrial emissions would be an appropriate choice. On the other hand, for an assessment in a relatively pristine area where all of the relevant industrial emissions associated with the project are included then the choice of a monitoring station from a small rural community under similar meteorological conditions would be appropriate.

When conducting a screening or refined assessment, the baseline value for the same substance must be added to the predicted value before a comparison to the AAAQO is made. Assessing the effects of the baseline component becomes more complex when short-term objectives (1-hour, 24-hour averages) are being considered.

The following method should be used to determine a baseline concentration:

1) All monitoring data should be subjected to validation and quality control to ensure its accuracy. Hourly, continuous ambient monitoring data is preferred over passive monitoring data where available.

2) The most recent three years of hourly ambient data should be averaged to form a baseline provided each year is at least 75% complete. If more than 25% of the hourly ambient data is missing (blanks) from a given year then it is acceptable to use the next most recent year of ambient data, provided it meets the 75% completeness criteria. Some additional considerations to the selection of the appropriate ambient data include:

   a) If less than three years of hourly ambient data is available then average over the available data provided at least one complete year of data is available. If one complete year of data is not available then the monitoring station cannot be used to construct a baseline.

   b) If an analyzer is changed during the period being used to construct a baseline the statistics of the monitoring data may change. This can be checked by visually comparing the mean and variance of monitoring data before and after the analyzer change. A noticeable step change in the mean value and/or a noticeable increase in the variance suggests the monitoring data statistics are different and the data from the two analyzers should not be combined. If there is a noticeable difference in analyzer performance and
there is not sufficient data to form a baseline with the current analyzer (at least one full year) then a different station must be used to form the baseline.

3) Screening assessments for all averaging periods should be based on average of the reduced hourly data set for each year, i.e., the top hourly values above the 99.9\textsuperscript{th} percentile non-blank ambient baseline data are removed. Do not include blank data as zero values when determining the 99.9\textsuperscript{th} percentile. For all averaging periods greater than one hour, the maximum calculated average for each averaging period, to be used as the baseline value for modelling purposes, must then be based on the reduced hourly ambient data sets. No further removal of maximum values for other averaging time periods is allowed.

4) Refined and advanced assessments should be calculated in a similar manner as the screening assessment but now based on a 90\% percentile. This allows for some variability in the baseline due to anthropogenic or unusual local sources.

Example. Suppose a screening assessment must consider a pollutant with an hourly and 24-hour AAAQO. The available monitoring for the three most current years of a pollutant have a completeness of 93\% of hourly values for the most recent year, a completeness rate of 97\% for hourly values for the second most recent year and a completeness rate of 83\% for hourly values for the third most recent year. The relevant baseline values for this scenario would then be:

1) **Hourly baseline value:** For the most recent (non-leap) year, there would be 8146 non-blank hourly values available to construct a baseline, 8497 non-blank hourly values from the second most recent (non-leap) year and 7270 non-blank hourly values from the third (non-leap) year. From these data sets, the 99.9\% value would be the 9\textsuperscript{th} highest hourly value for the most two most recent years and 8\textsuperscript{th} highest hourly value for the third year. The baseline hourly value to be used in the assessment would then be average of these 99.9\% hourly values.

2) **24-hour baseline value:** In forming the 24-hour baseline value for the assessment the top 99.9\% hourly values that had been excluded when determining the hourly baseline value should be set to blank. Hence, the most recent year would have a reduced data set of 8137 non-blank hourly values. Similarly, the second and third most recent years would have 8488 and 7262 non-blank hourly values. All 24-hour averages for each year must then be calculated using the reduced data set with the blank values in place as they occur. Once this is determined then each year’s 24-hour averages may then be ranked separately with the 24-hour average baseline for the assessment being the average of the top ranked 24-hour average from each year.
Modelling assessments that include TSP also require a TSP baseline value to be added to the modelling results. Monitoring of TSP in Alberta is not normally available so TSP baseline values should be derived from the most representative available PM\textsubscript{10} monitoring data after scaling by a factor of two (doubled) (Brook et al. 1997). If suitable TSP monitoring data is available it should be used to form a representative baseline rather than a PM\textsubscript{10} derived baseline.

### 7.3 Relationship between Nitrogen Oxides (NO\textsubscript{x}) and Nitrogen Dioxide (NO\textsubscript{2})

Of the several species of nitrogen oxides, only NO\textsubscript{2} is specified in the AAAQO. Since most sources emit uncertain ratios of these species and these ratios change further in the atmosphere due to chemical reactions, a method for determining the amount of NO\textsubscript{2} in the plume that takes these factors into consideration must be given. The recommended methods, described below, are implemented using a tiered approach as shown in Figure 4. The Total Conversion Method must be presented as part of the assessment for all scenarios.

