وزارة البيئة | MINISTRY OF ENVIRONMENT

تعليمات
استخدام النماذج الرياضية لتشتت ملوثات الهــواء

اعداد
قطاع نوعية البيئة
جهاز شئون البيئة

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مقدمة

يعد التلوث البيئي من أهم الموضوعات التي أخذت حيزاً متزايداً من الأهتمام نظراً لما له من تأثيرات مباشرة على صحة الانسان والبيئة، وتنقسم مصادر التلوث الى قسمين الاول المصادر الطبيعية مثل الغازات والأتربة الناتجة من ثورات البراكين ومن حرائق الغابات والاتربة الناتجة من العواصف وهذه المصادر عادة ماتكون محدودة في مناطق معينة تحكمها العوامل الجغرافية والجيولوجيا، ويعد التلوث من هذه المصادر متقطعاً او موسمياً.

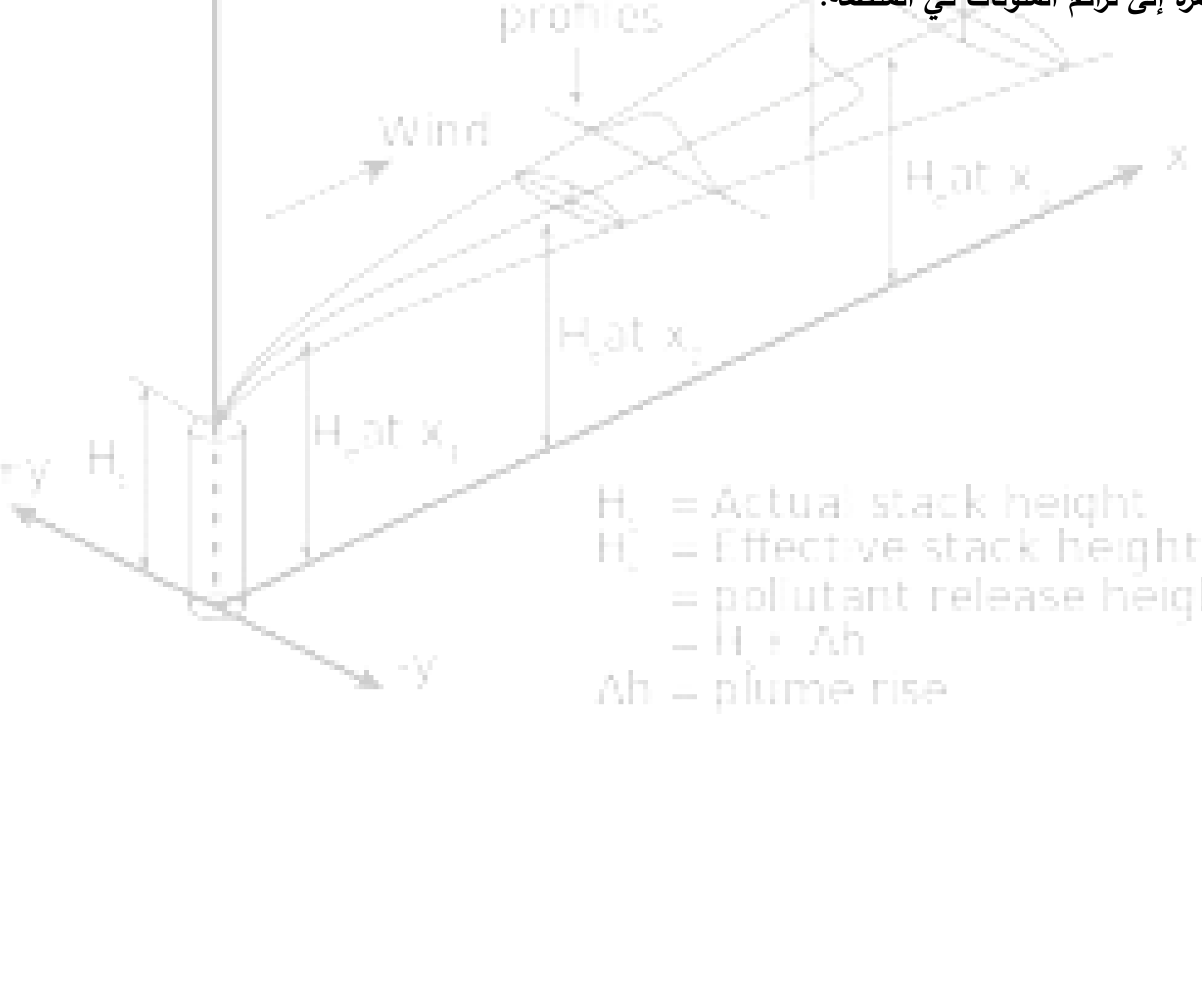
اما المصدر الثاني فهو نتيجة أنشطة الأنسان على سطح الأرض فاستخدام الوقود في الصناعة ووسائل النقل وتوليد الكهرباء يؤدي الى انبعاث غازات مختلفة وجسيمات دقيقة الى الهواء وهذا النوع من التلوث مستمر باستمرار أنشطة الأنسان ومنتشر بأنتشارها على سطح الارض في التجمعات السكانية, وهذا التلوث هو الذي يثير الأهتمام والقلق، والحقيقة أنه يمكن النظر الى قدرة الغلاف الجوي في اي مكان على استيعاب التلوث البيئي باعتباره نظام مفتوح يسمح للتلوث بالدخول اليه لكنه يقوم بنشره في جميع الأتجاهات ثم يتخلص منه بعد ذلك وإذا حدث اي عائق يحد من قدرة الغلاف الجوي على نشر التلوث هذا يجعله يتركز في البيئة المحلية الضيقة بمصادر التلوث مباشرة ويلحق اضراراً كبيرة بالأرواح والممتلكات.

نظام نموذج محاكاة جودة الهواء لتقدير تركيزات ملوثات الهواء AQMS (Air Quality Simulation Model System) هو تقنية أو منهجية رقمية لتقدير تركيزات ملوثات الهواء في المكان والزمان، إنها دالة لتوزيع الانبعاثات وظروف الأرصاد الجوية والجيوفيزيائية الحالية. الاسم البديل هو نموذج التشتت ، تسُتخدم تركيزات تلوث الهواء في الغالب كمؤشر لتعرضالإنسان للمخاطر، وهو مكون رئيسي لتقييم مخاطر ملوثات الهواءعلى صحة الإنسان، ويعالج مشكلة كيفية تخصيص الموارد المتاحة لإنتاج خطة تحكم فعالة من حيث التكلفة، وفي هذا السياق يمكن لـ AQSM الرد على العديد من التساؤلات .... كالمساهمات النسبية لتركيزات ملوثات الهواء سواء من مصادرمتحركة اوثابتة، وكذا تخفيضات الانبعاثات اللازمة للتركيزات الخارجية للوفاء بمعايير جودة الهواء، وايضاً أين يجب تحديد موقع المصدر المخطط للانبعاثات، والحالة المستقبلية لجودة الهواء في ظل سيناريوهات معينة لخفض الانبعاثات ... الخ .

ويجدر الاشارة الى أن وزارة البيئة المصرية عزمت اصدار تعليمات استخدام النماذج الرياضية لتشتت الملوثات للمساعدة في التأكد من أن دراسات نمذجة التشتت التي تم تطويرها للوزارة مناسبة لاحتياجات التطبيق، ويتم تطبيقها بشكل صحيح ومتسق وكذا استخدامها لتوجيه قرارات إدارة جودة الهواء بشكل موثوق .

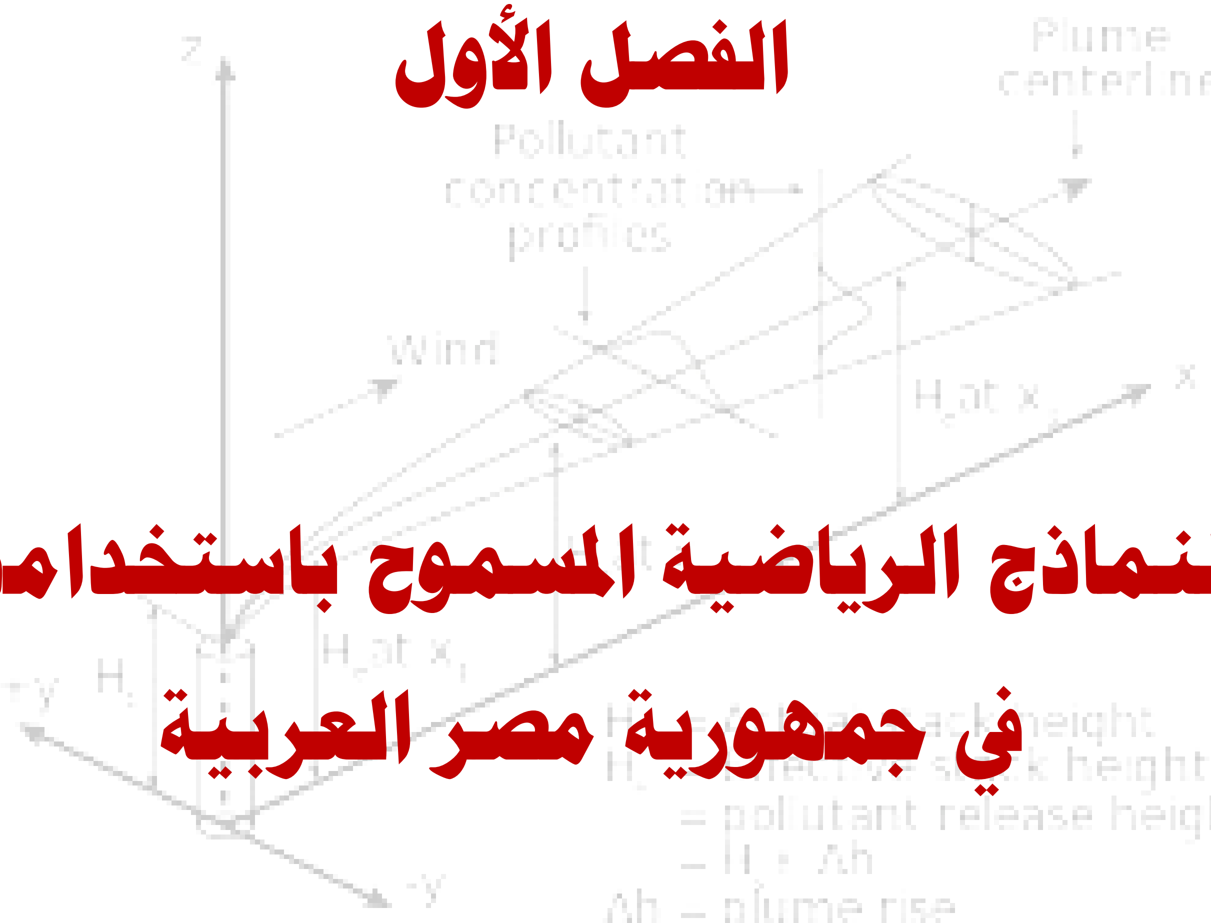
تعد دراسات نمذجة ملوثات الهواء مهمة وضرورية للعديد من الأسباب، وأولها في تقييم التأثير البيئي حيث تساعد دراسات نمذجة ملوثات الهواء على تقييم التأثير البيئي لمصادر التلوث المختلفة، وتحديد مدى تأثيرها على البيئة والصحة العامة وكذا في تخطيط السياسات والتشريعات حيث تساعد دراسات نمذجة ملوثات الهواء على تطوير السياسات والتشريعات المتعلقة بالحد من التلوث، وتحديد الأولويات في هذا المجال، كما أنها تساعد على تحديد المصادر الرئيسية للتلوث وتحسين جودة الهواء في المناطق المتأثرة، والتالي تحديد المخاطر الصحية المرتبطة بالتلوث وتطوير استراتيجيات للحد من هذه المخاطر وتحسين صحة الإنسان، كما أنها تساعد على تحسين الإدارة البيئية وتطوير أساليب جديدة للتحكم في التلوث والحد منه.

ويوجد العديد من العوامل التي تؤثر على انتشار الملوثات في الهواء كالعوامل المناخية مثل سرعة الرياح والرطوبة ودرجة الحرارة، حيث تشتت الرياح الملوثات وتخفف من تركيزها، بينما تحول دون تحرك الرياح في المناطق الجبلية إلى تراكم الملوثات في منطقة محددة، كذلك الأمطار تلعب دورًا في تصفية الجو من الملوثات من خلال التقاط الدقائق المعلقة في الهواء وتسقط بعدها على الأرض، فضلا عن ذوبان الأكاسيد، أيضاً التضاريس والجيولوجيا، حيث تؤثر تضاريس المنطقة على تحرك الملوثات في الهواء، وتؤدي الأراضي الصخرية إلى تراكم الملوثات في المنطقة.، كما يوجد عنصر هام جداً وهو النشاط البشري، حيث تنتج الملوثات من الصناعات والمركبات والمنازل والمزارع والمصانع والمحطات الكهربائية والمدافئ والمكيفات والسفن والطائرات والمعامل والمستشفيات والمدارس والمطاعم والمقاهي والمحلات التجارية، كذلك درجات الحرارة العالية والموجات الحارة تلعب دوراً هاماً، حيث تزيد درجات الحرارة العالية من تركيز الملوثات في الهواء، وتزيد الموجات الحارة من خطر الإصابة بأمراض الجهاز التنفسي والحرارة المرتفعة، وكذلك الرطوبة والتي تزيد من تركيز الملوثات في الهواء، وتزيد من خطر الإصابة بأمراض الجهاز التنفسي والحرارة المرتفعة، كذلك الرياح حيث تنقل الملوثات في الهواء من مصدرها إلى مناطق أخرى، وتؤدي الرياح الشديدة إلى تشتت الملوثات في الهواء، الضغط الجوي حيث يؤثر على تحرك الملوثات في الهواء، وتؤدي الأحوال الجوية الغير مستقرة إلى تراكم الملوثات في المنطقة.



الفصل الأول

النماذج الرياضية المسموح باستخدامها في جمهورية مصر العربية



تعد نماذج الانتشار مهمة للجهات الحكومية المكلفة بحماية وإدارة جودة الهواء المحيط، تُستخدم النماذج عادةً لتحديد ما إذا كانت المنشآت الصناعية الجديدة القائمة أو المقترحة متوافقة مع المعايير الوطنية لجودة الهواء المحيط أو ستلتزم بها، تعمل النماذج أيضًا على المساعدة في تصميم استراتيجيات تحكم فعالة لتقليل انبعاث ملوثات الهواء الضارة.

تُستخدم نماذج انتشار الهواء أيضًا من قِبل جهات السلامة العامة المستجيبة وموظفي إدارة الطوارئ للتخطيط لحالات الطوارئ المتعلقة بالانبعاث الكيميائي العرضي. تُستخدم النماذج لتحديد عواقب الانبعاث العرضي للمواد الخطرة أو السامة، ويمكن أن يؤدي الانبعاث العرضي إلى نشوب حرائق أو تسربات أو انفجارات تحمل بعض المواد الخطرة، مثل المواد الكيميائية أو النويدات المشعة. يمكن أن توفر نتائج نموذج الانتشار، التي تستخدم أسوأ حالات عبارات مصدر الانبعاث العرضي الرياضية وظروف الأرصاد الجوية، تقديرًا للمناطق المتأثرة بموقع الانتشار والتركيزات المحيطة، ويمكن استخدامها لتحديد الإجراءات الوقائية المناسبة في حالة حدوث أي انبعاث. يمكن أن تشمل الإجراءات الوقائية المناسبة الإخلاء أو الاحتماء في نفس المكان للأشخاص الذين يعيشون في اتجاه هبوب الرياح التي تحمل الانبعاث .

يعتد بنماذج النقل الكيميائي كنماذج رقمية حاسوبية تحاكي كيمياء الغلاف الجوي وتستخدم في التنبؤ بتلوث الهواء ، وتستخدم المعادلات الرياضية لوصف عمليات الغلاف الجوي التي تعمل على تشتيت الملوثات المنبعثة من المصادر المختلفة وتقديرها عند مستقبلات محددة بناء على معلومات العوامل الجوية وأحمال التلوث الصادرة عن المصدر وطبوغرافية الأرض لمنطقة المصدر والمستقبلات .

تاريخياً ، استند تقييم جودة الهواء إلى بيانات الرصد، حيث يعتبر هذا أقرب ما يكون إلى الواقع قدر الإمكان فضلاً عن كونه المعلمة التي تمت دراسة الآثار الصحية والنظام الإيكولوجيعليها، على الرغم من أن النمذجة غالباً مايُنظر إليها على أنها غير مؤكدة أكثر من المراقبة، إلا أن هناك أسباب رئيسية لاستخدام النماذج جنباً إلى جنب مع مراقبة تقييمات جودة الهواء، عادة ما تكون التغطية المكانية للرصد محدودة فيمكن أن توفر النمذجة تغطية مكانية كاملة لجودة الهواء، كذلك يمكن تطبيق النمذجة بشكل تنبؤي، أي يمكن استخدامها للتنبؤ بنوعية الهواء نتيجة للتغيرات في الانبعاثات أو تغير ظروف الأرصاد الجوية .

يوجد بعض المتطلبات الأساسية لاستخدام النماذج، وذلك وفقاً للإرشادات الفنية الواردة في هذه الوثيقة، وينبغي تطبيق المعايير العامة الملائمة حيث لابد ان يكون النموذج لديه الدقة المكانية والزمانية المناسبة للتطبيق المقصود، وأن يحتوي النموذج على العمليات الفيزيائية والكيميائية المناسبة لنوع التطبيق والمقياس والملوثات التي يتم تطبيقه عليها، وأن يتم تمثيل مصادر الانبعاث ذات الصلة بالتطبيق بشكل كاف، وأن تتوافر بيانات الأرصاد الجوية المناسبة.

في هذا الفصل سيتم استعراض النماذج الرياضية لتشتت الهواء والمسموح باستخدامها في مصر وذلك بشرح نبذة عن كل نموذج وكيفية الاستخدام والمدخلات وكيفية عملها وكذا المخرجات المتوقعة، ويتم استخدامها بحسب ظروف كل دراسة، كما سيتم الاشارة الى بعض الفروق بين بعض النماذج المستخدمة .

جدول النماذج الارشادية

النموذج الإرشادي الموصي به
نموذج أولي:AERSCREEN
النماذج المتقدمة: AERMOD CALPUFF (وضع No–Obs) CALPUFF (وضع Obs–Only)
النماذج المتخصصة: AERMOD CALPUFF (الوضع المختلط) * CALPUFF (وضع No–Obs) *

الشروط التي سيتم بموجبها النظر في نموذج بديل كالتالي :

- **النماذج المعتمدة ليست مناسبة بسبب قصور في بعض الجوانب الفنية للتطبيق .**
- **يعمل النموذج البديل بشكل أفضل من النموذج المعتمد استناداً إلى الأدلة التي تمت مراجعتها من قِبل المتخصصين (كوجود دراسات سابقة مرفق بها المراجع) حيث تم تطبيق النموذج البديل المقترح في موقف مماثل باستخدام مقاييس الأداء ذات الصلة بهذا التطبيق (مقارنات الحد الأقصى للتركيزات في الساعة، ومقارنات عتبة التجاوز، ومقارنات الأنماط المكانية، وما إلى ذلك) .**
- **النموذج البديل مفتوح المصدر أو متاح للجميع بدون قيود .**

مع الأخذ في الاعتبار عند القيام بأية تعديلات أن يتم اتباع الأتي :

- **إذا تم التخطيط لإجراء تعديلات على أي من النماذج المعتمدة، فقم بوصف خطوات إجراء التعديلات.**
- **إذا تم تعديل نموذج ، فقم بتضمين المعلومات التالية في خطة نمذجة التشتت :**

١. الاسباب المنطقية التي أدت لعمل هذا التعديل .