#### 7.3.1 Tier 1: Total Conversion Method

In the conservative screening approach all NO\textsubscript{x} emissions are assumed to be NO\textsubscript{2} leading to the maximum possible concentration of NO\textsubscript{2}. If the NO\textsubscript{2} AAAQOs are met, the methods in 7.3.2, 7.3.3 and 7.3.4 are not necessary.

#### 7.3.2 Tier 2: Ambient Ratio Method (ARM/ARM2)

The ambient ratio method (ARM) is based upon the premise that the NO\textsubscript{2}/NO\textsubscript{x} ratio in a plume changes as it is transported but attains an equilibrium value some distance away from the source. However, in most cases monitors being placed in the correct location and distance to correctly determine the equilibrium NO\textsubscript{2}/NO\textsubscript{x} ratio would be fortuitous at best. With this limitation in mind the use of the ARM method must use the following protocol, in order of preference:

1) If there are monitors located between 15 km and 80 km downwind and within the general direction (± 22.5\textdegree) of the maximum impact, then the average annual NO\textsubscript{2}/NO\textsubscript{x} for the most
recent year derived from all relevant monitors should be used (OLM/ARM Workgroup – Draft Recommendations 1998).

2) If there are no suitable monitors available then a NO₂/NOₓ value of 0.70 may be used for all averaging periods. This represents the average NO₂/NOₓ for Alberta for the period 2000 – 2010 for all permanent monitoring stations with at least three years of data.

The ARM method is not intended to be used with local NO₂/NOₓ ratios. ARM2, the method outlined below, is an extension of the ARM method that is based upon the statistics of the ratio of NO₂/NOₓ derived from many ambient monitoring stations (Podrez 2015). The US EPA recognized there were some restrictions in its use to ensure it was a conservative as more established Tier 3 methods, e.g., OLM and PVMRM (Owen and Brode 2014). The restrictions from this analysis relevant to the Alberta context are:

1) If the total conversion method’s predicted maximum NO₂ concentration for the project sources alone (without non-project sources or background added) are ≤ 200 ppb then use ARM2 without modification of the minimum ARM2 NO₂/NOₓ ratio.

2) If the total conversion method’s maximum NO₂ concentrations for the project sources alone (without non-project sources or background added) are > 200 ppb then use ARM2 with the appropriate modification based on the NO₂/NOₓ in-stack ratio (ISR) for the project sources:

a) If all of the project source ISR ≤ 0.2 then use ARM2 as is with default minimum and maximum NO₂/NOₓ ratios. Note: This is the default setting in AERMOD and is expected to be adequate for most modelling assessments.

b) If any of the project source ISR > 0.2 then adjust the minimum NO₂/NOₓ ratio for all project sources to equal their respective in-stack ratios. The selection of the appropriate ratio for all sources (project and non-project) should be determined as per the guidance below.

Determination of the in-stack NO₂/NOₓ ratio (for all project source and non-project sources) should be made in the following order of preference:

2 For completeness: The polynomial defining the ARM2 method for AERMOD (v19191) is: \((-1.1723e^{-17}x(\text{NO}_x)^6 + (4.2794e^{-14}x(\text{NO}_x)^5 + (5.8345e^{-11}x(\text{NO}_x)^4 + (3.4555e^{-8}x(\text{NO}_x)^3 + (5.6062e^{-6}x(\text{NO}_x)^2 + (2.7383e^{-3}x(\text{NO}_x)^1 + 1.2441\)) where NOₓ is the predicted ground level concentration assuming total conversion. Note that the upper and lower bounds of this conversion are defined by the minimum and maximum NO₂/NOₓ ratio as defined within the assessment.
i) From direct stack testing, provided the testing is representative of normal operating conditions, when available

ii) Source manufacturer’s test data (which must be included in the assessment report).

iii) From the literature. A listing of in-stack NO$_2$/NO$_x$ ratios for some source types can be found at:

[https://www3.epa.gov/scram001/no2_isr_database.htm](https://www3.epa.gov/scram001/no2_isr_database.htm)

iv) Assume an in-stack NO$_2$/NO$_x$ ratio of 0.50 for all project sources unless they have better source information as per i – iii above (Owen and Brode 2014).

v) All non-project sources should have their minimum ARM2 NO$_2$/NO$_x$ ratio set to 0.20 unless they have better source information as per i – iii above (Owen and Brode 2014).

### 7.3.3 Tier 3: Plume Volume Molar Ratio Method (PVMRM) in AERMOD

The PVMRM approach (in AERMOD) limits the conversion of NO$_x$ to NO$_2$ based on the amount of ozone available within the volume of the plume as well as the initial in-stack NO$_2$/NO$_x$ ratio of the emitted plume. The PVMRM approach also incorporates a technique for merging plumes and calculating the resultant plume volume from multiple sources for purposes of calculating the resultant ambient NO$_2$/NO$_x$ ratios (Hanrahan 1999 a, b, Alaska Department of Environmental Conservation 2005).

PVMRM has strengths and weaknesses when considering its suitability to air quality modelling applications (US EPA 2014). In particular:

- **PVMRM is recommended for relatively isolated, elevated sources.**

- **PVMRM is not recommended when a significant amount of the emissions (say >50% by mass) from project sources may not be properly modelled with the PVMRM algorithm, i.e., they are area or line sources, near surface releases, or groups of sources that are in close proximity to each other.** Note: Merging of similar stack sources is allowed (See Section 4.3) before PVMRM is applied.
When using the PVMRM the following defaults are recommended:

1) For baseline O₃, it is preferred to use an onsite time-series of hourly O₃ concentrations that match the meteorology being employed, if available. In the absence of such data use one of the hourly O₃ time-series provided in Appendix E as appropriate (urban if the project is within an urban setting, otherwise rural).

2) The default equilibrium ratio of NO₂/NOₓ used in the AERMOD-PVMRM model is 0.90. This represents the long range NO₂/NOₓ equilibrium.

3) The determination of the short range NO₂/NOₓ equilibrium is critically dependent on the in-stack ratios for all project and non-project sources. These in-stack ratios should be determined as per the instructions provided for the ARM2 method for projects where predicted ground level NO₂ concentrations from project emissions assuming total conversion > 200 ppb (but disregard this requirement for this method to be applied).

Note: PVMRM2 is not available at this time as a refined model but may be proposed and assessed as an alternate model.

7.3.4 Tier 3: Ozone Limiting Method (OLM)

Use of onsite O₃ data is always preferred for the OLM method. In the absence of such data use one of the hourly ambient O₃ time-series provided in Appendix E as appropriate (urban if the project is within an urban setting, otherwise rural).

Under the OLM method an estimate of the NO₂ ground level concentration is determined by the application of the following equation (Cole and Summerhays, 1979; Owen and Brode 2014):

\[
\begin{align*}
\text{If } [O_3]_{\text{ambient}} & > 0.9 \times [NOx]_{\text{predicted},i} \text{ then } [NO_2]_{\text{predicted},i} = [NOx]_{\text{predicted},i} \\
\text{otherwise } [NO_2]_{\text{predicted},i} & = [O_3]_{\text{ambient}} + ISR_i \times [NOx]_{\text{predicted},i}
\end{align*}
\]  

(4)

where ISRᵢ refers to the source in-stack ratio for the iᵗʰ source. According to Equation 4 if the ambient O₃ concentration is greater than 90% all predicted ground level NOₓ is assumed to be converted to NO₂. When this condition is not met the resulting ground level NO₂ concentrations are the sum of the NO₂ produced by thermal process at source (in-stack) and the NO converted to NO₂ by the oxidation with ambient O₃. All concentrations in Equation 4 need to be in ppm.
Selection of the appropriate ISRs for the OLM method should follow the same method as outlined for the PVMRM method (see Section 7.3.3).

The OLM method is preferred for assessments where the PVMRM method may not be appropriate (Owen and Brode 2014).

7.3.5 Treatment of NO$_2$/NO$_x$ Conversion in CALPUFF

7.3.5.1 Using the No Chemistry Option in CALPUFF

For regulatory applications that do not require a determination of the effects of acid deposition the chemistry option in CALPUFF should be turned off. When modelling in the no chemistry mode Total Conversion, ARM and ARM2 methods are directly available for modelling ground level NO$_2$ concentrations via post processing (CALPOST and CALSUM) and should be applied in the manner described above (See Sections 7.3.1 and 7.3.2). When using these methods all NO$_x$ emissions must be entered as NO$_x$ (NO$_2$ should not be included in the input parameter list).

The OLM can also be applied to NO$_x$ from individual sources using the guidance provided in Section 7.3.4 but each source will need to be treated separately and then summed (using a user developed script using CALSUM or any other readily available tool – there is no built in CALSUM script to perform this task) to determine the total ground level NO$_2$. When using this method all NO$_x$ emissions must be entered as NO$_x$ (NO$_2$ should not be included in the input parameter list); no other NO$_2$/NO$_x$ transformations are allowed.

PVMRM is not available in CALPUFF.

7.3.5.2 Using the Chemistry Option in CALPUFF (RIVAD/ISORROPIA + aqueous)

When a wet and dry acid deposition assessment is required in a regulatory application CALPUFF is the preferred model. AERMOD is not allowed. In this case modelling all species, including NO and NO$_2$, should be undertaken using the RIVAD / ISORROPIA+aqueous chemical formulation (MCHEM = 6, MAQCHEM = 1, MLWC = 1).
When using this chemical mechanism it is preferred to use an onsite time-series of hourly O\textsubscript{3} concentrations that match the meteorology being employed, if available. In the absence of such data use one of the hourly O\textsubscript{3} time-series provided in Appendix E as appropriate (urban if the project is within an urban setting, otherwise rural). If onsite NH\textsubscript{3} and H\textsubscript{2}O\textsubscript{2} data is available it should be used, particularly in areas where there are known sources of NH\textsubscript{3} (e.g., agricultural operations), otherwise use default values of 0.5 ppb for NH\textsubscript{3} and 0.2 ppb for H\textsubscript{2}O\textsubscript{2} (Lawrence 2012).