٢. خطوات اختبار التعديل وتقديم نتائج الاختبار .

1.1. DISPERSION MODEL TYPES

The Screening and Refined categories of model complexity include two types of dispersion models – both are based on the assumption that the horizontal and vertical distribution of the contaminant has a Gaussian distribution.

Straight Line Gaussian Plume models calculate contaminant concentrations for each hour assuming meteorological conditions are uniform over the horizontal and vertical space that is included in modelling domain. The vertical and horizontal distribution of the pollutants is assumed to be Gaussian ("bell shaped"). Because of the steady-state, straight-line nature of these models, they do not explicitly account for curved plume trajectories and variable wind conditions that occur in complex flow situations. In addition, these models cannot handle low wind speeds - a frequent occurrence in the bowls and deep valleys of especially during the winter. These types of models can be in

the Screening or Refined category of model complexity.

Curved Trajectory Gaussian Puff models treat the emissions as a series of puffs in time and space varying meteorological conditions. Although these models require more computing resources as they track puffs that represent discrete amounts of contaminants over time, they have the advantage of allowing meteorological conditions to vary in space (horizontally and vertically). In addition, they can address the accumulation of contaminants during calm conditions, the curved paths of plumes, and the effects of causality (where the previous position and conditions of the plume is accounted for in determining the current plume position). This type of model is in the Refined category of model complexity.

1.2. MODEL APPLICATION: LEVELS OF ASSESSMENT

There are a number of dispersion models available and it is important to choose and apply the model best suited to the situation. There are three general levels of assessment:

- Level 1 (Screening) Assessment
- Level 2 (Detailed) Assessment
- Level 3 (Comprehensive) Assessment

1.2.1. LEVEL 1(SCREENING) ASSESSMENT

A Level 1 Assessment is appropriate when decisions can be made based only on an estimate of the possible worst case air quality, independent of where or when they occur. Screening Assessments are appropriate for situations such as:

- "Go, no-go" evaluations (a critical acceptance/rejection criteria is exceeded or not exceeded: typically for low-risk sources).
- Permit/approval decisions for low-risk sources.
- Preliminary identification of air quality issues associated with proposed new sources or modifications to existing sources.

  Planning purposes (internal resources required to conduct assessment, need to consider other studies to support the decision-making process, need to contact other agencies).

- Identification of the need for more detailed modelling using Level 2 or 3 Assessment approaches (if exceedances of short-term objectives are predicted).
- Confirmation of refined model results that appear unusually high or low.

1.2.2. LEVEL 2(DETAILED)ASSESSMENT

A Level 2 Assessment provides a more realistic and detailed determination of air quality dispersion than what is provided in a Level 1 Assessment. This level requires a Refined model that uses a time series of hourly meteorological data (over a period of at least one year) and the geophysical conditions representative of the site.A Level 2 Assessment is appropriate when:

- A Screening (Level 1) Assessment indicates the potential for an exceedance of ambient objectives.
- There is a need to produce a maximum concentration for different time averages and distributions of the concentrations and/or depositions in time and space that reflect the actual meteorological conditions.
- The contaminant can be reasonably modelled by a straight-line, steady-state, Gaussian plume model with no chemical transformation. Although more complicated processes may be occurring (i.e., curved plume trajectory), a more complicated model that explicitly treats these processes is not necessary depending on the purposes of the modelling and the zone of interest. For example, if the area of interest is within 100 m, then curvilinear trajectories and chemical transformations are likely not critical.
- The emissions are from small sources (e.g., a small compressor station stacks) where the greatest concentrations are in the order of 100 m downwind.
- The source is considered to be low risk.
- The purpose is for a standard/generic permit or amendment process (such as an emissions reduction).
- To define conditions under which well test flaring can occur.
- Supporting other air management related investigations such as:
  - identify potential contributing sources; o identify worst-case meteorological conditions; o identify areas of air quality concern; o analyze historical air quality trends; and
  - Design monitoring networks (locations, contaminants, sampling period, frequency).

1.2.3. LEVEL 3 (COMPERHENSIVE) ASSESMENT

Level 3 Assessments require Refined models and corresponding input data, resources and model operator expertise to properly account for these factors. These models require detailed meteorological, geophysical and source input that may include:

One or more years of representative meteorological data (e.g., wind speed, wind direction, temperature, turbulence, and mixing height) at a number of sites in the domain of interest.

- Detailed emission inventories for point, line, area and volume sources in an air shed that could vary in time and where there is a mix of urban, industrial and natural sources.
- The speciation, emissions and time variation of different contaminants.

In general, a Level 3 Assessment is recommended in situations where:

- A Level 1 or 2 Assessment indicates predicted exceedances of ambient objectives.
- The purpose of the assessment requires detailed time and space variation of the concentrations.
- It is important to account for multiple source types, chemical transformations and effects associated with complex topography such as causality, calms, curvilinear plume trajectories, spatial variations in turbulent mixing.

- A source is considered to be high risk.

More specifically, Level 3 Assessments are recommended in situations where there is a need to:

- Evaluate air quality consequences under a permitting or Environmental Assessment process for large industrial developments that have considerable social, economic and environmental consequences.
- Assess contaminants resulting from non-linear processes (e.g., deposition, ground-level ozone, particulate formation, visibility).
- Evaluate consequences of air quality management approaches that involve multi-source, multi-sector contributions from permitted and non-permitted sources in an airshed.
- Provide information to support environmental, human and economic effects studies.
- Examine specific receptors that may be sensitive or of special interest such as individual residences, sensitive ecosystem areas.
- Assess contaminants in meteorologically complex situations ("complex flow" such as mountain valley flows, reversals, sea breeze, and fumigation).
- Assist in understanding of the underlying source and meteorological causes of episodes.

1.3. STEPS TO GOOD MODELLING PRACTICE

The following are recommended steps to follow for every modelling application. The steps help determine the modelling approach, the assessment level and help ensure the model output addresses the needs of the regulatory agencies.

1	**Set the contents**	**Define objectives and scope of the study**
2	Characterize Source	Gather information on sources, emissions and contaminants.
3	Characterize Physical and Meteorological Setting	Define the modelling domain and review geophysical characteristics and atmospheric behavior of the area.
4	Determine Assessment Level	Determine Assessment Level required to meet objective.
5	Select a Model	Select a dispersion Model by reviewing the technical capabilities of each Model and its recommended use.
6	Determine Model Inputs	Determine the Meteorological and geophysical data needs based on Assessment Level and Model Selected.
7	Determine baseline air quality	Consider the baseline Concentration of air contaminants if the intent is to assess the cumulative effects
8	Submit a dispersion Modelling Plan	A Dispersion Modelling Plan is required. The Plan is a tool to facilities communications between different Parties in order to avoid misunderstandings and delays
9	Prepare Input files, Execute Model	Format meteorological and geophysical data input files and Execute the Model
10	Quality Assurance and Quality Control(QA/QC)	Exercise a QA/QC procedure to confirm the accuracy of the inputs, meteorological data and behavior of the Model
11	Modelling Outputs and Documentations	In order for the Ministry to conduct a thorough review of the air quality assessment, input and output files and corresponding documentation may be required

2. APPROVED MODELS AND THEIR APPLICATION

Table 2 provides dispersion models recommended for use in and the appropriate assessment level. A brief description of each model and the specific situations under which they can be applied are provided in the following sections.

Table 22 Assessment Level and Corresponding Guideline Dispersion Model

Air Quality Assessment	Recommended Guideline Model
Level 1: Screening	Screening Models:AERSCREEN
Level 2: Detailed	Refined Models: AERMOD CALPUFF (No-Obs mode) CALPUFF (Obs-Only mode)
Level 3: Comprehensive	Refined Models: AERMOD CALPUFF (Hybrid mode) CALPUFF (No-Obs mode)*

*depends on several considerations (see Section 6.4.1).

2.1. LEVEL 1 (SCREENING) MODELS

2.1.1. AERSCREEN

AERSCREEN produces the worst-case 3-h, 8-h, 24-h and annual average concentrations from a *single* source. Note that if there are buildings and/or there is terrain to be included, then model initiation and execution can require the use of additional pre-processors BPPIPPRM (prepares building parameters) and AERMAP (prepares terrain data).

The use of AERSURACE and AERMAP for applications requires additional processing steps as the data formats for land use and terrain may need further manipulation before applying the preprocessors.

Recommended use:

- maximum 1-h, 3-h, 8-h, 24-h and annual average concentrations
- single point, capped stack, horizontal stack, flare, area (circular or rectangular), volume sources
- building wake effects on point, capped stack, horizontal stack, and flare sources
- flat and elevated terrain
- urban and rural areas
- transport distances of less than 50 km (depends on terrain)

Approved Version: The latest version available via the U.S. EPA Screening Models[2] should be applied.

Although the model can only handle a single source, multiple point sources can be accounted for by following the recommendations in Section 3.2: *Multiple Sources, Grouping (AERSCREEN)*.

AERSCREEN is the preferred screening level model for use in and Egypt.

2.2. LEVEL 2 AND 3(REFINED) MODELS

2.2.1. AERMOD

AERMOD is a regulatory straight-line, steady-state plume modeling system that consists of three components: AERMOD (calculates the concentrations), AERMET (prepares the meteorological input) and AERMAP (prepares the terrain input).

The meteorological preprocessor AERMET is required to process available meteorological data into a format suitable for use by AERMOD. AERMET is designed to operate on certain types of data: U.S. National Weather Service, Federal Aviation Administration or other hourly surface observations, upper air soundings, and data collected from on-site measurement program such as from an instrumented tower.

When applying AERMET, the appropriate surface characteristics (surface roughness length, albedo and Bowen ratio) must be specified. This can be done manually or through use of the preprocessor AERSURFACE which reads U.S. Geological Survey (USGS) Land Cover datasets and uses look up tables for surface characteristics that vary by land cover type and season to produce AERMET-ready surface data. Since AERMOD results are sensitive to these surface characteristics, AERSURFACE provides a level of consistency and objectivity to this step in the data preparation.

The preprocessor AERMAP processes terrain data to produce terrain base elevations for receptors and sources and other AERMOD required information (i.e., hill height scale for each receptor). If there are buildings that could cause downwash, then AERMOD requires building related information produced by the processor BPIPPRM.

The application of AERMOD for locations in requires additional processing steps to those noted above. The data formats for terrain, land cover, and meteorological data are different than the U.S. formats, so they may need further manipulation before applying the preprocessors. These input data issues will be discussed in Section 4.3: *Processing Land Use Data for AERSCREEN and AERMOD (AERMET) Surface Parameters* and Section 5.8: *Meteorological Data for AERMET (AERMOD's Pre-Processor)*.

Recommended use:

- sources in an industrial complex (single or multiple point, area, line, volume sources)
- situations where a straight-line, steady state model applies (non-complex flow)

via the U.S. EPA Preferred/RecommendedModels[3] website should be applied.

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[2] http://www.epa.gov/scram/air-quality-dispersion-modeling-screening-models

2.2.2. CALPUFF

CALPUFF is a curved trajectory, Gaussian puff model that can account for time- and space-varying meteorological conditions, different source configurations and contaminants, and chemical transformations. The CALPUFF modelling system is comprised of three components: CALMET (meteorological model), CALPUFF (calculates concentration and deposition output), and CALPOST (analysis and display of output). The meteorological fields used by CALPUFF are produced by CALMET — a meteorological model that includes a diagnostic wind field model. CALMET inputs include surface and upper-air meteorological data as well as the option to use the output produced by gridded numerical weather prediction models. CALMET can blend those input and apply treatments of slope flows, valley flows, terrain blocking effects, kinematic terrain effects (i.e., speed up over hills), lake and sea breeze circulations, and a procedure to ensure mass is conserved in the domain.

CALPUFF generates a variety of outputs that include concentrations, wet and dry depositions, and visibility parameters (extinction coefficients). It describes a continuous plume as a series of puffs, which in turn allows a better description of how a plume can curve, deform (e.g., passing through a narrowing in the valley), and even split apart in complex wind areas. Furthermore, unlike other straight-line Gaussian plume models, it can be applied under calm conditions.

Recommended use:

- complex flow: non-steady-state meteorological conditions (calms, time and space variability in wind and turbulence fields) such as found in complex terrain and coastal situations
- local scale (<10 km), regional scale (10-50 km) to long-range transport and dispersion (>50 to 200 km)
- multiple sources, source types (point, area, volume) and building(s) gaseous and particulate deposition
- wet and dry Sulphur and Nitrogen deposition
- $PM_{2.5}$ secondary formation
- visibility assessments for regional (>10 km) and long-range transport distances (> 50 km to 200 km)
- constant or time varying source conditions of gaseous and particulate contaminants
- fogging, icing and odor effects

Approved Version: The Ministry strongly recommends the use of the latest version of the CALPUFF system (i.e., CALMET, CALPUFF, CALPOST and associated utilities) that is publically available via Exponent®[4]. However, CALPUFF system version 6 is still acceptable until further notice. Be aware that the EPA approved CALPOST version V6.221 must be used if CALPUFF system version 6 is used.
Earlier versions of CALPUFF or any of its associated components can be used provided that the modifications in the later versions are not relevant to the application.
CALPUFF can be run in different "modes", which reflect the source of input meteorology used for CALMET processing. The mode selected depends on several factors which include the Assessment Level, the availability of meteorological input, whether the flow is complex, and whether output from a Numerical Weather Prediction

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[3] http://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models

Numerical Weather Prediction(NWP) model output is available. See Section 6.4.1: *CALMET Modelling Modes* for more information on selecting a CALPUFF mode.

Depending on the mode, CALPUFF can require professional judgment on selecting options and adjustable parameters, as well as establishing the right combination of these parameters requires expert understanding of large-scale and small-scale meteorological effects, especially when applied in complex flow situations.

As such, CALPUFF is technically superior for these situations and it is the only scientifically-based regulatory tool for complex flow.

2.3. CHOOSING A REFINED MODEL

Determining whether to use AERMOD or CALPUFF depends on the following considerations based on the CALPUFF FAQ's[5]:

- The degree in which the flow is "complex" (wind and turbulence patterns change over short distance, prolonged stagnations).
- The area of interest (i.e., transport distance) — shorter transport distances can be less influenced by complex flow and can be approximated by a straight line trajectory.
- The objectives of the application — even in a very complex flow situation, if only maximum concentrations are desired, then a straight line model may be appropriate, however if the concentrations at receptors around the bend of a valley is required for example, then CALPUFF is the better choice if representative meteorological data are available.

In , complex flow is inherent for most applications, and information needs for Level 2 and 3 Assessments require a model that provides spatial variations of the concentration/depositions fields (not just maximum concentrations).

2.3.1. ALTERNATE MODELS

Although the models recommended here can handle the vast majority of applications, there may be circumstances where an alternate model would be better suited. The conditions under which an alternate model would be considered are:

- The recommended models are not appropriate due to technical limitations for the application.
- The alternate model performs better than the Guideline model based on peer reviewed evidence where the proposed alternate model has been applied in a similar situation using performance indicators relevant for this application (maximum hourly concentrations comparisons, exceedance threshold comparisons, spatial pattern comparisons, etc.).
- The alternate model is publically available.

2.3.2. MODIFICATIONS TO MODELS

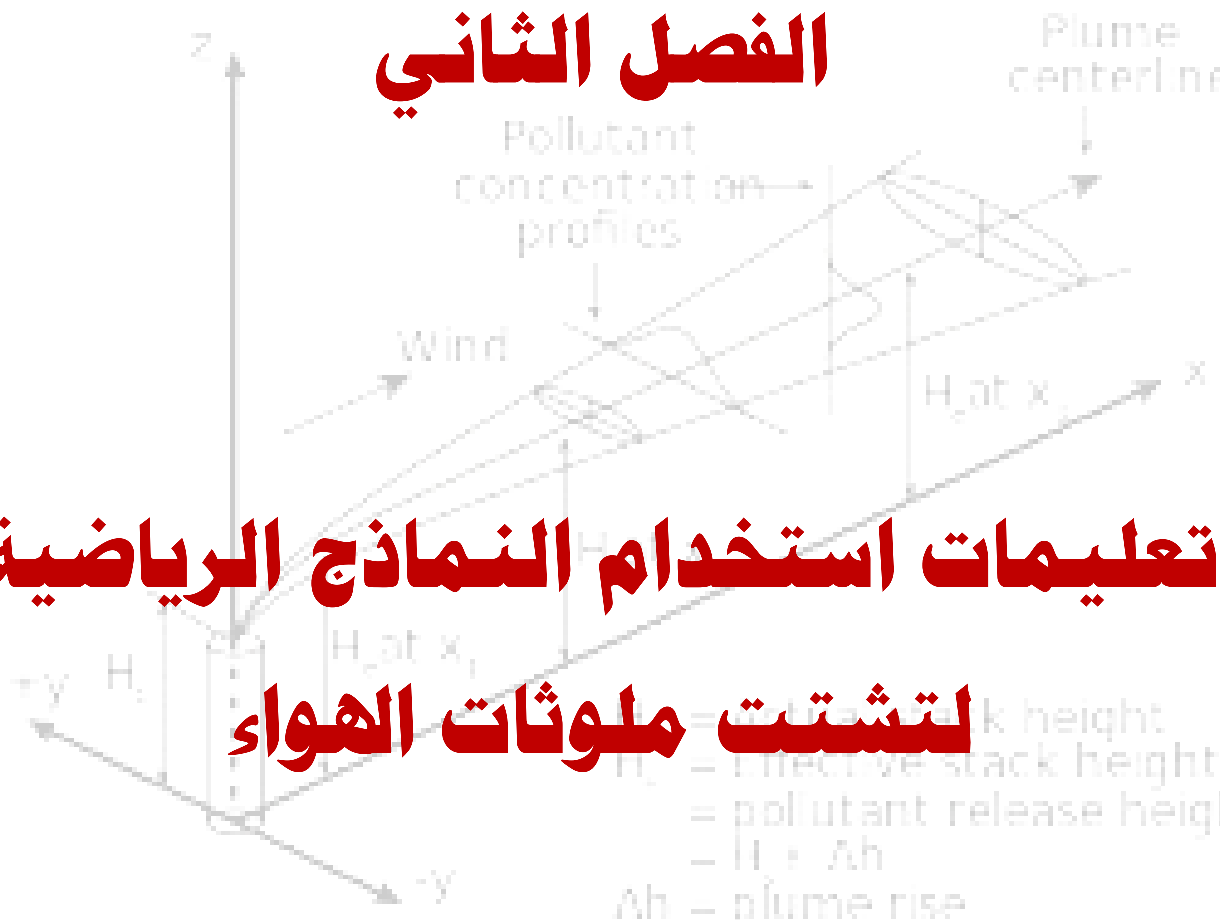
Modifications to the model program can result in unexpected results due to the complexity of the inter-related model components. If a model is modified, include the following information in the Dispersion Modelling Plan:

- The justification for such a modification.
- The modification is documented and testing results provided.
- For CALPUFF, proof that modified versions (with documentation) have been submitted to the program developer as per the CALPUFF End-User License Agreement[6]

[4] http://www.src.com/
[5] http://www.src.com/calpuff/FAQ-answers.htm
[6] http://src.com/calpuff/calpuff_eula.htm

الفصل الثاني

تعليمات استخدام النماذج الرياضية لتشتت ملوثات الهواء



جودة نتائج نمذجة تشتت الملوثات تتحدد أولًا بدقة حساب أحمال التلوث للمصادر، يمكن استخدام واحدة على الأقل من الطرق العديدة لحساب الأحمال، ويجب أن تكون طريقة ذات أسس علمية مجربة ومتعارف عليها وتم التحقق من جودتها ونشرت بدورية محكمة ذات تأثير في المجال .