When using this method it is not necessary to calculate NO\textsubscript{2} ground level concentrations as a separate modelling run. However, all NO\textsubscript{x} emissions must be entered as NO and NO\textsubscript{2} (NO\textsubscript{x} should not be included in the input list). It is important to make the initial NO/NO\textsubscript{x} partition at source using the appropriate ISR. This should be done as per the ARM2 method (See Section 7.3.2).
Figure 5  Flow chart showing options for converting NOₓ and NO₂
8.0 Obtaining Models and Resources

This section contains instructions for accessing information relevant to dispersion modelling. There are two areas of information, AEP web page, and the U.S. EPA web page. The AEP home page contains general information about AEP, Alberta regulatory information, regional meteorological data sets, and updates of these model guidelines. The U.S. EPA home page has a link to its Support Centre for Regulatory Air Models (SCRAM) page.

8.1 Alberta Environment and Parks Air Quality Modelling Home Page

Alberta Environment and Parks' link to air quality modelling information and data can be found here:


8.2 Alberta Energy Regulator Home Page

The address for the flaring tool web page is:

https://aer.ca/regulating-development/rules-and-directives/directivesdirective-060

8.3 U.S. EPA SCRAM Home Page

The SCRAM site covers topics related to dispersion models. The internet site can be accessed at the following address:

http://www.epa.gov/scram
8.4 Canadian Climate Normals

The Canadian Climate normals are available free of charge at the following web site:

http://climate.weather.gc.ca/climate_normals/

This information can be utilized for comparison with dispersion model results and to compare the representativeness of site data or other meteorological data for the region. If sufficient data are available, climatological wind directions, wind speeds, and temperatures can be analyzed to determine the frequency of particular meteorological conditions. This could be compared to the worst-case modelled condition, to help determine possible frequencies of occurrence of elevated concentrations.
9.0 Regional Modelling

Regional modelling may be conducted in support of Environmental Impact Assessment applications or upon request by the Director. Most commonly, regional modelling is undertaken to support regional environmental management initiatives or research studies.

9.1 Acid Deposition

Acid deposition takes into account the net effects of acidifying species on soil in conjunction with buffering that may occur due to the deposition of base cations and natural soil processes. The general method for determining an exceedance of this equilibrium (critical load) can be found in Alberta’s Acid Deposition Management Framework - ADMF (AEP March 2008, or as amended):

https://open.alberta.ca/publications/9780778567264

For regional acid deposition modelling, CALPUFF, or any other acid deposition model recommended by AEP for this purpose (not AERMOD), may be used. When undertaking acid deposition studies the appropriate chemical transformation mechanism must be used (for CALPUFF see Section 7.3.5.2) to ensure all required acidifying species are included.

To ensure that planned development in or around a region does not result in acid deposition issues, and also to guide management of acidifying emissions, a project proponent should complete an acid deposition assessment if:

1) The proponent’s combined emissions of SO₂, NOₓ, and NH₃ are greater than 0.175 t/d of H⁺ equivalent, i.e.,

   \[ \text{Total H}^+ \text{ equivalent (t/d)} = 2 \times (\text{SO}_2 \text{ t/d})/(64) + 1 \times (\text{NO}_x \text{ t/d})/(46) + 1 \times (\text{NH}_3 \text{ t/d})/(17), \]  
   \[ (5) \]

   or

2) There is evidence that regional soil and surface water is more sensitive to acidification than is estimated in the provincial framework, or

3) There is existing deposition and/or acidification impact monitoring that indicates a potential concern if acid deposition increases, or
4) At the discretion of the Director.

Acid deposition is a long-term effect that will vary from year to year with meteorology. Annual average acid deposition values should be calculated for each receptor for each year using Alberta’s regulatory meteorological data set. The median of these annual values at each receptor should be used as the receptor’s annual acid deposition value. When comparing receptor deposition values to the critical load maps provided by the ADMF the average value of all receptor values within the minimum critical load map cell should be used to determine whether or not an exceedance occurs.

As an example, in a modelling assessment receptors are typically placed 1000 km apart at the extreme edge of the modelling domain. If the minimum cell width of the critical load map under the ADMF is 2.5 km then the model should produce at least four receptors per cell. For each receptor the median annual deposition value should be calculated and then the average of all of these values within that cell should be used to determine whether or not the cell is exceeding the cell’s critical load.

9.2 Ozone and Secondary Particulate Matter (PM)

An advanced assessment or regional airshed management planning study may require ozone and secondary PM air quality modelling. Normally, AEP would accept models developed or recommended by the U.S. EPA. Examples of these models are: California Photochemical Grid (CALGRID) model, the Models-3/Community Multiscale Air Quality (CMAQ) modelling system, the Comprehensive Air quality Model with extensions (CAMx), the Regional Modelling System for Aerosols and Deposition (REMSAD), Second-order Closure Integrated Puff (SCICHEM), and the Variable Grid Urban Airshed Model (UAM-V) System. These models can be obtained through the U.S. EPA’s Support Centre for Regulatory Atmospheric Modelling (SCRAM). It should also be noted that the preparation of input data for these models typically require significantly more effort than other model assessments.

If air quality modelling of ozone or secondary particulate matter is required by the Director a modelling plan addressing the Director’s particular need must be submitted in writing to the Director before modelling commences. The modelling plan must be agreed to by the Director in writing before the modelling commences.
10.0 References


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Research Laboratory, Research Triangle Park, NC. NTIS PB-257 896, EPA-600/4-76-
030a.
Appendix A   Expected Content of Screening Assessments

Facility Information
- Facility address and company name
- EPEA approval or registration # (if applicable)
- AER facility number (if applicable)
- Industrial sector

1.0 Sources and Emissions

1.1 Source Data
- Number and type of sources (i.e., stack, flare, area, etc.)
- Plot plan
- Locations and dimensions of buildings (length, width, height)
- Design capacity (normal or average capacity may also be needed)

1.2 Characteristics of Emissions
- Chemical composition (substance type) and emission rates (g/s)
- Exit (stack) height above ground (m)
- Temperature (K) or heat content (MJ/m³ and cal/s)
- Exit velocity (m/s)
- Stack top inside diameter (m)
- Pseudo flaring parameters
- Other parameters if not a point source
- Calculations or explanations on how emissions were calculated

1.3 Potential Emissions for all modelling scenarios.

2.0 Topography

- Description and map if necessary
- Vegetation cover/land use
- Sensitive receptors nearby (public buildings, homes, etc.)
3.0 Results - Air Quality Modelling Predictions

- Summary of baseline concentration data (station used, years considered, data completeness, statistics of data)
- Building downwash (include whether effects seen on or off facility property)
- Tabulated predicted maximum ground level concentrations and ground level concentrations at all sensitive receptors for all relevant averaging periods and relevant emission scenarios (maximum and typical emission scenarios, as required) the project with baseline and all applicable non-project industrial sources. Applicable AAAQO values should be included in this table as well as the number of any exceedances of these objectives.
- Isopleths showing all predicted ground level concentrations for all modelled pollutants. Isopleth levels should be set from 10% to 90% in increments of 10%. The isopleths should also clearly indicate the project boundaries and the location of any sensitive receptors and their predicted ground level concentrations. The location and value of the maximum model ground level concentration in the study area should also be included.
- Predicted acid deposition assessment (if required)
- Comparison with existing monitoring data (if applicable)
- Soft copy of dispersion model input and output files including any control files used in the assessment. These should also be provided in digital format (i.e., on CD) or electronic format.
Appendix B Expected Content of Refined and Advanced Assessments

Facility Information
- Facility address and company name
- EPEA approval or registration # (if applicable)
- AER facility number (if applicable)
- Industrial sector

1.0 Sources and Emissions

1.1 Source Data
- Number, location, type (stack, flare, etc.) and category (point, area, line, volume) of sources, quantification method
- Plot plan
- Dimensions of nearby buildings
- Design, average and nominal capacity

1.2 Characteristics of Emissions
- Temperature or heat content at exit
- Exit velocity
- Stack top inside diameter (m)
- Exit height above ground
- Chemical composition and emission rates
- Water content
- Other parameters for non-point sources
- Explanations or calculations on how emissions were measured or estimated
- Identification of any stacks having rain caps and any non-vertical sources
- Classification of how sources typically operate (continuous, intermittent, emergency/upset)

1.3 Time Variations (Short and Long-Term)
- Hours of operation, including seasonal variation
- Duration and frequency of non-routine events
1.4 Potential emissions scenarios using maximum emissions, typical emissions and infrequent events, including confirmation of whether or not maximum emissions rates are within 10% of typical.