التعليمات تشمل على الأتي :

١- استخدام أحد النماذج المصرح بها والمذكورة في الفصل الأول .
٢- مدخلات النموذج الرياضي من العوامل الجوية يجب أن تغطي ٥ سنوات سابقة عن تاريخ إجراء الدراسة .
٣- يجب أن تكون القياسات الحقلية مدققة وذات جودة عالية .

كما تعتبر القياسات الحقلية لمصادر الانبعاثات الأدق ضمن كل الطرق سواء كانت تلك القياسات ضمن برنامج للرصد الذاتي المستمر للمنشآت أو قياسات حقلية تمت بغرض الحسابات على أن تراعي كافة المتطلبات للتأكد من دقة وجودة القياسات، كما يجب أن تكون نتائج القياسات التي سيتم حساب الأحمال البيئية لها باستخدامها قياسات الظروف المرجعية وذلك بتطبيق المعادلات اللازمة لذلك .

وتكون المعادلة العامة لحساب الحمل البيئي لمصادر التلوث كما يلي:

الحمل البيئي لملوث (كمية/ زمن) = تركيز الملوث (كمية / حجم) × معدل السريان (حجم / زمن)

Load Q = Conc. C × Flow Rate FR

ويراعى أن يكون زمن المتوسط الحسابي للتركيزات معلوم نظراً لاعتماد الحمل البيئي على الزمن، وتكون المعادلة العامة لحساب المتوسط الحسابي للتركيز اعتمادا على الزمن كما يلي:

التركيز المحسوب في زمن٢ = التركيز المقاس في زمن ١ × (زمن ١/ زمن ٢)

$$C2=C1*(t1/t2)$$

يمكن الاستعانة بالمعادلات المحقق ومؤكد جودتها ومنشورة ضمن مصادر أو دوريات ذات تأثير، وتكون الصورة العامة لمعامل الانبعاث كما يلي:

معدل الانبعاث = معامل الانبعاث × النشاط

حيث نحصل على قيم معاملات الانبعاثات من التجارب الموثقة سابقًا كما تم الإشارة، ويرتبط النشاط وطبيعته بمعامل الانبعاث المحسوب.

ويلاحظ أنه تستخدم هذه الصيغة في حالة عدم وجود أي وسائل للتحكم في الانبعاثات، وفي حالة استخدام وسائل للتحكم يضرب ناتج المعادلة السابقة في مجمل نسبة الاختزال الناتجة عن عمليات التحكم. ويحسب معامل الاختزال كما يلي:

معامل الاختزال = ١- كفاءة الاختزال %

يتم عمليات حساب التركيز للملوثات الصادرة والمنبعثة من مداخن المنشآت المختلفة والتي يجب أن يطبقها العامل في هذا المجال بشكل جيد حتى يمكن الحصول على نتائج صحيحة ودقيقة.

وفي حالة استخدام أحد الأجهزة المعتمدة للقياس من المداخن، يجب أن تحدد وحدة التركيز المستخدمة بشكل واضح لاختلاف المعادلات المستخدمة لحساب التركيز الحقيقي في حالة كون التركيز المرصود والمسجل من الجهاز المعتمد للقياس كان بوحدة (ppm) أو (mg/m٣) أو بوحدة (mg/Nm3) وذلك علي النحو التالي:

- أن تكون الطريقة المستخدمة في أعمال القياس من المداخن معتمدة لهذا الغرض. – تحديد نوعية القياس أو الرصد يجب أن يكون بشكل واضح بمعنى هل تمت عملية الرصد بإستخدام أحد الطرق القياسية (isokinetic sampling) العالمية والمعتمدة أم بإستخدام أحد الأجهزة الأخرى

- يجب في حالة إستخدام أحد الطرق القياسية isokinetic sampling المعتمدة وتنفيذ ما ورد بها من اشتراطات وقواعد على مستوى تجميع العينة وتحليلها معمليا فليس هناك حاجة لتطبيق القواعد الواردة في هذا الدليل نظرا لاحتواء تلك الطرق على هذه القواعد.

- في حالة استخدام أجهزة تعطي التركيز بوحدة (ppm) يتم التحويل الي وحدة (mg/Nm) باستخدام الوزن الجزيئي والحجم المعياري ولا توجد حاجه لتصحيح درجة الحرارة أو الضغط.

- في حالة استخدام أجهزة تعطي التركيز بوحدة (mg/m3) لا توجد حاجه للتحويل.

- في حالة استخدام أجهزة تعطي التركيز بوحدة (mg/m3) في ظروف القياس الفعلية (Stack) (conditions يتم التحويل الي الظروف العيارية (mg/Nm3) باستخدام معادلات تصحيح – درجة الحرارة والضغط الفعلية الي الظروف العيارية 273 k, 1 atm

- في كل الأحوال وبعد اجراء التحويل لوحدة التركيز الي ما هو وارد في اللائحة التنفيذية للقانون مليجرام /متر مكعب عياري) ، فانه يجب التصحيح للظروف المرجعية للأكسجين ونسبة الرطوبة.

ويجب أن يشمل التحويل كافة العوامل المرتبطة بالعينة (تركيز، سرعة العادم، ...).

3. DISPERSION MODEL INPUT – SOURCE PARAMETERS

The following provides guidance on determining source types and emission parameters as well as approaches to treat time-varying emissions for dispersion modeling applications. Any uncertainties and errors in these inputs will be reflected in the model results, so this step is critical to the quality of the dispersion modeling effort.

3.1. SOURCE TYPES: POINT, AREA, VOLUME, AND LINE

Emission sources can be categorized into four types based on geometry: point, area, volume, and line sources. All of the dispersion models listed in Section 2 can be used for point, area, and volume source types; however, with AERSCREEN, there are limitations for multiple source situations.

A *point source* is a stationary, specific point of origin where contaminants are emitted into the atmosphere (such as a stack). A flare is considered to be a point source, but requires special treatment (see Section 10.1). Stacks with rain caps and those horizontally oriented are special circumstances that AERSCREEN, AERMOD, and CALPUFF can handle explicitly. Section 10: *Special Topics* for guidance on these types of sources.

An *area source* is an emission into the atmosphere that is distributed over a stationary spatial area such as settling ponds and even urban regions that include multiple point sources (which combined together act as an area source). See Section 3.8: *Fugitive Sources* for guidance on fugitive emissions such as open pit mines.

A *volume source* is an emission to the atmosphere that has an initial width and depth at a stationary release point such as the dust emissions from an aggregate storage pile.

A *line source* is an emission to the atmosphere that is distributed over a line such as conveyor belts, roadways, and rail lines. 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.

3.2. MULTIPLE SOURCES, GROUPING (AERSCREEN)

The emissions from a facility can come from a number of sources of different types, locations, and characteristics. Deciding which sources should be included is largely dictated by the magnitude of the contaminant emission rate (e.g., a large emission rate has a large area of influence). A dispersion model may need to include sources outside the facility if they contribute to the contaminant load in the area (Section 8.1: *Adding Baseline Air Quality Concentrations)*. Decisions regarding the inclusion of nearby sources in the modelling effort may involve an iterative process, where subsequent model runs indicate which sources are important.

If the plumes from adjacent 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 the non-treatment in models is generally a conservative assumption, given that the modeled plume rise in these situations will be lower than in reality.

For Level 1 Assessments for multiple source situations, since AERSCREEN can only account for a single source, the following is recommended:

- Estimate the concentration by direct addition of the predicted worst-case concentrations for each source. This very conservative estimate is consistent with a screening approach.

- A group of closely spaced stacks can be modeled as a single source where stacks located less than one stack diameter apart and with the same release height, similar exit velocities, and flow rates can be treated as a single source. Follow Section 2.2 of EPA Screening Procedures for Estimating the Air Quality Impact ofStationary Sources[7] to calculate a pseudo diameter for the single source based on the total volume flow rate and exit velocity of the stacks.

- If sources cannot be grouped, then consider the use of a Refined model.

For Level 2 and 3 Assessments, the AERMOD and CALPUFF are capable of handling multiple sources. However, as mentioned earlier, there is no explicit treatment for plume rise in situations where the plume merges with others.

3.3. SOURCE EMISSION RATES

The basis for the emission rates used as input depends on whether dispersion modeling is used to assess the air quality consequences of a new or modified existing source, or whether it is used in a retrospective analysis – where historical air quality from existing sources are of interest.

If the emitted contaminant is assumed not to chemically transform in the atmosphere, the downwind concentrations are directly proportional to the emission rate of the contaminant (if all other source emission characteristics such as exit temperature do not change). Thus it is critical to use an emission rate that is both accurate and appropriate for the purpose of the modeling application.

Methods that can be used to establish emission rates are the following:

- approved/proposed emission limits
- continuous stack monitoring
- equipment manufacturer emission specifications
- published emission factors
- modeled emissions
- stack sampling survey (limited use)

3.3.1. CONTINUOUS STACK MONITORING

Large stacks at industrial facilities that emit a significant amount of air contaminants are often equipped with Continuous Emission Monitoring (CEM) systems that measure exit temperature, exit flow rate, and contaminant mass emission rates. The data can be analyzed to develop appropriate maximum, average, and upper percentile (e.g., 95th or 98th) operating conditions of the stack. Furthermore, the sequential time series of hourly average exit velocity, exit temperature, and emission rate data can be used by many of the recommended models to assess the effect of variations in emission parameters on predicted ambient air quality.

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[7] https://www.epa.gov/sites/default/files/2020-09/documents/epa-454r-92-019_ocr.pdf

3.3.2. EQUIPMENT MANUFACTURER EMISSION SPECIFICATIONS

For new facilities or in cases where measurements are not available, manufacturer specifications of contaminant emission rates can be used. Emissions rates may be provided for different load capacities and operating conditions. Confidence in manufacturer's ratings is reduced if the equipment:

- is old;
- has been retrofitted or modified;
- is not operating under optimum conditions; or
- is operated in substantially different conditions than the emission test (i.e., climatic conditions, altitude, process changes).

In such cases, the original manufacturer's specifications can be modified if there is evidence (i.e., stack samples, data from other studies) that supports a different value.

3.3.3. PUBLISHED EMISSION FACTORS

When no appropriate measured emission rates are available, published emission factors can be used (see the U.S. EPA's AP-42 emission factors[10]). These emission factors provide the mass of contaminants discharged per mass of fuel consumed, product processed or activity rate and are rated (i.e., from A to E) to reflect their uncertainty. This rating and the applicability of the AP-42 emission factors to conditions in must be considered before they are used. For example, emission factors associated with dust from mineral crushing have a rating of E (poor). Modelling forthis type of source using these factors will be limited in its value as it is subject to large uncertainty.

In some situations there may be more recent information available for a specific source type that would be more appropriate than the AP-42 emission factors. In this case, provide the reference and the rationale for this alternative factor(s) in the Dispersion Modelling Plan.

3.3.4. MODELLED EMISSIONS

There are various models available that estimate emissions using a calculation methodology that is specific to a source type. For example, emission models for wastewater treatment plants, landfills, and other sources are available from U.S. EPA's Emission Factors Estimation Tools[11]. In addition, follow the link for information on U.S. EPA emissions estimation methods for on-road and non-road mobile sources[12].

1.1.1. STACK SAMPLING SURVEY DATA

Stack sampling survey data provide a snapshot in time of the emissions and are normally conducted for permit compliance reasons, rather than to characterize the emissions for modelling purposes. Unless "sufficient" survey data (based on expert judgment) are available to determine the range of possible emissions from a source, they should only be used in situations where the air quality at the time of the survey is of interest or when there are no or little reliable data from other sources of information on emissions. Stack survey information may also be useful to estimate emission rates under reduced operation/production rates (discussed in the following section) if there are corresponding records of production rate.

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[10] https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

[11] https://www.epa.gov/air-emissions-factors-and-quantification/emissions-estimation-tools

[12] https://www.epa.gov/moves

1.2. EMISSION RATE VARIABILITY

Most sources of air emissions will exhibit variability in the contaminant emission rates over short or long-term periods. This variability can be due to changes in operating/production capacity and abnormal/upset conditions. Although the recommended Refined models have the ability to handle time-varying emission rates, many model applications are for proposed (i.e., yet to be built) sources. In these cases, a single emission value is assumed to apply for the entire simulation period. The following provides guidance on selecting the appropriate emission rate and examining the air quality consequences of this variability.

1.2.1. EMISSIONS UNDER NORMAL OPERATIONS

Emission rates may vary when a process is not operated continuously 24 hours per day or when the process rate (e.g., loading capacity, fuel consumption) varies with time. This variability means that the maximum short-term emission rate experienced over a period of a year can be much greater than the annual average emission rate.

If modelling is conducted to assess air quality that results from a future contaminant emission scenario, it is desirable to use the maximum emissions under normal operating conditions to determine compliance with ambient air quality objectives. Given that many ambient objectives are 1-h averages, this means using the maximum expected 1-h emission rate for dispersion modelling. See Section 3.5: *Appropriate Time Averages* for recommendations on longer time averages.

1.2.2. EMISSIONS UNDER REDUCED OPERATIONS

Maximum predicted ambient concentrations may not necessarily occur under maximum normal operating conditions. Although emission rates can be lower at a reduced capacity, there can be a corresponding reduction in plume rise due to the lower gas effluent volumes and temperatures. Higher concentrations could result under the reduced operation scenario than under maximum capacity emissions especially when there is nearby terrain, where a lower plume means impingement on the surface closer to the stack. Furthermore, some contaminants, such as NO_x, may have higher emission rates when a combustion source is not operating at full load due to lower operating efficiencies. In such cases:

- For elevated sources, examine the air quality consequences of the 25, 50, 75, and 100 % capacity scenarios (if such scenarios could occur) by using a Screening model (i.e. AERSCREEN) to ensure that the source conditions causing the highest concentration are identified.

1.2.3. EMISSIONS UNDER ABNORMAL OPERATIONS

Ambient concentrations should also be predicted for abnormal operating conditions since it is these situations that can result in the poorest air quality. "Abnormal operations" are known situations based on operational history, anticipated scheduled maintenance of control equipment, by-pass operations for plant safety, and start-up/shut-down situations.

Abnormal emissions are anticipated, but it is not known whether they will occur and when the dispersion conditions are good or poor. Although the probability of abnormal emissions occurring at the same time as poor dispersion conditions may be very small, decision makers are often interested in the worst-case air quality scenario that could potentially occur. In this case, the following is recommended:

- Establish the realistic emission scenarios associated with abnormal emissions and their anticipated frequency of occurrence (start-up, shut-down, maintenance, etc.).

- Apply a Screening model (i.e. AERSCREEN) to determine the potential worst-case air quality and the associated meteorology under these scenarios.

- Estimate the likelihood of the abnormal emission occurring at the same time as the worst-case meteorology.

Whether the abnormal emission scenario is an important factor in management decisions regarding the sourcedepends on an assessment of both the probability of the maximum concentration occurring and the air quality consequences if it does occur.

Finally, “upset conditions” on the other hand are *unanticipated* emissions (i.e., accidents) that result from unexpected equipment/process failure. Since the emissions under these scenarios are unknown, modelling the air quality that results from these scenarios is not possible.

1.2.4. EMISSIONS FROM EXISTING SOURCES

If the objective is to reconstruct a past air quality event, actual emissions that correspond to that event should be used. An hourly emissions file can be input into the Refined models recommended here, and variations in theemissions can be accounted for explicitly if the data are available (such as from a continuous emission monitor). Alternatively, equipment manufacturer emission specifications can be used. If specific events are of interest, stack sampling data can be used if it corresponds to the time of the event.

1.3. APPROPRIATE TIME AVERAGES

Given that emission rates can vary over time, the maximum short-term emission rate experienced over a period of a year can be much greater than the annual average emission rate. In order to determine compliance with shorter (1-h) and longer-term average (8-h, 24-h, annual) ambient air quality objectives, the following is recommended:

- For 1-h average concentrations use the maximum 1-h emission rate over the complete period of simulation.

For longer term averages (8-h, 24-h, annual), the maximum emission rate that corresponds to the concentration averaging period can be used (e.g., annual average emission rate for annual average predictions) over the complete period of simulation.

1.4. $PM_{2.5}$ AND PM_{10} STACK EMISSIONS

Emissions of $PM_{2.5}$ and PM_{10} consist of a filterable portion (directly emitted “primary” solid and liquid particles) and can include a condensable fraction (vapors that condense into $PM_{2.5}$ when cooled to ambient temperatures). This latter component can be significant as some sources, such as veneer dryers, may have a condensable fraction 5 – 10 times greater than the filterable portion. Other sources may have only a small condensable fraction, in which case it can be ignored.

The information available on PM emissions may not be size specific and may not include the condensable fraction. For example, if emission factors or manufacturer’s specifications are used, the distinction between sizes and/or condensable may not be available. Given this situation, the following is recommended for estimating PM emission rates:

- If information that distinguishes PM_{10} and $PM_{2.5}$ is available, the corresponding emission rates should be used as model emissions input to determine PM_{10} and $PM_{2.5}$ concentrations.
- If the filterable and condensable fractions of the PM emissions are specified, then use the total (i.e., filterable + condensable) as the emission rate for modelling.

  If there is no information available on whether the emission rates include the condensable portion, then use the rate as is.

1.5. PM EMISSIONS AND SIZE FRACTIONS FOR PARTICLE DEPOSITION ESTIMATES

AERMOD and CALPUFF can model particulate deposition for a range of user specified particulate sizes, mass fractions and the particle densities. If this is enabled, then a range of particle size categories is required along with information such as corresponding mass fractions and the particle densities.

For CALPUFF, using the pre-configured (default) $PM_{2.5}$ and PM_{10} distribution curves can lead to concentrations of $PM_{2.5}$ greater than PM_{10} due to inconsistencies in the distribution within the $PM_{2.5}$ range. In order to avoid this situation, for INPUT GROUP 8 in the CALPUFF.INP file, use Table 3.1 for $PM_{2.5}$ and PM_{10} deposition calculations.

Table 3.1 PM Granulometry Distributions for 6 PM Species

PM Species	Size Range (µm)	Geometric Mean Dia. (µm)	Geometric Standard Deviation	Affiliation	
				PM2.5	PM10
P1	0.5 - 0.75	0.625	0.0	X	X
P2	0.75 - 1.0	0.875	0.0	X	X
P3	1.0 - 1.25	1.125	0.0	X	X
P4	1.25 - 2.5	1.875	0.0	X	X
P5	2.5 - 6	4.25	0.0		X
P6	6 - 10	8	0.0		X

When the Geometric Standard Deviation is set to 0.0, CALPUFF assigns the diameter to the entire bin (i.e., there is no size distribution about the geometric mean diameter). In addition, CALPUFF uses the number of species size categories as input by the user and the number of categories as specified by NINT is ignored. $PM_{2.5}$ and PM_{10} concentrations can be calculated at the post processing stage (using CALSUM or POSTUITL) by adding the relevant PM size categories. In other words:

$PM_{2.5}$ = P1 + P2 + P3 + P4

PM_{10} = P1 + P2 + P3 + P4 + P5 + P6

1.6. FUGITIVE SOURCES

Fugitive sources are difficult to characterize since their emissions may vary with wind speed and time of day (for particle emissions) or process changes, and the control efficiency of mitigation measures applied to reduce emissions can be only crudely estimated with attendant large uncertainties. Fugitive sources are typically near the ground and have their greatest effect near the source. Whether they need to be considered in the assessment starts with an identification of these sources and the potential for any sensitive receptors to be in the affected area. The emissions estimates for fugitives are frequently based on AP-42 emission factors, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources[14], which in turn have a rating of E (poor, i.e., large uncertainty). AERMOD and CALPUFF can handle various source configurations often associated with such emissions. These models can account for the deposition of fugitive dust (with particle-size distributions and settling velocities) from areas such as gravel parking lots.

Due to the large uncertainties associated with establishing fugitive emissions and the difficulties in modelling them, consider:

- An emphasis on ambient monitoring to establish the fugitive emission contribution to air quality.
- Dispersion modelling to provide the concentration magnitude in order to demonstrate whether proactive fugitive emissions control/management needs to be adopted. Furthermore, the modelling can be used to assess the effectiveness of mitigation plans (relative changes) with less emphasis on the absolute results.
- If possible, report the modelling results of fugitive sources separately from the modelling results associated with sources where there is greater certainty in the emissions (point sources for example).

1.7. EMISSIONS FROM OTHER SOURCES

It is possible that the emissions from other nearby sources need to be included in the dispersion model simulation. Guidance on when to include such sources is provided in Section 8.1: *Adding Baseline Air Quality Concentrations.*

The contaminant emission rates for these other sources depend on their type and the information available (some may be operating under permit, and others such as marine sources need to be estimated). The methods used to estimate the contaminant emission rates would follow the same guidance as provided the previous sections.

2. DISPERSION MODEL INPUT - GEOPHYSICAL DATA

AERSCREEN, AERMOD, and CALPUFF require a description of the geophysical characteristics of the location to be modeled. This can include detailed topographical and land use information with corresponding surface parameters such as surface roughness, albedo, and Bowen ratios.

2.1. Simple Elevated, Complex and Flat Terrain

For situations where the terrain around the facility is not relatively flat or gently rolling, AERMAP may be used to assign elevations to the receptors and to generate hill heights. Terrain elevations, relative to the facility base elevation, can have a large impact on the air dispersion and deposition modelling results and therefore on the estimates of potential risk to human health and the environment.

- The terrain around a modelled facility can be defined as simple elevated or complex. In complex terrain, there are terrain elevations within 50 km of the stack that are above the height of the stack under study. Simple elevated terrain is defined as terrain that is above the base elevation of the stack but below the top of the stack. AERMOD does not require the modeller to determine whether terrain in the regionbeing modelled is complex or simple elevated. The degree of terrain and its effects are automatically determined using the terrain data provided.

- The AERMOD "flat terrain" option, which AERMOD internally sets all receptor heights to zero, is valid in gently rolling areas as it allows the plume to follow the terrain. While there may be some savings of work and time by running AERMOD in "flat terrain mode", the ministry recommends that terrain information is always incorporated into AERMOD by using AERMAP or any other sources.

2.2. TERRAIN DATA

AERMAP, the AERMOD terrain processor, requires terrain data in USGS Digital Elevation Model (DEM). There is also an option to input XYZ gridded terrain elevations manually, but they must be first converted to a form that mimics the USGS DEM data format (US Environmental Protection Agency, 2021). USGS DEM format are available on the SCRAM website[15] in a document titled "On inputting XYZ data into AERMAP" which is embedded in the zip file *XYZ Elevation Data Preparation and Entry Procedure*.

AERSCREEN, AERMOD, and CALPUFF terrain processor, supports processing of terrain data in the USGS DEM format, as well as several other types of data that provide terrain at different spatial resolutions .The DEM files are produced in two planar projections – UTM and Albers. All coordinates in the file are based on the 1983 North American Datum, and all elevations are calculated in meters above mean sea level. For the DEM data, the following is recommended:

- The UTM projection of the Egypt DEM data can be converted into an XYZ terrain elevations data file using any available software. The generic XYZ data file (where the first column must contain the X coordinate of a specific location, the second column contains the Y coordinate of the location, and the third column contains the terrain elevation) can be directly read.

- Alternatively, the UTM projection of the DEM data can also be converted to the USGS 7.5-minute DEM format (readable by AERMAP) by using available software or by special processing by the user.

Before any terrain data are used as input, the following is recommended:

- Plot the terrain surface and visually scan for any anomalous points that are not consistent with the observed topography.
- Ensure that the terrain data are of a spatial resolution that is sufficient to resolve the important terrain features so that the dispersion models can properly characterize the effects of the terrain on the transport and dispersion.

[14] https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-13miscellaneous-0

[15] https://www.epa.gov/ scram/air-quality-dispersion-modeling-related-model-support-programs

2.3. LAND USE DATA

Characterization of representative land use data in the vicinity of a site is necessary to determine the appropriate surface characteristics, which govern how plumes are dispersed as they move away from a source. This data is used for AERMOD and AERSCREEN but not required for SCREEN3. Surface characteristics such as roughness, albedo and Bowen Ratio are used by AERMET in the development of the surface meteorological data (.sfc files). The surface characteristics can be determined manually using

the approach described in Section 3.1 of the AERMOD Implementation) or using the U.S. EPA AERSURFACE program (if the required data are available in the appropriate format). The MAKEMET module of AERSCREEN also uses surface characteristics it its generation of screening meteorology.

The following sources of data are recommended:

- USGS Global Land Use Characterization data[16] This provides land use in USGS land use codes at a 1 km grid resolution that can be read and processed directly by CALPUFF preprocessor CTGPROG. This resolution may be adequate for regional scale applications of CALPUFF.
- Extract land use manually from contour maps, aerial photography, or Google Earth images.
- Any user defined tool for extracting land use data and discussed the method of extracting with the Ministry.

For CALPUFF (CALMET), a file of land use data in the form of gridded land use types is required by CTGPROG, a preprocessor which produces the fractional land use for each grid cell in the modelling domain or it can be input directly into the GEO.DAT file.

AERSCREEN and AERMOD require the specification of surface roughness, albedo, and Bowen ratio which are defined by different land use types in the area surrounding the location where the input meteorological data were collected. The user can enter direction specific (i.e., wind sector), monthly, annual, and season-dependent surface values as well. AERSCREEN and AERMOD results can be sensitive to these variables, so their selection (especially surface roughness) is important. The AERMOD Implementation Guide[17] (US Environmental Protection Agency, 2021) provides guidance on how to determine these parameters

3. DISPERSION MODEL INPUT - METEOROLOGICAL DATA

Air quality dispersion models require meteorological data as input, either in the form of a matrix of pre-determined meteorological conditions (Screening Models) or a time series of hourly sequential meteorological data (Refined Models). Regarding the latter, in order to reduce uncertainty in the model predictions, the meteorological data must be representative of the expected conditions.

In order of preference, the Guideline recommends the following for meteorological input to dispersion models:

- A site specific collection program.
- Measurements from a different location that represent the key features of the conditions at the site.
- Output produced by an Numerical Weather Prediction (NWP) model.

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[16] https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-13miscellaneous-0

[17] http://www3.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_3August2015.pdf

3.1. ON-SITE AND EXISTING ALTERNATE SOURCES OF METEOROLOGICAL DATA

Ideally, the meteorological input data would come from a specially designed and sited meteorological collection program and would represent the dispersion conditions at the site. Such data can be from a site specific (on-site) meteorological collection program or from a nearby collection program that provides data that are "representative" of the site conditions.

Based on Meteorological Monitoring Guidance for Regulatory Modeling Applications[18] (US Environmental Protection Agency, 2000) consider the following factors in determining whether an alternate source of meteorological data from a nearby existing collection program is appropriate for the site under consideration:

- Determine whether the geophysical situation at an alternative site characterizes the geophysical conditions at the site under consideration.
- Determine whether the climatic regimes between the existing meteorological program is similar to the site under consideration.
- Determine the purpose of the existing collection program and the measured parameters, the type of instrumentation and data collection, and the height of the measurements. Certain parameters may be missing or not suitable for modelling.
- Determine the instrument specifications, siting criteria and data treatment (response thresholds, data collection and handling protocols, special data entry flags). This will indicate the limitations and quality of the data. If this information is not available, then review the following and apply professional judgment to assess data quality:
    - low wind speed thresholds and frequencies
    - consistency with expected behavior for the given location
    - range checks
    - hour-to-hour changes

3.2. DATA SOURCES: SURFACE DATA

Egyptian Meteorological Authority **EMA** has archives of meteorological data collected at reporting airports, climate stations, buoys, and special studies. Typically, airport data provide most if not all of the required surface meteorological parameters for AERMOD and CALPUFF. Data from non-airport stations can also be useful as they may be more representative of the site conditions. If there are multiple stations, they can be used to better define the spatial variability of the meteorological fields over the domain (important for CALMET applications).

EMA data[19] are available (Fees apply). Available hourly variables include element wind speed – km/s, wind direction, dry bulb temperature), relative humidity - %, and station pressure

The available data do not provide all the necessary data, so ceiling height, total cloud, total cloud amount and elements present weather codes, which can be used to determine precipitation codes), contact EMA for more info.
Request the data to be provided in a column oriented text file, or Excel file.

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18 https://www.epa.gov/air-https://www.epa.gov/sites/default/files/2020-10/documents/mmgrma_0.pdf

EMA hourly airport observation data are primarily designed to generate long-term climate statistics and to satisfy aviation weather requirements. In particular, it is important to note that:

- Wind speed is usually measured at 10 meters above the ground.
- The wind measurement may not be a true hourly average, but can be an observer estimated average over the last two minutes of every hour. It is important to determine what method is applied. If the latter, the quasi-instantaneous measure of wind speed/direction to predict the hourly average concentrations at a specific location increases the uncertainty of the individual hourly predictions.
- Wind directions are reported to the nearest 10˚.
- The wind direction is assigned a zero when the wind speed is zero.
- There can be differences in wind instrumentation from these stations – for example, some stations use sonic anemometers (with a starting threshold of 0) and others use older instruments with an **Anemometer Starting Threshold** (AST) of 1 or 2 knots (approximately 1 m/s). Any wind less than the AST is reported as zero for speed and direction. If there are frequent periods when the wind speeds are less than the AST (which commonly occurs in valleys/basins), there will be an unrealistically high frequency of calms (zero wind speed).For EMA data, check the record to confirm the lowest non-zero wind speed in the data record as this will define the AST.

The location of the airport may not adequately represent the meteorological conditions at the site under consideration. Note however that some parameters, such as cloud amounts, ceiling heights and precipitation, can have a broad spatial area of applicability, so observation of these parameters made at a distant airportcould be applicable to the location of interest.

3.3. DATA SOURCES: UPPER-AIR

EMA UPEER AIR DATA[20]upper-air data are available (Fees apply),also The upper-air data are available online from the NOAA Radiosonde Database[21] (http://esrl.noaa.gov/raobs/) but must take permission from EMA before use it, and can be downloaded in original FSL format. The original FSL format data can be read directly by AERMOD and CALPUFF.

3.4. LENGTH OF RECORD

For Level 2 or Level 3 Assessments, the following is recommended:

- Minimum period of data is one recent year with up to five recent and consecutive years preferred.
- At least three years of data should be used for the applications where there are significant public concerns about impacts of air quality.
- One year of data is acceptable if these data are obtained from a site specific meteorological collection program. If more data are available, they should be used.

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[19] https://www.epa.gov/air-https://www.civilaviation.gov.eg/Companies/Meteorology

3.5. MISSING DATA

AERMOD (AERMET) and CALPUFF (CALMET) require an hour-by-hour sequential time series of meteorological input data. AERMET skips missing data periods while CALMET will not run with gaps in the data series.

The recommended limit for data completeness is:

- 90% (i.e., if more than 10% of data are missing over the simulation period, more data should be collected before running the model). If the data completeness recommendation of 90% cannot be met, the consequences of a lesser amount of data need to be outlined in the Dispersion Modelling Plan.
- The following is a guide to define "data completeness":
    - Lost data due to calibrations or other quality assurance procedures are considered missing data.
    - The 90% recommendation applies on a monthly basis such that 12 consecutive months with 90% recovery are required for an acceptable one-year database.
    - The 90% recommendation applies to each of the variables required in a model, such as wind direction, wind speed, and temperature.
    - The 90% recommendation for temperature may be relaxed as model results are typically not sensitive to variations in temperature.
    - A variable is not missing if data from a backup, co-located sensor are available.
- If the data is greater than 90% complete, use the data filling procedures as described below for both AERMOD and CALPUFF.

Based on the Meteorological Monitoring Guidance for Regulatory Modeling Applications[22] (US Environmental Protection Agency, 2000) the following are recommended protocols to "fill" missing data gaps:

- If the missing period is four hours or less, use linear interpolation (do not use persistence – use of data from the previous time period (hour)).
    - For transition periods (e.g., sunrise/sunset), use an appropriate interpolation technique depending on the parameter.
- For periods greater than four hours, first determine if data from a nearby representative site are available to substitute for the missing hours. If such data are not available, use interpolation techniques based on how the parameter typically changes during this period.
    - Use the criteria listed in Section 5.1: *On-Site and Existing Alternate Sources of Meteorological Data* to determine if the station data are adequately representative.
- For data with large data gaps during a day (i.e., anything greater than 6 hours), replace the entire day with the previous valid full day.
    - Data from a different station can be used to fill in gaps provided they are representative of the site.
- If there are multiple measurements at different levels on a tower, or upper-air sounding data, then missing data for one level can be replaced by data from an alternative level. If the data are available, this method is the preferred approach to fill longer missing data periods.

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[20] https://www.civilaviation.gov.eg/Companies/Meteorology
[21] http://esrl.noaa.gov/raobs/

Any data which are filled should be flagged to assist in the interpretation of model output and the uncertainty associated with the concentrations predicted during periods of substituted data. The greater the missing data period, the greater the potential for error in the filled data.
Other data filling approaches can be used but introduce greater uncertainty in the predictions. The following methods should be detailed in the Dispersion Modelling Plan submitted prior to modelling. These methods include:

- substitution from measurements at nearby locations with dissimilar meteorological characteristics.
- substitution of NWP output, subject to the validity checks in Section 6.1: *NWP Model Output for Dispersion Modelling*. Ensure that the time period of the replacement data is the same as the missing data, and also the user should adjust elevation levels between the replacement station and the missing data station.

3.6. LIGHT AND NO WIND CONDITIONS

The term **calm** is defined as a period of time when the wind speed is recorded as zero**. Zero values can be due to:**

- a "meteorological" calm which refers to the condition of no movement of air (no wind).
- an "instrument" calm, where there may be wind, but it is below the AST.

It is important to review the hourly data to understand what the lowest wind speed recorded (the low wind speed cut off), and the frequency of calms. For MSC, Ministry and MV wind data, the calm treatment is described in Section 5.2: *Data Sources: Surface Data*.

While CALPUFF can explicitly handle calms, AERMOD does not. AERMOD will skip the period when wind speeds are less than approximately **0.28 m/s** and will not calculate concentrations. While this is an acceptable treatment for an occasional calm, it is inappropriate if calms occur frequently and/or last for long durations (a common occurrence in valleys during the winter). AERMOD will not calculate a 24 h average (e.g., for $PM_{2.5}$) if there are more than 8 hrs in a 24 h period that are skipped due to calms. Since it is common for the highest 24 h average concentrations to occur under light wind conditions, the highest 24 h averages may be missed completely as a result of the calms treatment.

Given this, determine the frequency and duration of winds less than the threshold of **0.28 m/s**. Depending on the results, CALPUFF may be the only appropriate model to use.

3.7. NWP MODEL OUTPUT:

Recommendations on the use of NWP model output for dispersion modelling and the availability of such output for Egypt are discussed in Section 6.1: *NWP Model Output for Dispersion Modelling* and Section 6.2: *WRF Data Availability*. Critical to the decision on the use of the output for these purposes are tests to confirm the validity of the data for the location of interest.

3.8. METEOROLOGICAL DATA FOR AERMET (AERMOD'S PRE-PROCESSOR)

3.8.1. MINIMUM METEOROLOGICAL DATA REQUIREMENTS

AERMET requires hourly surface meteorological data observed at an airport or a site specific collection program and the morning upper-air sounding from a nearby (or representative) upper air station.

The following are recommendations on the minimum data requirements for AERMET from the User`s Guide for the AERMOD Meteorological Preprocessor (AERMET)[23] (US Environmental Protection Agency, 2021):

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[22] https://www.epa.gov/sites/default/files/2020-10/documents/mmgrma_0.pdf

- Data must be horizontally and vertically representative - judged independently for each variable.
- Surface characteristics around the meteorological site must be similar to the surface characteristics in the modelling domain.
- Surface characteristics around the meteorological site should be input.

Adequately representative data for each of the following variables constitute the minimum set of meteorological variables that AERMOD requires:

- Wind speed (scalar mean, generally at a height of 10 m).
- Wind direction (scalar mean or unit vector, generally at a height of 10 m).
- Ambient temperature (generally at a height of 2 m).
- Cloud cover – use opaque cloud cover first; use total cloud amount if cloud opacity is unavailable.
- Morning upper-air sounding (12 UTC in TD-6201 or original FSL format).

If gaseous and particulate_deposition (wet, dry) is to be modeled, in addition to the above, AERMET requires station pressure and hourly precipitation (amount) data. Data from a site specific meteorological program can be used by AERMET to provide meteorology in situations where there are no representative airport data. However since cloud cover is a required input, airport data must be used as_typically observers estimate cloud cover. If there are no representative cloud cover data, an equivalent cloud cover can be calculated byAERMET, using the Bulk Richardson Number approach (select the BULKRN option) if temperature measurements at two levels and wind speed at one level are available from a site specific measurement program. In addition, given the paucity of upper air stations and the complex terrain in, the nearest upper air sounding will sounding will sounding will

sounding will_likely not be representative of the location of interest especially near the surface. In such situations, first test the sensitivity of the modeled maximum concentrations using soundings from different locations. If the results are sensitive to this input, one of the following methods is recommended:

- Use the sounding that results in the highest maximum ground level concentrations.
- NWP model output can be mined (subject to the conditions of use in Section 6.1: *NWP Model Output for Dispersion Modelling*) to create a morning upper air sounding by extracting the vertical profiles of wind and temperatures at the location of interest.
- Use commercial software available to estimate the upper air sounding for AERMET; however these estimation methods assume flat terrain, so the application is limited.

3.8.2. <u>CALMS TREATMENT</u>

As discussed in Section 5.6, a calm (where the wind speed = 0.0) can be a true calm (i.e., no wind movement) or_instrument induced where the wind speed is less than AST. With respect to calms, AERMET is able to handle wind speeds ≥ **0.28 m/s.**_For wind speeds less than the lesser of the AST and **0.28**, AERMET skips the hours and flags those multiple-hour average concentrations that include a model calm period in the output file.

[23] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/met/aermet/aermet_userguide.pdf

For data from a site specific meteorological program, the user must specify the AST. AERMET assigns the wind speed as calm (**0.0 m/s**) in the meteorological file if the wind speeds are less than a user-specified AST. Any wind speeds less than approximately **0.28 m/s** will be treated as calm (even if the AST is lower than this value). Note that AERMET does not allow an **AST > 1.0 m/s** when data from a site specific meteorology program are used.

For airport data obtained from EMA (see Section 5.2) , AERMET does not require the AST to process the SURFACE pathway as any wind speeds less than the AST would be already be recorded as zero. As previously discussed, AERMET will skip these calm hours.

Finally, AERMOD includes several options related to calms treatment to address concerns about model performance under low wind speed conditions. For these parameters, the Guideline, the Guideline recommends the default values (i.e., do not enable these options).