1.5 Other Major Existing or Proposed Sources
- Identification of existing industrial sources within study area
- Identification of major proposed or approved (but not constructed) facilities within study area
- Facility type of industrial sources within study area
- Number, unique identifier and type of sources (stack, flare, etc.) for each facility
- Geographic locations of each source (UTM or Lat/Long NAD 83)
- Chemical composition (substance type) and emission rates (g/s)
- Data sources for other facility emission rates and identification of the quantification methods used (if known)
- Exit (stack) height above ground (m)
- Temperature (K) or heat content (MJ/m³ and cal/s)
- Exit velocity (m/s)
- Stack top inside diameter (m)

2.0 Topography
- Description and map
- Elevation maxima and minima
- Vegetation cover/land use
- Receptor grid resolution and domain size
- Sensitive receptors
- Parks, campgrounds, and wilderness areas
- Population centres and public facilities
- Location of meteorological and air quality stations

3.0 General Climatology (as needed)
- Temperature
- Precipitation
- Pressure
- Solar radiation
• Wind
• Cloud cover

4.0 Meteorology (as needed)

• Sources of data
• Representativeness of measurements (time and space)
• Topographic influences

4.1 Wind
• Speed and direction distributions (roses)
• Relation of short-term on-site to long-term off-site
• Persistence
• Diurnal and seasonal variations
• Extreme values
• Mean speed
• Prevailing and resultant winds
• Relation to visibility restrictions
• Relation to topographic effects

4.2 Temperature
• Inversion heights, strengths, frequencies, and persistence
• Mixing layer heights, diurnal and seasonal variation
• Magnitude and behaviour, diurnal and seasonal variation

4.3 Turbulence
• Direct measurements - frequency distributions, diurnal and seasonal variations
• Indirect determinations, definition of stability parameter (thermal/mechanical turbulence index) and description of inference scheme
• Frequency distribution, diurnal and seasonal variations

5.0 Air Quality Modelling Summary

5.1 Air Quality Modelling Setup
• Identification of the specific model version and switches used. These should be provided in tabular form side-by-side with the default settings.
• All appropriate air quality model and data references
5.2 Air Quality Modelling Predictions

- Summary of baseline concentration data (station used, years considered, data completeness, statistics of data)
- Building downwash (include whether effects seen on or off facility property)
- Tabulated predicted maximum ground level concentrations and ground level concentrations at all sensitive receptors for all modelled pollutants for all relevant averaging periods and relevant emission scenarios (maximum and typical emission scenarios, as required). Applicable AAAQO values should be included in this table as well as the number of any exceedances of these objectives. This data should be provided for each meteorological year modelled.
- Isopleths showing all predicted ground level concentrations for all modelled pollutants. Isopleth levels should be set from 10% to 90% in increments of 10%. The isopleths should also clearly indicate the project boundaries and the location of any sensitive receptors. This data should be provided for each meteorological year modelled.
- Predicted acid deposition and/or particulate deposition, as required
- Comparison with existing monitoring data (if applicable)
- Soft copy of dispersion model input and output files including any control files used in the assessment. These should also be provided in digital format (i.e., on CD) or electronic format
- Discussion regarding any topographic, meteorological or building effects germane to the project
- Any other relevant information that will assist the Director evaluate the environmental impact of the project

6.0 Special Topics

- Risks due to uncontrolled releases
- Unusual natural phenomena
- Atmospheric chemical transformations
- Chemical reactions between plumes containing different substances
- Synergistic effects of multiple-component emissions
- Icing caused by water vapour emissions

7.0 Conclusion

- Summary of impact on air quality (ambient concentrations, depositions, visibility, and odour) from assessment
Appendix C  Competencies for Performing Air Quality Modelling

INTRODUCTION

Competencies are any attitude, skill, behavior, motive or other personal characteristic that are essential to perform a job, or more importantly, differentiate superior performers from solid performers.

The following lists the tasks and knowledge required for competent air quality modelling. The introductory sections- Context, Core Knowledge and Abilities, and Quality Assurance- are integral to further understanding the Task and Knowledge and Experience requirements.

CONTEXT

The competencies must be interpreted within the following context:

- Communication with field workers, technicians, laboratories, engineers and scientists during the process is important to the success of the model, as well as
- Record keeping is important to support the accountability of the model.

CORE KNOWLEDGE AND ABILITIES

An air quality modeller must have the following core knowledge and abilities, in addition to specific technical knowledge, that includes:

- Knowledge of chemical and physical meteorology
- Understanding of the chemical and physical interactions of atmospheric pollutants
- Knowledge of primary pollutants, and their interaction with other substances (natural or industrial) to form secondary pollutants
- Knowledge of risks due to uncontrolled releases
- Knowledge of legislation, regulations and guidelines in regards to Ambient Air Quality Objectives (AAAQO) and limits
- Knowledge of information sources relevant to the model
- Ability to read and understand map information
- Ability to prepare reports and documents as necessary. Ability to review reports to ensure accuracy, clarity and completeness
• Communication skills
• Team skills.