3.8.3. METEOROLOGICAL DATA ACQUISITION AND PREPARATION

5.8.3.1. REFORMATTING HOURLY SURFACE DATA INTO AERMET READY FILES

Data from a site specific meteorological program can be used by selecting the ONSITE pathway inAERMET. Any ASCII text files (e.g., .txt, and .csv files) of hourly sequential data can be read – as long as the order of the parameters and their corresponding formats are specified. If hourly site specific data are in an Excel spreadsheet, the file should be saved as a text file which contains numeric values only. The variables in the site specific hourly data must have the following units:

- wind direction (degrees from north)
- wind speed (m/s)
- dry bulb temperature (^{o} Celsius)
- sky cover/cloud cover (tens of percent)
- station pressure (millibars*10)
- precipitation amount (centimeters)
- relative humidity (percent)

Data from hourly airport data obtained from EMA can be processed by AERMET by selecting the SURFACE pathway. However, these data must first be converted to a format readable by AERMET, such as CD-144, SCRAM, or SAMSON. Care is required to ensure that the proper units associated with each of these formats are assigned (e.g., the wind speeds in CD-144 data are in knots).

5.8.3.2. WIND DIRECTION TREATMENT FOR MSC HOURLY AIRPORT DATA

Wind directions in MSC data are in 10’s of degrees. For use in AERMOD, the secondary keyword RANDOM should be selected so that AERMET will randomize the wind direction within a 10 ° sector.

5.8.3.3. UPPER AIR DATA

The morning upper air sounding data for processing by AERMET can be in TD-6201 or original FSL format. Upper-air soundings in original FSL format are available from the Radiosonde Database Access website[21] (with permission from EMA). For AERMOD applications within, the required morning sounding corresponds to the 12 UTC sounding. The website has options for specifying the range of dates, levels, format and units of winds speed of upper air data to extract. Select “all levels” and choose “original FSL format (ASCII text)” as the output format. Once a requested series of soundings over the range of requested dates is displayed on the website, it can be copied and pasted as a text file which can in turnbe used directly by the UPPER AIR pathway of AERMET.If there are no appropriate upper air soundings available for the modelling domain, extracting upper air soundings from NWP model output (subject to the conditions on the use of NWP output listed in Section 6.1: *NWP Model Output for Dispersion Modelling*) is an alternative.

3.9. METEOROLOGICAL DATA FOR CALMET (CALPUFF'S PRE-PROCESSOR)

3.9.1. SURFACE METEOROLOGICAL DATA PREPARATION FOR CALMET

SMERGE is the primary pre-processing utility for creating a CALMET-ready, surface data file (called SURF.DAT). It assumes that the data have already been validated through quality assurance checks by using a utility called METSCAN (for CD-144 formatted data) or some other equivalent method. Typically data obtained from MSC, the Ministry or MV have already been validated, thus avoiding the need to run METSCAN (and the need to reformat the data into CD-144 format in order to run it). For validated data, SMERGE can read data in a variety of U.S. data formats (including CD-144), as well as a generic comma delimited (.csv) format. This latter format is most convenient for applications as hourly data obtained from government agencies are normally stored in a text file (.txt) or spreadsheet. A spreadsheet can easily be manipulated to SMERGE requirements (described as follows) then saved in the .csv format – ready for processing by SMERGE. The instructions are asfollows:

a) Place each parameter listed below into a specific column, with the proper units as listed as follows:

Column 1 – month (e.g., 1, 2, ... , 12)
Column 2 – day (e.g., 1, 2, 3, ... , 31)
Column 3 – year (4 digits, e.g., 2010)
Column 4 – hour (multiplied by 100, e.g., 0, 100, 200, ... , 2300)
Column 5 – temperature (Celsius)
Column 6 – precipitation amount (mm)
Column 7 – pressure (mb)
Column 8 – relative humidity (%)
Column 9 – wind direction (degrees)
Column 10 – wind speed (m/s)
Column 11 – cloud cover (tenths)
Column 12 – ceiling height (hundreds of feet)

b) A missing value of a real variable must be replaced with 9999.0 and for an integer variable: 9999 with the exception of the station ID, month, day, year, and hour.

c) No blank cells are allowed.

d) Ceiling height and cloud cover are only available from EMA. These parameters can be combined with other parameters from an on-site measurement program if they apply to the site under consideration.

Table 5.2 is a sample spreadsheet which is used to prepare meteorological data input for SMERGE and reflects the data and formats as described in the previous steps a-d. In this example, the Station ID=1234.

Station	ID	=	1234	Temp	Precip	Pressure	RH	Wind Dir	Wind Speed	Cloud Cover	Ceiling Height
Month	Day	Year	Hour	˚C	mm	Mb	%	deg	ms-1	tenths	100's of feet
8	1	2010	0	10.8	9999.0	961.4	89	177	0.2	3	888
8	1	2010	100	9.5	9999.0	961.8	95	334	0.5	0	888

8	1	2010	200	7.4	9999.0	961.9	98	211	0.4	0	888
8	1	2010	300	7.3	9999.0	961.9	100	324	0.2	3	888
8	1	2010	400	6.1	9999.0	961.9	100	323	0.1	3	888
8	1	2010	500	5.9	9999.0	961.8	100	153	0.6	4	888
8	1	2010	600	6.4	9999.0	961.8	100	157	1.6	5	888
8	1	2010	700	8.5	9999.0	961.6	94	144	1.2	6	20
8	1	2010	800	11.4	9999.0	961.5	82	132	0.8	8	50
8	1	2010	900	13.2	9999.0	960.7	74	172	0.7	9	40
8	1	2010	1000	15.1	9999.0	9999.0	9999	9999	9999.0	9999	9999

Once the spreadsheet is arranged, save it in a comma delimited file (.csv file) as in the example shown in Table 5.3. No blank spaces are allowed between the commas.

The file must contain the first three lines as shown in Table 5.3 exactly as shown with the exception of the Station ID number. In this example, it is 1432, but could be any integer number.

Table 5.3 Sample of a Comma Delimited Input File Ready for SMERGE

GENERIC,Version,'2.0',Manually generated, Time as ending hour

Station,ID,=',1432,Temp,Precip,Pressure,RH,Wdir10m,Wspeed10m,Ccover,Cheight
Month,Day,Year,Hour,DegC,mm,mb,%,deg,ms-1,tenths,hundreds_of_feet

8,1,2010,0,10.8,9999.00,961.4,89,177,0.2,3,888

8,1,2010,100,9.5,9999.00,961.8,95,334,0.5,0,888

8,1,2010,200,7.4,9999.00,961.9,98,211,0.4,0,888

8,1,2010,300,7.3,9999.00,961.9,100,324,0.2,3,888

8,1,2010,400,6.1,9999.00,961.9,100,323,0.1,3,888

For the merging of multiple surface data files specify each file name, station identifier (i.e., Station ID) and corresponding time zone in the SMERGE.INP file see the CALPUFF Modeling System Version 6 User Instructions [24] (Exponent, 2011) . SMERGE will combine these individual files into a singular SURF.DAT file - ready for input to CALMET.

For missing data, when multiple surface stations are selected for CALMET, the only requirement is that a valid value of each parameter is available for each hour from at least one of those stations. The exception to this is the precipitation type code which can be missing from all of stations. For the other parameters CALMET will automatically substitute a missing parameter from another surface station (if it exists for that period). However, if such a substitution is inappropriate, or there are no other surface data available for that missing period then data filling methods can be used depending on the parameter and the extent of the missing record. SMERGE will generate a list of missing data, which can be further examined to determine how these periods are to be treated (see Section 5.5: *Missing Data*).

[24] http://www.src.com/calpuff/download/CALPUFF_Version6_UserInstructions.pdf

3.9.2. UPPER AIR DATA PREPARATION

Data for the twice-daily soundings released at 00 and 12 UTC for one or more stations are required in TD- 6201 or original FSL formats. READ62 is the upper-air data preprocessor that produces a formatted UP.DAT file for use by CALMET and conducts a number of quality assurance checks (missing data, out of range values, etc.). These missing values can be eliminated or if retained there are options on how to treat missing data. Users are referred to the CALMET User's Guide[25] and the CALPUFF FAQ's[26] for different upper air data filling methods.

As mentioned in Section 5.3: *Data Sources: Upper-Air*, upper-air soundings (1990 – present) in original FSL format are available from the Radiosonde Database Access[21] website. Users can specify a range of dates, levels, format and units of wind speed of upper air data to extract. Select "all levels" and choose 'original FSL format (ASCII text)' as the output format. Once the requested data are displayed, they can be copied, pasted and saved as a text file which can be used as the input file for READ62.

3.9.3. PERCIPITATION CODE AND HOURLY PRECIPITATION FOR LONG-TERM,WET DEPOSTION CALCULATIONS.

In order to model wet deposition, CALMET requires hourly precipitation and precipitation code (i.e., frozen vs. liquid precipitation). However, the precipitation code is not included in the surface data available from EMA. Fortunately, if the surface data are processed in a *.csv format by SMERGE (as per Section 5.9.1), the precipitation code is calculated automatically based on hourly precipitation and dry bulb temperature and then is written into the list of parameters that comprise the SURF.DAT file.

EMA data can include hourly precipitation, although some stations only report daily precipitation amounts. In this case, the hourly weather code can be used (elements 086 to 098 that indicate rain, snow, drizzle, etc.) to determine the hours when precipitation occurs. Partitioning of the total daily precipitation equally over the precipitation hours is acceptable given that calculated depositions are long term accumulations (i.e., annual wet-deposition).

For wet deposition calculations, hourly precipitation data are required in a separate PRECIP.DAT file. Pre-processors, PXEXTRACT (for quality assurance of precipitation data) and PMERGE (to merge data from multiple stations, account for stations in different time zones, etc), are available to create a PRECIP.DAT file if the hourly precipitation data are in TD-3240 format.

For preparing Canadian precipitation data, users can select the free-formatted option by creating the PRECIP.DAT file directly in free-format as described in Section 8 of the CALPUFF Modeling System Version 6 User Instructions[27].

Note that the use of precipitation data collected at airports may underestimate the orographic enhancement of precipitation at higher elevations, or the precipitation data may not be representative of the domain. In such cases, if there is no PRECIP.DAT file, the precipitation fields provided by the NWP model output (when used either in Hybrid or No-Obs mode) can be used by CALPUFF for wet deposition calculations.

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[25] http://www.src.com/calpuff/download/CALMET_UsersGuide.pdf

[26] http://www.src.com/calpuff/FAQ-questions.htm

[27] http://www.src.com/calpuff/download/CALPUFF_Version6_UserInstructions.pdf

4. METEOROLOGICAL MODELLING

4.1. NUMERICAL WEATHER PRIDICTION(NWP) MODEL OUTPUT FOR DISPERSION MODELLING

NWP models include sophisticated physics and produce hourly forecasts of meteorological parameters at horizontal grid resolutions in the order of a kilometer and in multiple vertical levels over a large domain. This ability means that NWP models can produce meteorological information in areas where no observations exist – an attractive benefit for air quality assessments in, given that the meteorological monitoring network in is sparse with limited spatial applicability due to the complex terrain.

NWP model output can be used for dispersion modelling purposes, either to supplement observational data or as a substitute for observations depending on the Assessment Level and the dispersion model (see Section 2). However, whether the output data from an NWP model can be used for dispersion modelling depends on the applicability and quality of the output and as such it must undergo a QA/QC process described in this Section.

Subject to the considerations and QA/QC tests, the following is recommended:

- For AERMOD, NWP output can be used to extract surface meteorological variables and vertical profiles in situations where there is no meteorological data. However, the priority should always be to obtain representative meteorological data rather than relying on NWP model output. Section 6.3 provides guidance on extracting AERMET-ready files.
- For CALPUFF, NWP output can be used in several ways, depending on the application (and the corresponding CALMET mode) as per Section 6.4.1.

Since air quality assessments involve dispersion models that use historical meteorological data, NWP models can be run for periods in the past to produce historical prediction (hind cast) output that is pieced together to create a continuous historical, model-produced meteorological record. This hind cast approach can be taken a step further, where actual observations can be used to “nudge” the model toward what was actually observed at these locations, and in doing so improve the rest of the meteorological fields.

NWP models offer an alternative to meteorological measurements as input for dispersion models such as AERMOD and CALPUFF. This approach offers many advantages:

- Provides data for any location (important in regions where there are no surface and/or upper air data).
- Takes less time in hind cast mode to generate a data set than a monitoring program (in forecast mode it takes the same time).
- Avoids subjective decisions regarding the applicability of meteorological data collected in a different location (for example, adjusting/rotating winds to account for different terrain orientations).
- Provides details of the space and time variability of the meteorology in three dimensions within a modelling domain, of critical importance for given the complex geophysical setting.

While NWP models offer many advantages, they require computational resources (processing, storage) that escalate rapidly with domain size, grid resolution and simulation duration. Therefore, it is impractical to apply these models for dispersion modelling in situations where it is required to simulate one or multiple years of hourly meteorology at a fine enough grid scale (on the order of 100 m) and vertical levels in order to resolve the effects of small-scale terrain features - a common need in .

In order to take advantage of their sophisticated physics in situations which their application would be limited (i.e., fine grid resolutions over long period simulations), the relatively coarse spatial resolution NWP model output can be used as an initial guess field for the fine spatial resolution diagnostic model, CALMET. The diagnostic model further applies dynamically consistent diagnostic algorithms based on terrain effects and observations to develop meteorological adjustments on a fine scale. This hybrid approach uses the strengths of both models and makes it practical to produce fine-scale meteorological fields for long period simulations.

Note that there is a spatial limit to the terrain effects and weather phenomena that NWP model can resolve. NWP models can completely resolve phenomena with spatial scales greater than 7 to 10 times the grid resolution. Anything less will be only partly resolved, and at 2 times the grid resolution such effects will be filtered out completely. Typical grid resolutions for fine scale NWP models are 4 km, which means that the flow features that affect the pollution transport in for many local-scale applications will only be partly accounted for at best and may be completely ignored. For this reason, combining the coarse scale NWP output with a fine scale model such as CALMET is the only way to resolve these small scale terrain flow features.

"*Research on the Applicability of Modeled Site Specific Meteorological Data to Well Test Flaring Assessments in* " (Levelton Consultants Ltd., 2002) concluded that the hybrid approach "significantly improves resolution of thelocal scale wind system in complex terrain." Furthermore, the study found that this combination of models is an objective means to produce meteorological data at a site for straight-line, Gaussian models that are at least as representative for that site as applying and adapting data from other locations.

NWP output can be used in ways other than the hybrid approach as CALMET has the ability to use NWP output as the only source of input meteorology. Guidance on the recommended application of these various modes is provided in Section 6.4.1.

Although NWP models offer many advantages, there are other factors to consider:

- They require considerable expertise and computational resources to run.
- The boundary layer has traditionally been a challenge to simulate for these models especially in geophysically complex settings.
- The limitations of grid resolution mean that terrain effects and weather phenomena with small spatial scales may only be partly resolved or completely ignored.
- There are several NWP models that can be configured and initialized in different ways all providing potentially different results (McEwan and Murphy, 2004).
- The installation of an on-site meteorological station(s) may still be required given the ability of CALMET to be used in Hybrid mode to resolve small scale terrain flow features.

Given that NWP models are evolving and experience on their use for dispersion modelling is relatively recent, NWP model output for dispersion modelling purposes can be applied only if the use of a particular NWP model and its modelling configuration has been carefully determined based on an initial analysis of the simulations, especially within the boundary layer. This would involve model testing in the domain of interest to determine whether it produces realistic meteorological fields in a qualitative sense, as well as comparing model output to observations using quantifiable performance measures such as those described in "*Use of High ResolutionNumerical*

NWP model output may not be necessary or may offer marginal benefit in the following situations:

- There are relatively flat areas with representative upper air soundings and a network of surface observing stations.
- The modeled sources are near the surface (<50 m) and the domain is limited (on the order of a few km), the surface observing station(s) in the domain may provide data representative of the conditions at the location of interest.

4.2. MESOSCALE MODEL INTERFACE PROGRAM (MMIF):PROCESSING NWP OUTPUT FOR DISPERSION MODELS

User's Manual for the Mesoscale Model Interface Program (MMIF) [28] facilitates the use of NWP output for air quality modelling applications. Version 3.4.2 is available from the U.S. EPA.

MMIF can convert output fields from an NWP model (the Fifth Generation Mesoscale Model [MM5], version 3 and WRF-ARW, version 2 and 3) to the parameters and formats suitable as an input to AERMET. MMIF can also replace AERMET by producing output data which can be input directly into AERMOD.

MMIF is able to act as an alternative to CALMET to process NWP model output directly to a suitable format for CALPUFF. However, if MMIF is used as a replacement for CALMET, the addition of terrain effects that CALMET can apply to produce a final wind field is by-passed.

MMIF does not perform any coordinate transformation. Therefore, CALPUFF must be run in the same coordinate system and datum as the NWP model output. In addition, MMIF does not provide output with a grid resolution finer than the one of the NWP output, and MMIF cannot process additional observation data as well. All of these factors limit the use of MMIF for CALPUFF.

Although MMIF is still under testing and development, the following is recommended:

- The use of MMIF should be identified in the Dispersion Modelling Plan.
- MMIF can be used to extract meteorological output suitable for AERMOD applications in situations where there are no meteorological data and terrain within a modelling domain is flat. However, the priority should always be to obtain representative meteorological data rather than fully relying on NWP model output (see Section 6.1).
- Given CALMET's current ability to ingest and process NWP output in No-Obs mode and its ability to apply further terrain effects, the use of MMIF as a replacement for CALMET is not recommended until further experience with MMIF demonstrates its superiority.

4.3. CALMET METEOROLOGICAL MODELLING

CALMET consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers (Scire, Strimaitis, & Yamartino, 2000). A two-step approach can be used to produce wind fields where the Step 1 fields are created from an Initial Guess field that is adjusted for the kinematic effects of terrain, slope flows, and terrain blocking effects. In Step 2 an objective analysis procedure blends observational data (if available) into the Step 1 field in order to produce a final Step 2 wind field.

4.3.1. CALMET MODELLING MODES

CALMET can be run in 3 different ways as follows:

1. No Observation (No-Obs): CALMET relies entirely on NWP model output
2. Observation Only (Obs-Only): CALMET relies entirely on observation data
3. Hybrid: CALMET uses observations and NWP model output

The selection of a particular mode depends on the recommendations provided in the following sections.

[28] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/mmif/MMIFv3.4.2_Users_Manual.pdf

6.3.1.1. NO OBSERVATION(NO-OBS)

In this mode, output from an NWP model is CALMET's only source of meteorological data. For CALPUFF applications, the critical considerations should this mode be selected are that the key features of the complex flow that define the dispersion and transport can be resolved by the grid resolution of the NWP model output. The use of No-Obs mode is recommended for:

- Level 2 Assessments.
- Level 3 Assessments only if there are no appropriate surface observations to run in the Hybrid mode.
- The use of NWP model output is subject to the tests/conditions described in Section 6.1.
- The NWP model output is introduced as an Initial Guess field.

Regarding the last recommendation, CALMET's grid resolution is typically finer than the grid resolution of the NWP model. This finer resolution is required in order to capture the relevant complex flow features of the situation. In this case, introducing the NWP model output as an Initial Guess field takes advantage of CALMET's ability to apply the finer scale terrain effects (kinematic, slope, and blocking) to create a more realistic flow field.

6.3.1.2. OBSERVATION ONLY(OBS-ONLY)

Obs-Only mode works best when available representative surface and upper air data are close to a facility and the expected area of impact is within a few to several kilometers. For complex flow situations, relying fully on observational data as input to CALMET would require a network of surface and upper air stations to adequately simulate the meteorological fields. Given that such networks are rare in , the use of this mode using actual meteorological observations would be limited to:

- Simple (i.e., non-complex) flow where available observational data have a wide spatial applicability.
- Level 2 Assessments.

6.3.1.3. HYBRID

Hybrid mode combines three-dimensional NWP output with surface (or both surface and upper air station) data and optional data such as overwater buoy data and precipitation data. Coarse grid resolution NWP model output provides a spatially and temporally varying meteorological field. The NWP output is interpolated to the CALMET grid with a grid resolution finer than the NWP output's (e.g., 4-km grid spacing), and CALMET uses fine-resolution terrain data and observations to make adjustments to produce a final Step 2 wind filed. The Hybrid approach uses the strength of both NWP and CALMET model to produce at least as good as or often better results than the use of observations alone.

Often appropriate surface station data are available, but due to the paucity of upper air stations in , appropriate upper air observations may be limited. As such this mode allows the use of surface station observations in combination of NWP output to "fill in" the upper air information.

For CALPUFF applications, this mode is recommended for the following situations:

- Level 3 Assessments.
- Appropriate observational data (surface data at a minimum with upper air data if available).
- "Complex" flow situations.
- The NWP model output is subject to the quality checks described in Section 6.1.
- The NWP model output is introduced as the Initial Guess field.

When upper and surface observations are used in CALMET, there are seven user defined parameters that require expert judgment: BIAS, IEXTRP, RMAX1, RMAX2, TERRAD, R1, and R2. Due to their importance in creating a realistic CALMET wind field, based on TRC (2011), explanation and guidance on these parameters are provided in Table 6.1.

One common problem associated with Hybrid mode is “doughnut” patterns that occur around surface observation stations under low wind speed conditions. This may point to a problem with the NWP model output at that specific location or an issue with relatively high anemometer starting thresholds where low wind speeds are reported as zero. In these situations a difference in the wind speed at the meteorological station vs the surrounding area as defined by the NWP model output appears as a “doughnut” pattern.

Eliminating or minimizing the spatial extent of this artifact can be done through the following:

- Review the user defined values: R1 and RMAX1 (increase or reduce; see Table 6.1).
- Review the NWP model output at the specific location for reasonableness (see Section 6.1).

4.3.2. DOMAIN AND GRID RESOLUTION:

The CALMET domain depends in part on the area where the predicted concentrations/depositions are needed. Given this, select the CALMET domain that will include all terrain affecting the flows that determine the dispersion within the area of interest (i.e., CALPUFF domain). In addition, if meteorological data outside ofthe area of interest can help better define the CALMET generated meteorological fields within the area of interest, then extend the meteorological domain to include these observations.

The choice of grid resolution depends on the whether the resolution will allow CALMET to capture the important features of the flows that govern the behavior of the dispersion. For example, modelling the dispersion of a plume in a narrow, winding valley that is 2 km wide (a common situation in) would require a CALMET grid resolution on the order of 250 m. This is a common grid resolution for local scale applications in . For regional scale applications where dispersion on the order of 100 km is of interest, then a coarse grid resolution (i.e., 1 km) may be appropriate.

In all cases, selecting the appropriate grid resolution must be balanced by the need to resolve the important features of the flow fields and the computer resources required to generate the winds for every grid point. Given the professional judgment involved, it is critical that the grid resolution and domain size are identified in the Dispersion Modelling plan and discussed with the Ministry.

4.3.3. GUIDANCE ON KEY CALMET MODEL OPTIONS

Due to the number of user-defined variables and options, many of which require expert judgment, guidance on the switches/options and user defined factors for CALMET (Version: 6.4.0, Level: 121203) Input Group 4 and 5 are provided in Tables 6.2. The switches/user defined parameters are shaded according to the following:

Black = do not touch (if changed, provide justification)
Dark Grey = recommended default

Light Grey = expert judgment required

White = not used

This guidance is based on the collective experience of practitioners in , CALPUFF Modeling System Version 6 User Instructions[29], the CALPUFF FAQ’s[30], and the New South Wales CALPUFF guidelines (New South Wales Department of Environment and Conservation, 2005). Although these Tables are intended to be as specific as possible, expert judgment is required as every CALMET application is unique. For these reasons, it is recommended that CALPUFF users:

- Are familiar with the above documents,

- Have attend a CALPUFF basic and advanced training course
- Have a background in boundary layer meteorology

[29] http://www.src.com/calpuff/download/CALPUFF_Version6_UserInstructions.pdf
[30] http://www.src.com/calpuff/FAQ-questions.htm

Table 6.1 An Explanation of the 7 Critical User-Defined, Site Specific Parameters When Using Observational Data in CALMET (Scrie & Barclay, 2011)

Option	Parameter	Recommended Value	Explanation and Justification
Terrain radius of influence (km)	TERRAD	No Default Requires user input. Value in km specific to each model domain. <u>Used in both No-Obs and Obs modes</u>	TERRAD, a terrain scale, used in computing slope flow effects (ISLOPE) and terrain blocking effects (IFRADJ) on the wind field. Consider TERRAD as the distance (km) that CALMET 'looks' at in computing each of these effects. For instance the distance of the slope of the nearby terrain is needed to compute theslope flow. TERRAD should not be too small otherwise nearby valley walls which contribute to the slope flow will not be seen. On the other hand, TERRAD must not be so large that hills more than one valley away are seen. TERRAD can be estimated as the typical ridge-to-ridge distance divided by two, and usually rounded up. Typical values of TERRAD are between 5-15 km with an upper limit of about 20 km (except for very large grid spacing simulations). See TRC (2011) Section 3.2.3 for further guidance.
Vertical extrapolation of surface wind observations	IEXTRP	Default (-4): 'to extrapolate using similarity theory" and to exclude upper air observations from Layer 1 <u>Not used in No-Obs mode</u>	This switch affects whether the model allows vertical extrapolation of surface data or not. This switch was developed since upper air observations are typically only taken every 12 hours. The vertical extrapolation of surface wind observations allows for the hourly surface data to impact layers above the surface layer. The default is -4, which means similarity theory is used to extrapolate the surface winds into the layers aloft, which provides more information on the observed local effects to the upper layers. A value of IEXTRP < 0 means that the lowest layer of the upper-air observations will not be considered in any interpolations. IEXTRP = 0 means that no vertical extrapolation from the surface wind data is used.

Table 6.1 (Cont'd) An Explanation of the 7 Critical User-Defined, Site Specific Parameters When Using Observational Data in CALMET (Scrie & Barclay, 2011)

Option	Parameter	Recommended Value	Explanation and Justification
Layer dependent weighting factor of surface vs. upper air wind observations in defining the Initial Guess Field (IGF) winds. Observations are always weighted byinverse distance squared ($1/R^2$) from the station to the grid point. The BIASparameter changes that weight.	BIAS (NZ)	Default (NZ * 0) is to not change the $1/R^2$ weighting given equally to surface and upper air data <u>Not used in No-Obs mode</u> Requires user input, depending on validity of surface and upper air stations	BIAS is most often used in complex terrain. It ranges from -1 to +1, and a value is input by the user for each vertical layer. A value of -1 means the surface station has 100% weight for that layer, while a value of +1 means the upper air stationhas 100% weight for that layer. In simple terrain situation, BIAS is often set tozero (0) for each vertical layer (i.e., the upper air and surface wind and temperature observations are given equal weight in the $1/R^2$ interpolations used to initialize the computational domain). The BIAS affects how the initial Step 1 winds will be interpolated to each grid cell in each vertical layer based on upper air and surface observations. By setting BIAS to -1, upper-air observations are eliminated in the interpolations for this layer. Conversely by setting BIAS to +1, surface observations are eliminated in the interpolations for this layer. An example where non-default settings for BIAS may be used is for a narrow, twisting valley, where the only upper-air observations were 100 km away, and the only local surface wind observations were in one location in the valley. For this example, set BIAS to -1 within the valley forcing surface data only to be used for the lowest layers, and BIAS to +1 above the valley (which could be double the valley depths depending on how much the valley effects the flow above it) forcing upper air data only to be used aloft, and BIAS might go from -1 to +1 in the transitional layers at the top of the valley.

Table 6.1 (Cont'd) an Explanation of the 7 Critical User-Defined, Site Specific Parameters When Using Observational Data in CALMET (Scrie & Barclay, 2011)

Option		Recommended Value	Explanation and Justification
Weighting parameter for Step 1 wind field vs. observations in Layer 1 (R1) and Layer 2 and above (R2)	R1 and R2	No Default Requires user input. Value in km specific to each model domain, 1 value represents all stations <u>Not used in No-Obs mode</u>	The value of R1 and R2 are used in the construction of the Step 2 wind field, where the observed winds are 'blended' in with the Step 1 winds. R1 represents the distance from a surface observation station at which the surface observation and the Step 1 wind field are weighted equally. R2 represents the comparable distance for winds in layers 2 and above. It is important to note that all the results of the diagnostic wind model (kinematics, slope and blocking effects) are contained in the Step 1 wind field, thus if too much weight is given to the observations, then you will essentially erase all the information generated in creating the Step 1 winds. Rule of thumb is to start with small R1 and R2 values and slowly increase these values if you do not believe the surface stations are showing enough weight. Typically for observation sites in flat terrain values of R1 and R2 are larger than in mountainous terrain where a station's flow is limited by the valley segment.

Maximum radius of influence for meteorological stations in layer 1 (Step 2) and layers aloft (Step 2)	RMAX1 and RMAX 2	No Default Requires user input. Value in km specific to each model domain One value represents all stations Not used in No-Obs mode	The values of RMAX are also used in the construction of the Step 2 wind field, where the observed winds are 'blended' in with the Step 1 winds. Any observation for which R_k (the distance from the grid cell to the k-th observation location) is greater than RMAX1 in the surface layer or RMAX2 aloft is excluded from the 'blending' formula. RMAX1 and RMAX2 can be used to exclude observations from being inappropriately included (as they are in the next valley, on the other side ofa mountain, etc.). Note, if RMAX1 and RMAX2 are used to exclude observations, then do not set LVARY to T, as CALMET will increase the values of RMAX1 and RMAX2 to at least capture the nearest observation, regardless of whether this makes sense. Typically values of R1 and R2 are smaller than RMAX1 and RMAX2, this way 'sharp' boundaries between the Step 1 wind field and the weighted observation station are prevented.

Table 6.2: Recommendations for Key CALMET (Version: 6.4.0, Level: 121203) Model Options in Input Group 4 and 5

Black (do not touch) Dark Grey (recommended default)
Light Grey (expert judgment required to determine) White (not used)

Option	Parameter	Value	Explanation & Justification
Determines whether observation data are used, or in combination with NWP model output, or NWP data only	NOOBS	0, 1 or 2	(0) CALMET is run with observation data only, (1) a combination of observations and NWP output, (2) or just NWP output. See Section 6.4.1 for further guidance.
Cloud Data Option: 1,2,3,4	MCLOUD	4	If gridded NWP model used: (4) compute the gridded cloud cover from prognostic relative humidity at all levels.
Wind field model selection variable.	IWFCOD	1	(1) Use diagnostic wind module for wind field creation via 2-Step approach, (0) objective analysis only: not recommended.

Compute Froude number adjustment effects?	IFRADJ	1	Used to evaluate thermodynamic blocking effects of the terrain on the wind flow and are described using the critical Froude number (see CRITFN to define). Used only if IWFCOD=1.
Compute kinematic effects?	IKINE	0	(0) Do not compute a terrain-forced vertical velocity in the initial guess wind field. When IKINE=0, DIVLIM, NITER and ALPHA do not need to be specified.
Use O'Brien procedure for adjustment of the vertical velocity?	IOBR	0	No adjustment to the vertical velocity profile at top of model domain.
Compute slope flows?	ISLOPE	1	Slope flow is parameterized as a function of sensible heat flux, distance to the crest, and terrain slope.
Extrapolate surface wind observations to upper levels	IEXTRP	-4	(-4) Extrapolate surface observations using similarity theory. (1) no extrap, (2,3) other extrap methods used. See Table 6.1. If IEXTRP<0: ignore layer 1 data of upper air stations if surface station nearby as it is likely more representative.
Extrapolate calm winds aloft?	ICALM	0 or 1	If surface meteorological data and upper air soundings are used alone to run CALMET, ICALM should be: • (0) when unrealistically high % of calm (due to high anemometer starting threshold) and the location is not prone to calms/inversions. • (1) when % calm is realistic (low threshold anemometer) and the location is prone to frequent stagnant conditions (valleys). If NWP model output is used in CALMET, ICALM=0.
Layer-dependent biases.	BIAS	varies	-1<=BIAS<=1. See Table 6.1 Note: BIAS is only used when using observations to develop initial guess field. Not active when No-Obs =1,2
Min. distance (km) between upper air stn and srfc stn for which extrapolation of srfc winds will be allowed.	RMIN2	-1	(-1) when IEXTRP = ± 2,3,4 to ensure extrapolation of all surface stations (i.e., unlimited distance). Option designed to avoid extrapolated surface data "competing" with upper air measurements when both surface and upper air measurements are co-located. However, the better time resolution of the hourly surface data suggests extrapolating may be appropriate. RMIN2 defines the distance between measurements defining "co-located".

Use gridded prognostic wind field (NWP) model output?	IPROG	0 or 14	(0) No (14) where NWP output used as Initial Guess field.

Time step (hrs) of the NWP output used as input data	ISTEPPGS	3600	(1) Usually, it is an hourly time step (3600 seconds)
Use coarse CALMET fields as initial guess fields?	IGFMET	0	(0) Off. If (1) the coarse CALMET fields from an earlier run will be used to define the initial guess fields (could be used if no NWP output available).
Use varying radius of influence?	LVARY	F	(F) Off (T) use objective analysis only rather than the 2 Step diagnostic wind module (when IWFCOD=0). Radius of influence is expanded when no stations are within the fixed radius of influence value. Caution: RMAX is effectively enlarged to incorporate the "nearest" station regardless of it suitability.
Max radius of influence over land of the surface layer.	RMAX1	varies	Used to exclude obs at surface from being inappropriately included (i.e., if they are in the next valley). See Table 6.1
Max radius of influence over land aloft.	RMAX2	varies	Used to exclude obs aloft from being inappropriately included. See Table 6.1
Max radius of influence of over water – all layers	RMAX3	varies	Must be large enough so that all grid points over water are within the radius of influence of at least one observation.
Min. radius of influence used in the wind field interpolation.	RMIN	0.1	Use small value (0.1 km). Prevents a divide-by-zero error when a grid point and station are co-located.
Radius of influence of terrain features	TERRAD	varies	Requires expert judgment. See Table 6.1
Distance from a sfc stn at which the obs and 1st guess field are equally weighted.	R1	varies	Requires expert judgment. See Table 6.1
Distance from an upper air stn at which the obs and 1st guess field are equally weighted.	R2	varies	Requires expert judgment. See Table 6.1

Relative weighting of the prognostic wind field data.	RPROG	0	Change this value if IPROG=1 (CSUMM model winds are used in the Step 1 wind field). CSUMM output is rarely used and not recommended.
Maximum acceptable divergence in the divergence min. procedure.	DIVLIM	5x10^{-6}	Not used since IKINE=0
Maximum # of iterations in the divergence min. procedure.	NITER	50	Not used since IKINE=0
# of passes in the smoothing procedure.	NSMTH (NZ)	2,4,4,4,…	2 passes in the lowest layer, and 4 passes in the higher layers. More passes will smooth the final wind field and may be needed in complex terrain - but rarely altered
Max # of stns used in each layer for the interpolation of data to a grid point	NINTR2	99	Use default.
Critical Froude number.	CRITFN	1	If Froude no. < CRITFN, wind has an uphill component and direction is changed to be tangent to the terrain. If Froude no. > CRITFN, no adjustment is made.
Empirical factor controlling the influence of kinematic effects.	ALPHA	0.1	Not used since IKINE=0
Multiplicative scaling factor for extrapolation of surf obs to upper layers.	FEXTR2 (NZ)	NZ * 0.0	Seldom used and not used when IEXTRP = ± 4.
Number of barriers to interpolation of the wind fields.	NBAR	0 depends	Usually not used. Use barriers to block out a certain station effects. Barriers can extend from the surface layer to userdefined upper layer limit.
Level (1 to NZ) up to which barriers apply.	KBAR	varies	Used only if NBAR > 0. User defined switch to control vertical extent of barriers. Requires careful examination of the resulting wind field at each level.

X and Y coordinates of barriers.	XBBAR YBBAR XEBAR YEBAR	varies	Use only if NBAR > 0 to define the coordinates of the barrier.
Diagnostic module surface temperature option.	IDIOPT1	0	Surface temperatures computed internally using hourly surface observations or NWP model output. (1) read pre-processed values from DIAG.DAT.
Diag module sfc station to use for the sfc temp (stn ID).	ISURFT	-1	(-1) 2-D spatially varying surface temperatures
Diagnostic module domainaveraged lapse rate option.	IDIOPT2	0	(0) Lapse rate computed internally from twice-daily upper air observations or NWP model output. (1) read pre-processed values from DIAG.DAT.
Diagnostic module upper air stn (stn ID) to use for lapse rate to use.	IUPT	-1	(-1) 2-D spatially varying potential temperature lapse rate
Depth through which the domain-scale lapse rate is computed.	ZUPT	200	Units: Meters. Only used if IDIOPT2 = 0.
Initial guess field wind components	IDIOPT3	0	(0) Computed internally from observations or NWP output wind fields. (1) read pre-processed values from DIAG.DAT
Upper air station to use for domain-scale winds.	IUPWND	-1	Use 3-D initial guess fields. Used only if IDIOPT3 = 0 and NOOBS = 0.
Bottom and top of layer through which the initial guess winds are computed.	ZUPWND	1, 1000	Units: Meters. Used only if IDIOPT3 = 0
Observed surface wind components for windfield module.	IDIOPT4	0	Read wind speed and wind direction from a surface data file (SURF.DAT). DIAG.DAT not used.
Observed upper air wind components	IDIOPT5	0	Read wind speed and wind direction for an upper air data file (UP1.DAT, UP2.DAT, etc.). DIAG.DAT not used.
Use Lake Breeze Module?	LLBREZE	F	No, do not use Lake Breeze Module.

# of boxes defining region.	NBOX	0	Used only if LLBREZE = T.
X Grid line 1 defining the region of interest X Grid line 2 defining the region of interest	XG1 XG2	0	Used only if LLBREZE = T. One set per box.
Y Grid line 1 defining the region of interest Y Grid line 2 defining the region of interest	YG1 YG2	0	Used only if LLBREZE = T. One set per box.
X Point defining the coastline (straight line)	XBCST	0	Beginning x coordinate (km) of user defined coastline. Used only if LLBREZE = T. One for each box.
Y Point defining the coastline (straight line)	YBCST	0	Beginning y coordinate (km) of user defined coastline. Used only if LLBREZE = T. One for each box.
X Point defining the coastline (straight line)	XECST	0	Ending x coordinate (km) of user defined coastline. Used only if LLBREZE = T. One for each box.
Y Point defining the coastline (straight line)	YECST	0	Ending y coordinate (km) of user defined coastline. Used only if LLBREZE = T. One for each box.
Number of stations in the region	NLB	0	Surface and upper air stations in a box. Used only if LLBREZE = T. One for each box.
Station ID's in the region. Surface stations first, then upper air stations.	METBXID (NLB)	0	Used only if LLBREZE = T. One set per box.