QUALITY ASSURANCE

• Use of standard assessment and modelling protocol
• Selection of appropriate practitioners for the task. Referral to specialists when the situation requires specialized training

Tasks
• Obtain, review and interpret data from monitoring sites
• Obtain, review and interpret meteorological data
• Identify potential pollution (emission) sources and rates:
  ▪ Gather information on sources such as mass flow rates (e.g., kg of SO₂/hr), stack top temperature, velocity (i.e., m/s) or volumetric flow rate (e.g., cubic meters/second), and stack height and diameter. Calculate emission rates based on collected information
• Identify land use (urban/rural)
• Identify land cover/terrain characteristics
• Identify the receptor grid/site
• Prepare and execute dispersion model
• Interpret results of model
• Prepare reports and recommend changes based on modelling results
• Determine if further assessment is necessary.

Knowledge and Experience

• Knowledge of chemical and physical meteorology:
  ▪ Familiar with terminology, principles and interactions
  ▪ Understanding of data collection methods and technologies
  ▪ Ability to identify good and bad data points/sets
  ▪ Understanding of how to deal with incomplete/missing meteorological data

• Knowledge of chemical and physical interactions of atmospheric pollutants:
  ▪ Familiarity with fate and transport of pollutants in air
  ▪ Understanding of meteorological impacts on pollutants
  ▪ Knowledge of primary pollutants and the synergistic effects with other substances (natural or industrial) to form secondary pollutants
• Knowledge of surface characteristics:
  - Ability to identify and describe soil, water, drainage and terrain conditions
  - Understanding of their interaction
  - Familiarity with surface roughness

• Knowledge of pollution sources (point, line, area, volume):
  - Familiarity with emission control technologies
  - Knowledge of AAAQO
  - Understanding of baseline concentrations.

• Understanding/ experience with computer modelling programs/ applications and limitations:
  - Selection of model which best meets needs of the task
  - Understanding of model input parameters
  - Understanding of modelling results

• Ability to read and understand map information:
  - Ability to create predicted concentration isopleths with model results
Appendix D  Allowed Non-Default and/or Alternate Model Options for Air Quality Modelling

**These switches represent allowed alternate model options, which may be used as part of any regulatory application. Requirements as specified in the body of the Guideline, e.g., the requirement to model for total conversion of NO\textsubscript{x} to NO\textsubscript{2}, must still be met. Administrative switches, e.g., switches related to the type and style input/output data, grid domain, etc., may be changed as required for a particular regulatory application without additional modelling. When not specified in the following table the default value for a model option must be used.**