5. DISPERSION MODELLING

5.1. SIZE OF DOMAIN

The model domain will generally be greater for tall stacks with buoyant emissions where a domain of 50 by 50 km centered on the stack may be required due to the large area affected by the emissions. For shorter stacks, a smaller domain may be appropriate (e.g., 10 km by 10 km). Some recommended ways to establish the domain are:

- As a starting point, establish the domain on the basis of the isopleth resulting from the project only case that represents 10% of the ambient air quality objective.
- For AERSCREEN and AERMOD, consider the terrain in defining the domain boundaries (e.g., elongated domain for valleys defined by bounding mountain ridges).
- Consider sensitive receptor areas (e.g., a hospital, recreation area or neighborhood) or areas of interest such as nearby residents/communities where interest in the predictions may be high.
- Consider other emission sources that need to be included in the modelling such as sources that contribute to baseline (see Section 8.1) whether they currently exist or could be built in the future.

CALPUFF domain should be big enough to capture potential recirculation of pollutants.

5.2. RECEPTOR SPACING

Receptors are the locations within the model domain where the concentration/deposition predictions are calculated. The location and number of receptors must be judiciously selected in order to achieve a balance between enough receptors to resolve maximum concentrations and too many receptors where computer processing times and output files become unreasonable.

Consider the following receptor spacing as a minimum:

- 20 m receptor spacing along the plant boundary (as defined in Section 7.3)
- 50 m spacing within 500 m of source
- 250 m spacing within 2 km of source
- 500 m spacing within 5 km of source
- 1000 m spacing beyond 5 km of source

The above are for general guidance for a single point source or for multiple sources that are close and will depend on several factors such as source types, the distance to plant boundary, etc. For example, area sources such as an open pit mine, the “source” may cover a large irregularly shaped area, so the initial receptor spacing as recommended above may have to be adjusted based on the facility boundary and the shape of the area source.

Finally, receptor spacing may also depend on whether there are specific areas where predictions are of interest such as populated areas where higher resolution may be required even though the concentration/deposition gradients are low.
These are considered to be sensitive receptors (see Section 7.4)

5.3. PLANT BOUNDARY

Model output is typically compared to ambient air quality objectives. Although the areas of applicability of the ambient air quality objectives are not defined, often they are applied to areas where there is public access (i.e.,beyond the plant boundary). The plant boundary is determined to be the following:

- The facility fence line or the perimeter of disturbed area that defines where public access is restricted.
- If a facility is located within another larger facility boundary, the plant boundary is the boundary of the encompassing facility.
- If a public access road passes through the plant, the plant boundary is the perimeter along the road allowance.

There may be areas outside the plant boundary such as over a large body of water where public access is likely to be very rare. In this case, the human and environmental risk is low even though these areas may have predicted contaminant concentrations. The applicability of the model output and ambient air quality objectives for such areas is a matter to be discussed with the Ministry.

5.4. SENSITIVE RECEPTORS

It may be desirable to predict the concentrations (maximums or some percentile) at sensitive receptors such as individual residences, residential areas, schools, hospitals, commercial day care and seniors' centres, campgrounds, parks, recreational areas, and sensitive ecosystems. AERMOD and CALPUFF have the ability to output concentrations at specified receptors in addition to a grid of receptors, and AERSCREEN is able to output concentrations at specified distances in addition to gridded distances.

5.5. FLAG POLE RECEPTORS

Dispersion models allow the user to select the receptor height, called flagpole receptors. Under most situations, ground-level (i.e., a receptor height of 0 m) concentration predictions are sufficient since the concentration profile within the first few meters of the ground is expected to be fairly homogeneous due to mechanical mixing. For very short stacks (i.e., a few meters), the difference in flagpole receptor height between 0 and 1.5 m may lead to large differences in the predicted concentrations in areas near the source.

Elevated flagpole receptors may be required to determine concentrations for treetop concentrations in order to assess the potential for vegetation effects, or to estimate the exposure to humans where 1.5 m flag pole receptors would be considered to be breathing height. Flagpole receptors should be identified in the Dispersion Modelling Plan.

5.6. BUILDINGS

If emissions occur close to buildings, the downwind dispersion can be affected by the flow deformation and enhanced turbulence created as air moves over and around the building. For example, building downwash may occur where emissions from stacks on or near buildings may be drawn in the cavity zone behind the building (and re-circulate resulting in high concentrations) and/or caught in the wake turbulence, mixing the plume to the ground rapidly resulting in high ground-level concentrations. All of the Guideline models can handle the effects resulting from a single or several buildings with different dimensions and orientations.

For AERSCREEN, if downwash from only one building is to be accounted for building downwash, the following parameters must be provided:

- orientation of maximum building horizontal dimension relative to north (0-179 degrees)
- building height

- maximum horizontal building dimension
- minimum horizontal building dimension
- angle from north of stack location relative to building center (0-360 degrees)
- distance between stack and building center

Building Profile Input Program for PRIME (BPIPPRM) can be used to prepare downwash related input for the Plume rise Model Enhancements (PRIME) building downwash algorithm. BPIPPRM can determine whether a stack is subjected to wake effects from a structure(s), and calculate building heights (*BH*) and projected building widths (*PBW*) for cases when the plume is affected by building wakes.

In multiple building situations, BPIPPRM determines building separation distances and will fill in the gap between the buildings under specific circumstances if they are "sufficiently close". With the addition of more buildings and stacks, a maze of influence zones results, and BPPPRM automates these calculations for these complicated situations.

BPIPPRM requires the following information:

- X and Y coordinates for all building corners and stacks,
- Height of all stacks and buildings, and for buildings with more than one height or roofline, then each tier height with respect to the building base elevation, and Base elevations of all stacks.

BPIPPRM produces a file for AERSCREEN, AERMOD and CALPUFF if downwash is to be treated. For AERSCREEN, the output from BPIPPRM can be read directly by specifying the filename of an existing BPIPPRM output file. For AERMOD and CALPUFF, the output file must by copied and pasted into the required Input Group for source and building information.

In addition to PRIME, CALPUFF also includes the ISC model downwash treatment. Evaluations of both methods for buildings with different aspect ratios (building width/building height) show that the ISC treatment performs better for buildings with aspect ratios > 5 (squat buildings). For CALPUFF applications, the ISC treatment is recommended if aspect ratios > 5 (see Table 6.1). When the ISC downwash option is selected for CALPUFF, only the HEIGHT and WIDTH output parameters from BPIPPRM are required as input into the Point Source Parameters (Input Group 13).

5.7. AERMOD: REGULATORY DEFAULT SETTINGS (CORE MODEL OPTIONS)

The regulatory default option is controlled from the MODELOPT keyword on the CO pathway. As its name implies, this keyword controls the selection of modelling options. Unless specified otherwise through the available keyword options, it is recommended that the following AERMOD default options are selected:

- Use the elevated terrain algorithms.
- Use stack-tip downwash (except for building downwash cases).
- Use the calms processing routines.
- Use the missing data processing routines.
- Use a 4-h half-life for exponential decay of SO_2 for urban sources.

Recommendations in Section 8.2 should be followed for NO_x to NO_2 conversion. The parameters used to specify options on the MODELOPT keyword are "secondary keywords" that are descriptive of the option being selected. For example, to ensure that the regulatory default options are used for a particular run, the user would include the secondary keyword "DFAULT" on the MODELOPT input.

5.8. CALPUFF: INPUT GROUP 2 AND 12 SWITCH SETTINGS

In order to promote consistency in the application of CALPUFF, similar to the switch setting recommendations for CALMET provided in Section 6.4.3, the following section provides guidance for CALPUFF Input Group 2 and 12 Switch Settings. The switches/user defined parameters are shaded according to the following:

- **Black** = do not touch (if changed, provide justification)
- **Dark** Grey = recommended default
- **Light** Grey = expert judgment required
- **White** = not used

Table 7.1 Recommendations for Key CALPUFF (Version: 6.42, Level: 110325) Model Options in Input Group 2 and 12

Option	Parameter	Value	Explanation & Justification
Vertical distribution used in the near field.	MGAUSS	1	Gaussian.
Terrain adjustment method.	MCTADJ	3	Partial plume path adjustment.
Subgrid scale complex terrain module flag.	MCTSG	0	Usually 0, but allows for CTDM-like treatment of subgrid scale hills
Near-field puffs modelled as elongated?	MSLUG	0	No slug model. However it is the recommended approach for area sources with receptors in the very near field or for episodic time-varying emissions such as accidental releases.
Transitional Plume Rise modelled?	MTRANS	1	Transitional rise computed.
Stack-tip downwash?	MTIP	1 or 2	(1) Stack-tip downwash modelled, particularly if ratio of stack gas exit velocity to wind speed is < 1.5. (2) No stack tip downwash for flares if pseudo-stack parameters are calculated using the AERflare/ABflare spreadsheet.
Method selected to compute plume rise for point sources not subject to downwash.	MRISE	1	Briggs plume rise.
Method used to simulate building downwash?	MBDW	1 or 2	(2) PRIME method. (1) ISC type method if building aspect ratios of W/H are > 5 (see Section 7.6)
Vertical wind shear above stack top modelled in plume rise?	MSHEAR	0	No vertical wind shear. Variable flow in the vertical is based on upper air data. If used (1) a power law wind speed extrapolation is applied above stack top.
Puff splitting allowed?	MSPLIT	0	No puff splitting for short-range modelling. In long range transport, puff splitting may be necessary.
Chemical Transformation Scheme.	MCHEM	0 or 6	(0) No chemical transformation (6) transformation internally calculated using updated RIVAD scheme with ISOROPPIA equilibrium. Computationally intensive.

Aqueous phase chemistry flag	MAQCHEM	1	Used only if MCHEM = 6 or 7. Transformation rates and wet scavenging coefficients adjusted for in-cloud aqueous phase reactions. Consult Ministry if an alternative scheme is requested.
Liquid Water Content flag	MLWC	1	Used only if MAQCHEM = 1. MLWC = 1 is recommended if gridded cloud liquid water content data are available (obtained by CALMET from MM5/WRF output and stores in an auxiliary "calmet.dat.aux" file).
Wet removal modelled?	MWET	0 or 1	(0) no, (1) if wet deposition modelled. Important for long range transport but may be used for near-field in appropriate.
Dry deposition modelled?	MDRY	0 or 1	(0) no, (1) if dry deposition modelled. Important forlong range transport but may be used for near-field in appropriate.

Gravitational settling (plume tilt)?	MTILT	0 or 1	(0) turns off plume tilt, recommended for small particles. (e.g. combustion size particles less than 10 µm) (1) yes, recommended for very large particles with substantial gravitational settling effects.
Methods used to compute the horizontal and vertical dispersion coefficients.	MDISP	2	(2) turbulence based dispersion coefficients is recommended.
Sigma measurements (σ_v/σ_θ, σ_w) from PROFILE.DAT used to compute σ_y, σ_z	MTURBVW	3	When measured sigmas are available, use observed σ_v/σ_θ, and σ_w from the PROFILE.DAT file to calculate σ_y and σ_z. Used only if MDISP =1 or 5.
Backup method to compute dispersion when measured turbulence data are missing.	MDISP2	3	Used only if MDISP=1 or 5. Backup method is PG-based dispersion coefficients for RURAL areas when turbulence data are missing
Method used for Lagrangian time scale for σ_y	MTAULY	0	(0) Lagrangian time scale (617.284s). Only used when MDISP = 1 or 2.
Advective-Decay timescale for turbulence	MTAUADV	0	(0) no turbulence advection.

Method used to compute turbulence σ_v and σ_w profiles	MCTURB	1	(1) use standard CALPUFF subroutines. (2) use AERMOD algorithms to compute turbulence profiles. Model evaluations have shown both options have similar performance.
PG σ_y and σ_z adjusted for roughness	MROUGH	0	(0) adjustment for surface roughness is not needed.
Partial plume penetration of elevated inversion?	MPARTL	1	(1) Evaluate partial plume penetration into elevated inversions applied to point sources.
Partial plume penetration from buoyant area sources	MPARTLBA	1	Model partial plume penetration into elevated inversions. Important for very hot buoyant area sources such as forest fires.
Strength of temp inversion provided in PROFILE.DAT extended records	MTINV	0	(0) computed from default gradients and upper air data. Otherwise (1) if PROFILE.DAT contains detailed temperature profiles
Probability Distribution Function used for dispersion under convective conditions	MPDF	0 or 1	(1) only if MDISP = 2 (turbulence based dispersion coefficients). Otherwise (0)
Sub-grid TIBL module used for shore line	MSGTIBL	0 or 1	(0) do not use, however may be used for applications located along a coastline. If used (1) a coastline file (COASTLN.DAT) must be prepared to specify the location of the land-water boundary.
Boundary conditions (concentration) modeled?	MBCON	0	(0) boundary conditions are not used. (1) when boundary conditions may be important
Configure for FOG Model output?	MFOG	0	(0) FOG model not run. (1) if condensed (visible) plume assessment is required.
Test options specified to see if they conform to regulatory values?	MREG	0	(0) No checks made. (1) to check for conformity with US EPA Long Range Transport Guidance
Minimum turbulence velocities, sigma v and sigma w for each stability class over land and water	SVMIN SWMIN	σ_v =.2 for A, B, C, D, E or F σ_w = default	For applications where calm wind and stagnationevents are significant, set SVMIN = 0.2 to better represent lateral spread of the plume. Leave SWMIN as default value.

6. POST PROCESSING

6.1. ADDING BASELINE AIR QUALITY CONCENTRATIONS

Although it is useful to know the predicted incremental air quality contribution of the source, it is the cumulative air quality that is of importance. This is especially important when comparing model predictions to ambient objectives. The cumulative air quality is given by:

Cumulative = Baseline + Predicted Increment (contribution from the source(s) modeled)

"Baseline" is the concentration due to emissions from both natural and human-caused sources. In other words, it is the result of the contribution from all sources except the source(s) being modeled. The baseline may be determined from air quality monitoring data or may be estimated from modelling other contributing sources or a combination of both.

Choosing the appropriate baseline concentration can be critical in assessing overall air quality. In order of priority, the information sources used to establish the baseline concentration level are:

- A network of long-term ambient monitoring stations near the source under study;

- Long-term ambient monitoring at a different location that is adequately representative; Modeled baseline.

Given the importance of the baseline level, it is recommended that the Dispersion Modelling Plan includes a description of the method to establish baseline.

6.1.1. SITE SPECIFIC MONITORING DATA

The baseline concentration can be determined through the use of existing ambient monitoring data collected at the site. Current and historical air quality monitoring data at various sites across are available from the Ministry.

6.1.2. MONITORING DATA FROM A DIFFERENT LOCATION

If there are no representative ambient data available for the site, it is possible to use data from another location on the condition that the alternate site is located in a similar meteorological and air quality regime. Factors to be considered are:

- Differences in geophysical characteristics (meteorology, topography, surface features).
- Differences in emissions types (point sources, roads, etc.).
- Differences in emissions changes (rapid urban growth, nearby temporary sources, etc.)
- Distance from sources that could influence the monitor.

Finally, a review of the instrumentation and the data collection protocols used in the off-site program is recommended.

6.1.3. ESTABLISH A MONITORING PROGRAM

Establishing a monitoring program in order to determine existing levels of air quality should be considered for the following reasons:

- To establish a baseline in situations where existing levels are critical to the assessment of air quality in an area.
- To conduct post-construction assessment, after a source is operational, to evaluate the air quality assessment and/or to determine compliance with ambient air quality objectives.

Although a fully instrumented, continuous monitoring station operating for at least a year is ideal, establishing baseline could be determined from a short-term study or passive monitoring. Details of any new ambient monitoring program need to be reviewed with and accepted by the Ministry.

6.1.4. SELECTING A BASELINE LEVEL USING MONITORING DATA

When representative monitoring data are available, the next step is to select an appropriate baseline level. Typically a single value is chosen as baseline, which is assumed to apply for every hour of the year and for every location within the modelling domain. Choosing an appropriate single value from a year's worth of monitoring data is problematic given the variation in concentrations that will occur in time and space over the period.

The value selected for baseline depends on the purposes of the modelling assessment. If a conservative estimate of the potential cumulative air quality changes due to the source is desired (when determining compliance with ambient objectives/guidelines, worst-case analysis, potential risk exposure estimates), a conservative value should be used to establish baseline levels.

To select a baseline level, the following is recommended:

- If the monitoring data are deemed representative of the area under consideration, the baseline should be based on the most recent year of hourly monitoring data. At least one year of data is required, and a data record that is 75% complete in each quarter of the year is recommended.
- Select baseline levels for time averages that correspond to the modeled time averages. For example, cumulative air quality compared to a 24-h average ambient objective would require a 24-h average model prediction and a 24-h average baseline level.
- The monitoring data can be pre-screened to exclude any periods when an intermittent source has a significant influence on the monitor.
    - For example, if there are episodes where wildfire smoke is the major contributor, such periods could be eliminated from the data only if it is supported by analysis of the air quality and meteorological record.
- For Level 1 Assessments, select the maximum measured concentration (100th percentile) from the screened or unscreened data set as the baseline level.
- For Level 2 and 3 Assessments, baseline levels for 1-h cumulative prediction values should be determined as follows,
    - For SO_2, use the 99th percentile of daily maximum 1-h values.
    - For NO_2, use the 98th percentile of daily maximum 1-h values.
    - For other pollutants, use the 98th percentile from the screened hourly data set.
- For Level 2 and 3 Assessments, use the 98th percentile of the 24-h (daily) values from thescreened data as the baseline level for a 24-h cumulative prediction.
- For an annual average cumulative prediction, use the annual mean calculated from the screened or unscreened hourly data over a year.
- If there is more than one representative monitoring site, follow the previous steps to establish baseline for each site for the different averaging periods. The representative baseline value would be the arithmetic average of the 1-h, 24-h and annual average values obtained for each site.

In figures and/or tables that present the modelling results, provide the total air quality (baseline plus the increment due to the source(s) modeled) and the modeled incremental concentration (due to the source(s) modeled).

6.1.5. MODELLING BASELINE (CONTRIBUTING SOURCES)

If there are no representative ambient monitoring data, a model can be used to estimate the baseline concentration for sources where emissions can be quantified. In addition, for practical reasons such an approach would be limited to areas with a limited number of contributing sources. The decision to include or exclude sources that may or may not contribute to the baseline concentration depends in part on the scale of the modelling domain. Which sources to include can be guided **by following these recommended steps**:

- Run a Screening Model (i.e. AERSCREEN) for each source in order to determine the contribution of each source to the concentrations in the area around the source and assess their relative importance.
- Consider the surrounding terrain where a source may be close to the source under consideration

but is in an adjacent valley separated by high ridges where its contribution to thearea of interest is minimal.

- Final decisions on what sources to include to produce a modelled baseline concentration may require an iterative approach.

The guidance that is outlined in Section 3.3 regarding source emission rates for model inputs also applies to those sources included in the modelling to estimate baseline.

6.1.6. FUTURE BASELINE

There may be situations where the current emissions that contribute to the air quality in the area of interest are expected to change dramatically in the future (new sources or decommissioning of existing sources). In this case, the current baseline may not be an appropriate starting point. Estimating the future baseline could be informed by dispersion modelling only if there is certainty in the emission characteristics from the new or decommissioned sources. The question of whether the future baseline needs to be considered should be identified in the Dispersion Modelling Plan.

6.2. NO TO NO_2 CONVERSION

Given that NO_2 is the contaminant of interest due to its effects on human health and the environment, the conversion for NO to NO_2 must be accounted for by a chemical transformation treatment built into the model itself, and/or through a conversion factor applied to the modeled NO_x concentration.

The recommended methods for obtaining the NO_2 concentration from the predicted NO concentration are based on a step-wise approach that involves different conversion treatments which are summarized as follows:

- 100% conversion. If there are exceedances, use one of three methods described next.
- If there are adequate (at least one year) hourly NO and NO_2 monitoring data, use the ambient ratio method.
- If adequate monitoring data are not available, use the ozone limited method.
- If AERMOD is used, apply the plume volume molar ratio method.