Table 5  Allowed Non-Default and/or Alternate Model Options

<table>
<thead>
<tr>
<th>Model</th>
<th>Allowed Non-Default/Alternate Model Options**</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERSCREEN</td>
<td></td>
<td>As required.</td>
</tr>
<tr>
<td>AERMET</td>
<td>Adjusted_U*</td>
<td>Preferred. Note: When using on site meteorology do not use this option.</td>
</tr>
<tr>
<td>AERMET</td>
<td>Flat &amp; Elevated Terrain</td>
<td>As required.</td>
</tr>
<tr>
<td>AERMOD</td>
<td>Conversion of NO\textsubscript{x} to NO\textsubscript{2}</td>
<td>Total conversion of NO\textsubscript{x} to NO\textsubscript{2} always required. Pay special attention to the use of the best available information for in-stack ratios (ISR) when using ARM2, OLM and PVMRM. Use Regulatory provided O\textsubscript{3} concentrations (Appendix E) unless onsite data available.</td>
</tr>
<tr>
<td>AERMOD</td>
<td>Capped and Horizontal Stack Releases</td>
<td>Allowed.</td>
</tr>
<tr>
<td>AERMOD</td>
<td>Adjusted Friction Velocity (u*)</td>
<td>Preferred. This must be used with Adjusted_U* created by AERMET. Note: See AERMET comment. At this time, until the US EPA approves settings (not defaults) for wind speed options (LOW1, LOW2 and LOW3) these are not allowed to be used.</td>
</tr>
<tr>
<td>CALMET</td>
<td>Input Group 2</td>
<td>ZFACE = 0.0, 20.0, 40.0, 80.0, 120.0, 280.0, 520.0, 880.0, 1320.0, 1820.0, 2380.0, 3000.0, 4000.0</td>
</tr>
<tr>
<td>Model</td>
<td>Allowed Non-Default/Alternate Model Options**</td>
<td>Comment</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Input Group 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M C L O U D</td>
<td></td>
<td>Use cloud cover derived from the AEP provided meteorological data (M C L O U D  = 4 is preferred) unless complete set of surface observations are available (M C L O U D  = 1). Provide explanation of choice.</td>
</tr>
<tr>
<td>N O O B S</td>
<td></td>
<td>Use N O O B S  = 0 for onsite meteorology. Use N O O B S  = 1 when blending ground data into AEP provided meteorological data. N O O B S  = 2 when using AEP meteorological data only.</td>
</tr>
<tr>
<td>Input Group 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I W F C O D</td>
<td></td>
<td>Set I W F C O D  = 1.</td>
</tr>
<tr>
<td>I E X T R P</td>
<td></td>
<td>Set I E X T R P  = +/-1 when N O O B S  = 2.</td>
</tr>
<tr>
<td>I T P R O G</td>
<td></td>
<td>Set I T P R O G  = 0 or 1 for N O O B S  = 0 or 1; I T P R O G  = 2 when N O O B S  = 2.</td>
</tr>
<tr>
<td>R 1, R 2</td>
<td></td>
<td>Set to one half the resolution of the AEP meteorological data set. These are only suggested values, variation from these values do not require additional modelling. Provide explanation of choice.</td>
</tr>
<tr>
<td>R M A X 1, R M A X 2, R M A X 3</td>
<td></td>
<td>Set to twice the resolution of AEP provided meteorological data set. These are only suggested values, variation from these values do not require additional modelling. Provide explanation of choice.</td>
</tr>
<tr>
<td>T E R R A D</td>
<td></td>
<td>Set T E R R A D  according to terrain features in modelling domain. Provide explanation.</td>
</tr>
<tr>
<td>Input Group 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M N M D A V</td>
<td></td>
<td>Set M N M D A V  = 10</td>
</tr>
<tr>
<td>I P R O G</td>
<td></td>
<td>Set I P R O G  = 14.</td>
</tr>
<tr>
<td>I T W P R O G</td>
<td></td>
<td>Set as required when considering assessments over water.</td>
</tr>
<tr>
<td>I L U O C 3 D</td>
<td></td>
<td>Set to Land Use category ocean to be consistent with prognostic dataset and I T W P R O G , e.g., For MM5 v3.0 data I L U O C 3 D  = 16.</td>
</tr>
<tr>
<td>T R A D K M</td>
<td></td>
<td>Set T R A D K M  to twice the resolution of AEP provided meteorological data set.</td>
</tr>
<tr>
<td>Model</td>
<td>Allowed Non-Default/Alternate Model Options**</td>
<td>Comment</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>CALPUFF</td>
<td>MBDW</td>
<td>Use the Prime algorithm for downwash (MBDW = 2) unless criteria for selecting ISC downwash (MBDW = 1) are met. See discussion on downwash (Section 5.2).</td>
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<tr>
<td></td>
<td>MCHEM</td>
<td>MCHEM = 6 (RIVAD/ISORROPIA) chemistry is preferred. All other chemical paths are considered alternate models.</td>
</tr>
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<td></td>
<td>MAQCHEM</td>
<td>Set MAQCHEM = 1 given MCHEM = 6.</td>
</tr>
<tr>
<td></td>
<td>MLWC</td>
<td>Set MLWC = 1 given MAQCHEM = 1.</td>
</tr>
<tr>
<td></td>
<td>MHN3, MH2O2</td>
<td>Set MHN3 = 0, MH2O2 = 0. Use on site values if available otherwise use Regulator suggested monthly defaults (Section 7.3.3).</td>
</tr>
<tr>
<td></td>
<td>MDISP</td>
<td>Set MDISP = 2.</td>
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<tr>
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<td>MPDF</td>
<td>Set MPDF to match the selected MDISP setting (MPDF = 1).</td>
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<tr>
<td></td>
<td>MPARTLBA</td>
<td>Allow for partial penetration of plume (MPARTLBA = 1).</td>
</tr>
<tr>
<td></td>
<td>MREG</td>
<td>Waive MREG check (MREG = 0).</td>
</tr>
<tr>
<td></td>
<td>ZFACE</td>
<td>As for CALMET.</td>
</tr>
</tbody>
</table>
Appendix E  AEP Recommended Ozone Levels

Based on ambient air quality monitoring data in Alberta from 2000 to 2010 (Urban: Calgary North, Calgary Central, Calgary East, Edmonton South, Edmonton Central, Edmonton East, Fort Saskatchewan – 92nd Street and 96th Avenue, Lethbridge, Red Deer – Riverside; Rural: Anzac, Beaverlodge, Caroline, Elk Island, Fort Chipewyan, Genesee, Tomahawk, Violet Grove).

### Table 6  AEP Recommended Ozone Levels

**Urban (ppm)**

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<thead>
<tr>
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<td>1</td>
<td>0.013</td>
<td>0.015</td>
<td>0.021</td>
<td>0.026</td>
<td>0.026</td>
<td>0.022</td>
<td>0.018</td>
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<td>0.021</td>
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<td>0.021</td>
<td>0.018</td>
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<td>0.017</td>
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<td>0.017</td>
<td>0.018</td>
<td>0.016</td>
<td>0.013</td>
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