6.2.1. 100% CONVERSION

For any of the models recommended in this Guideline, the most conservative approach is to assume that all of the NO is converted immediately to NO_2. If there are exceedances of the ambient NO_2 objective, then the following alternate methods can be used.

6.2.2. AMBIENT RATIO METHOD

The Ambient Ratio Method (ARM) is a conversion factor based on measurements of NO and NO_2. If there are at least one year of representative ambient hourly NO and NO_2 monitoring data, an empirically derived conversion formula can be applied. Alternatively, as a simple alternative to the full conversion curve, the monitoring data may be used to create a single conversion factor that is based on a range of expected concentrations. The approach should be outlined in the Dispersion Modelling Plan and approved by the Ministry.

An illustration of the method is provided in RWDI (2005) but is outlined here:

- Plot all the 1-h observations of NO_2/NO_x (y axis) vs NO_x (x axis). The scatter will be limited to a distinct envelope (see example, Figure 8-1).

- Estimate up to what NO_x concentration the NO_2/NO_x ratio should be 1. This is the lower NO_x limit.
- Estimate the NO_x concentration where $NO_2 = 0.1\ NO_x$. This is the upper NO_x limit.
- Fit an exponential equation of the form to the upper envelope of the scatter:

$NO_2/NO_x = a\ NO_x^{\ b}$

Where a and b are selected through an iterative process to produce a curve that fits the upper bound of the envelope of the scatter (see example, Figure 8.1).

- The formula should not be used for concentrations below the lower NO_x limit in order toensure that the calculated NO_2/NO_x ratio never exceeds unity.
- Check the equation: make sure that NO_2 does not decrease with an increase in NO_x.
- To account for baseline, follow Section 8.1.4 to establish the baseline 1-h and annual average NO_x. Add the modelled NO_x to this baseline to obtain a total 1-h NO_x. Apply the ARM curve to obtain the total NO_2 concentration.

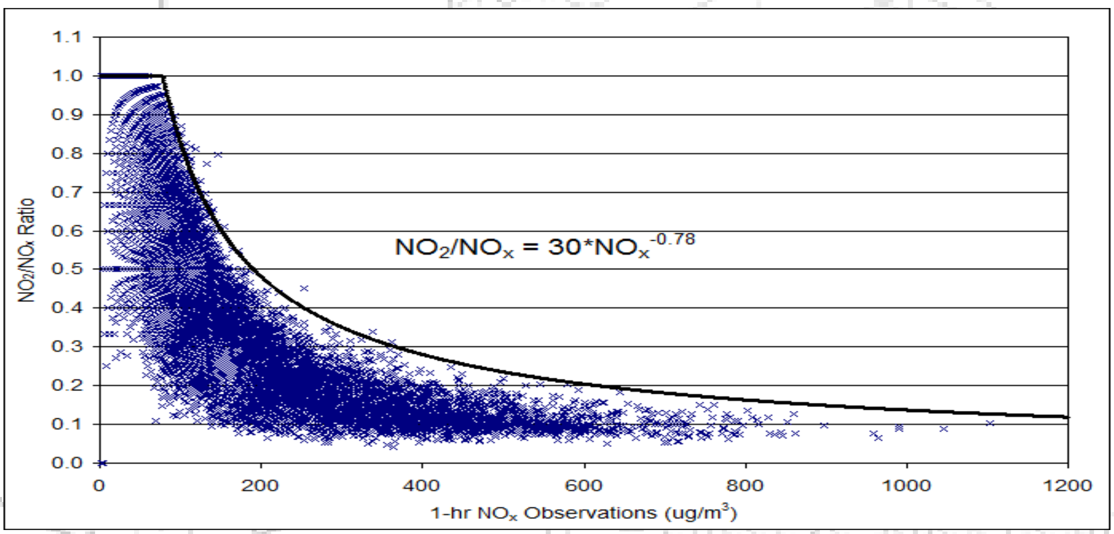

Figure 8.1 Example: Dependence of NO2/NOx Ratio to 1-h Average NOx Concentration, (RWDI, 2005)

6.2.3. OZONE LIMITING METHOD

If adequate hourly NO and NO_2 monitoring data are not available, the Ozone Limiting Method (OLM) can be applied with the approval of the Ministry. The NO_2 concentration can be determined using the following equation (Cole & Summerhays, 1979):

$NO_2 = 0.1*\ NO_x$ + the lesser of (O_3 or $0.9\ NO_x$) + baseline NO_2

The initial 10% conversion of NO to NO_2 (the first term in the equation) may not be appropriate for all types of NO_x sources. In this case, it is acceptable to use an initial conversion value that better corresponds to the source type. This should be identified with suitable justification in the Dispersion Modelling Plan.

The above equation assumes the concentrations for all constituents are in vol/vol units (e.g., ppm). For modelling purposes, NO_x is the predicted concentration as NO_2 since the NO_x emission rate is generally expressed as NO_2 equivalent. If there are multiple plumes that have merged together, apply OLM to the combined plume NO_x concentration. Otherwise for plumes that do not merge, apply OLM to each plume separately.

The O_3 concentration used for the OLM is based on the maximum hourly O_3 concentration measured from one-year of representative monitoring data (i.e., typically the closest station if it represents the conditions that the plume would experience). Select the maximum hourly O_3 value (100th percentile) from this data set for the input O_3. Care is required in selecting the appropriate O_3 value, as it may already be depleted (or scavenged) by local NO_x sources.

6.2.4. PLUME VOLUME MOLAR RATIO METHOD (AERSCREEN AND AERMOD ONLY)

For AERSCREEN and AERMOD applications use the Plume Volume Molar Ratio Method (PVMRM) for NO_x conversion (Hanrahan, 1999). This method limits the conversion of NO to NO_2 based on the amount of O_3 available in the plume and accounts for the changing plume volume due to dispersion. The method also accounts for merging plumes in multi-source modelling scenarios. There are different input options for baseline O_3, the NO_2/NO_x equilibrium ratio, and the in-stack NO_2/NO_x ratios. The following are recommended input options when selecting this method:

- For baseline O_3 , use a single value based on the maximum hourly O_3 concentration measured from one-year of representative monitoring data. Care is required in selecting the appropriate O_3 value, as it may already be depleted (or scavenged) by local NO_x sources.
- NO_2/NO_x equilibrium ratio = 0.90 unless information is available to justify using a different value.
- NO_2/NO_x in-stack ratio = 0.10 unless information is available to justify using a different value.

6.2.5. RIVAD/ARM3 AND RIVAD/ISORROPIA CHEMICAL TRANSFORMATION

The CALPUFF chemical conversion modules (i.e., MESOPUFF II, RIVAD/ISORROPIA) are used for acid deposition and secondary $PM_{2.5}$ estimates. In addition, the RIVAD/ARM3 and RIVAD/ISORROPIA chemical transformation schemes are able to provide predicted NO_2 concentrations as part of the output suite of parameters. However, the use of these modules directly for local and regional scale NO_2 estimates has not been evaluated. Until more evidence emerges on the use of CALPUFF for this specific purpose, the Ministry does not recommend the use of RIVAD/ARM3 and RIVAD/ISORROPIA for NO/NO_2 conversion.

6.3. DISPERSION MODEL OUTPUT

If the model output is to be submitted to the Ministry for review and acceptance, the recommended information should include sufficient information (tables, figures) that address the objectives of the study, the methodology and other supporting information to prove that the model has been applied properly and the model output can be used to inform decision makers. It is crucial that documentation includes sufficient methodology such that the reviewer can understand the assumptions and steps involved in the work. Recommended documentation for Level 1, 2 and 3 Assessments are defined below.

6.3.1. LEVEL1 ASSESSMENTS

The following documentation is recommended for Level 1 Assessments:

- Description of emission sources (locations, elevations).
- Stack dimensions, exit parameters, and emission rates that characterize the emissions.
- Receptor grid resolution and domain size.

- Description of topography, land use and sensitive receptors in model domain.
- Building dimensions.
- Identification of the screening model, assumptions and switches/options used.
- Maximum concentration of contaminants predicted including location and corresponding meteorological conditions.
- Baseline concentration of the contaminants of concern.
- Input files (e.g. AERSCREEN.INP, terrain data file, and external file that provides the values of surface characteristics).
- Printout of screening model output.

6.3.2. LEVEL2 OR 3 ASSESSMENTS

The following documentation is recommended for Level 2 or 3 Assessments:

Site Description

- A site plan showing location and elevation of emission sources and buildings.
- Description of topography and land use in model domain and geophysical data used in assessment (map showing contours, residential areas, roads, prominent geographic features).

Emissions Description

- Stack dimensions and exit parameters that characterize the emissions.
- Emission rates used in assessment.

Meteorological Data Description

- Description of meteorological data used in assessment, reasons for their use, and presentation of wind roses (seasonal and annual).
- If CALMET applied, examples of meteorological data (winds, temperature, stability) in space and time.
- Any pre-processing utilities and assumptions applied to prepare the data set.
- Description of meteorological conditions leading to air quality episodes.
- If NWP model output used, description of QA/QC tests undertaken to assure the quality of the output.

Model-Related Information

- Identification of model used for assessment, stating any assumptions and modifications and identifying settings used in the model.
- Receptor grid resolution and size.
- Description of QA/QC procedures used to ensure model input (e.g. CALMET-generated wind fields) is correct, and model behavior is reasonable.

Specific Output for All Pollutants Modelled (not all required, but depends on objectives of modelling study)

- Baseline concentration and an explanation as to why these baseline values were chosen.
- Figures showing the isopleths of maximum (for all averaging times of concern) and annual average predicted concentrations overlaid on a map of the model domain. Map must show the terrain, identify the sources modelled and all sensitive receptors.
- Exceedance frequencies above a specified threshold concentration.
- For multi-year dispersion modelling, map showing isopleths of maximum concentrations (including 1-h, 24-h, and annual average) over the model period (e.g. 3 years) as well as each individual year and including all receptors modelled.
- Concentrations based on different emission scenarios (permitted, normal operation and other operating conditions as specified).
- Model output may include scenarios of existing sources, individual new sources, project case and cumulative.
- Figures showing isopleths of 98th or 99th percentile values. This may be based on hourly concentrations or daily maximum hourly values.
- Time series of model output for additional sources for a receptor located at an existing monitoring site for the same monitoring period. Model predicted concentrations should be added to monitored concentrations to determine the change in air quality at that receptor.

6.3.3. COPUTER FILES

Electronic copies of input and critical output files must be compiled and available upon request by the Ministry.

7. QUALITY ASSURANCE AND QUALITY CONTROL

Good modelling practice involves the examination of the input files to ensure that specific data treatments have been applied properly (missing data, calms, formats and units). However, even with error-free input files, there is no assurance that the model output will be correct. For example, CALPUFF has user-adjustable parameters, where expert judgment is required to set the right combination of these parameters in order to improve model realism. A review of the output is essential as it can indicate whether the model is behaving as expected under different circumstances. Spotting odd model behavior and errors through this type of analysis comes from experience as well as expert training.

Section 9.1 provides guidance on the application of QA/QC for CALPUFF as this model can involve more professional judgment for its proper application than the other recommended models. A discussion on model performance and uncertainty can be found in Section 9.2.

7.1. CALMET/CALPUFF QA/QC PROCESS

Much of the quality assurance for CALPUFF depends on following the recommendations for preparation of the input data and the appropriate selection of model parameters as outlined here and the CALPUFF User's Guide[41]. Further efforts for quality control are recommended in the following sections. They are not exhaustive, nor are all of them necessary. They focus on CALMET, as this component of the CALPUFF modelling system involves the greatest amount of data preparation, option choices and user-defined parameters.

7.1.1. CALMET/CALPUFF QA FILES

A good starting point is to review the QA files produced by CALMET/CALPUFF to plot and check the locations

of the grid, NWP grid points, and source locations as these reflect the locations actually seen by CALMET/CALPUFF, including any undetected errors in the input files (blanks, comma instead of period, wrong UTM zone, etc.).
The following sections provide more detailed QA/QC procedures on the input data and output files.

7.1.2. CALMET INPUT DATA

- Plot the terrain and land use from the GEO.DAT input files to ensure they match with other maps of the area.
- Plot the locations of the meteorological observation stations to check whether they are located properly in the horizontal and vertical.
- Compare all the CALMET-ready input files with the raw data to ensure no errors in data conversion to CALMET-ready files (reformatting, unit conversions, etc.).
- Compare each month of CALMET input meteorological files with each other to ensure all parameters are consistent from month to month.
- For meteorological files, plot wind roses and frequency distributions of the various inputmeteorological parameters and check for reasonableness given the location and geophysical characteristics. If NWP model output is used, the QA/QC process is provided in Section 6.1.
- For the CALPUFF.INP file, review all source information (values, formats, units) associated with Input Group 13-16 of the CALPUFF.INP file to ensure emission information is correct.
- Plot the source locations to ensure that they are located properly and ensure that their vertical location (stack base relative to terrain height for that location) is correct.
- For the CALPUFF.INP file, review locations (horizontally and vertically) of all specified receptors.

7.1.3. CALMET OUTPUT DATA

- Select a few representative periods where thermally driven flows (i.e., upslope and drainage flows) would be expected. Plot the wind vector fields at various levels to confirm that the wind fields are reasonable given the terrain and the meteorological conditions.
- Plot the frequency distribution of surface wind speeds for different locations in the domain and at the surface station locations and check for reasonableness (compare with observations, consider the location, and what might be expected given the topography).
- Plot annual and seasonal surface wind roses for different locations as well as the surface station locations and check for realism (compare with observations, consider the location, and what might be expected based on topography).
- For different 24-h periods within a summer and winter season, plot a surface, mid-level and upper-level wind field every hour for a 24-h period with light winds and stable conditions. Check for reasonableness of the wind fields in the domain (extent of terrain effects and the appropriateness of the settings that require expert judgment).

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[41] http://src.com/calpuff/download/CALPUFF_UsersGuide.pdf

- Plot time series of average surface temperature by month for the source location as well as surface station locations. Compare with observations/climate normals. Check for reasonable monthly variation for the given locations.

- Plot time series of average surface temperature by hour-of-day for the source location as well as surface station locations. Compare with observations/climate normals. Check for reasonable diurnal variation for the given locations.

- Plot time series of average precipitation by month (if precipitation is an input) for one location as well as surface station locations. Compare with observations. Check for reasonable monthly variation for the given locations.

- Plot the frequency distribution of mixing heights for different locations. Check for reasonableness.

- Plot a time series of mixing heights for a 24-h summer and winter period during a light wind, and a clear sky period. Examine the diurnal behaviour for reasonableness.

- Although the Guideline recommends the AERMOD type dispersion option for local scale applications (on the order of <50 km) in CALPUFF, it is a good idea to also produce P-G stability class and plot the frequency distribution for the source location as well as surface station location. Compare to the airport observation PG class frequency distribution (if available). Check for reasonableness for the given locations.

- If NWP model output is used, examine CALMET-generated wind fields for a 24-h period of light winds, and clear skies at surface, mid and upper levels with and without NWP output and check for reasonableness.

7.2. MODEL PERFORMANCE AND UNCERTAINTY

Although a simple comparison between model predicted concentrations and observations may indicate that the model is over or under-predicting by some factor, model predicted concentrations cannot be adjusted by this factor to “make the results closer to reality”. Proper model evaluation requires considerable expertise in order to interpret the performance of a model, and as such “adjustment factors” cannot be applied to the output.

Measurements and model predictions can be compared in a variety of ways, each providing a different perspective on model performance. A model may show good competency in certain predictions (e.g., maximum concentrations) but poor in others (e.g., the frequency of concentrations above a certain threshold). Although it is common to blame the model for poor performance, there are other reasons that are often not considered. These include:

- Uncertainties in the input values of the known conditions (e.g., poor quality or unrepresentative meteorological, geophysical and source emission data).

- Errors in the measured concentrations that are used to compare with model predictions.

- Inadequate model physics and formulation.

The sources of uncertainty in the model predictions listed above are considered “reducible”. That is, they can be controlled or minimized by collecting the proper input data, preparing the input files correctly, checking and rechecking for errors, correcting for odd model behavior, ensuring that the errors in the measured data are minimized and applying better model physics. However, even if the reducible uncertainty is eliminated (i.e., perfect input with the perfect model), there is always “inherent uncertainty” in model predictions that cannot be eliminated.

Dispersion models use known conditions (as defined by wind speed, stability, emission rate, etc.) to produce concentrations for this specific event. Even though much is known about the processes involved in dispersion, there are unknown conditions (turbulent processes that are not completely known and cannot be resolved by measurements and known science). These unknown conditions may vary even under seemingly identical repetitions of an event (under what seems to be exactly the same wind speed, stability, emission rate, etc.) and can result in differences between the model prediction and observations for that event. Such differences could be due to "inherent uncertainty", something that would occur even if the inputs, models and modellers were all "perfect". See EPA (2005) for a more complete rendering of this concept.

The U.S. EPA has developed the following general statements on model performance (US Environmental Protection Agency, 2005). Such statements must be considered in their totality (i.e., quoting one of the statements in isolation of the others does not provide a complete picture).

- Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations.
- The models are reasonably reliable in estimating the magnitude of *highest* concentrations occurring sometime, somewhere in the area. For example, errors in *highest* estimated concentrations of ± 10 to 40% are found to be typical (assuming appropriate inputs).
- Estimates of concentrations that occur at a specific time and site are poorly correlated with actual observed concentrations (paired in space and time) and are much less reliable.
- The above poor correlations between paired concentrations at fixed stations may be due to reducible uncertainties (i.e., error in plume location due to input wind direction error can result in large differences) or un-quantified inherent uncertainties. Such uncertainties (which can be on the order of 50% for the maximum concentrations) do not indicate that an estimated concentration does not occur, only that the precise time and locations are in doubt.

It is recognized that model performance will vary depending on the application. For example, in some cases a model may consistently over-predict, and in others, it may consistently under-predict. Although this behaviour may change depending on the application specifics, it is not necessary to conduct a full model performance evaluation every time a model is used. To do so properly involves considerable effort and regulatory agencies (including the Ministry) assume the results of carefully controlled tests conducted and/or reviewed by the U.S. EPA provide insight on how well they will perform in a variety of other applications.

The goal of the Guideline is to minimize the reducible error by providing direction on input data, the appropriate choice and application of models, and directions on preparing model input files and settings. There is considerable reliance on the training and experience of the modeller to ensure each of these steps is done properly. If the guidance provided here (i.e., the 11 Steps to Good Modelling Practice) is followed and there are no errors in the selection, setup and application of the model, model performance is expected to be similar to the performance under U.S. EPA test situations. Under these conditions, the predictions from models can be viewed as the "best estimate" available to inform decision making.

8. SPECIAL TOPICS

8.1. FLARING

The flaring of sour gas (i.e., gas streams with H_2S) results in emissions of SO_2. Continuous flaring with relatively constant emissions and can be treated by models as a continuous point source. However, flaring can be short-term with variable emissions over hourly or sub-hourly periods and as such adjustments are required to account for these situations. The following sections provide modelling guidance for these different types of flaring.

8.1.1. FLARE SOURCE PARAMETERS

The Guideline Screening model AERSCREEN has an explicit treatment of flare stacks. AERSCREEN requires:

- emission rate of SO_2
- flare stack height
- total heat release rate
- radioactive heat loss fraction

The use of 55% of the radioactive heat loss fraction is recommended although there is evidence (Guigard, Kindzierski, & Harper, 2002) that this value for these types of flares is very conservative.

The Guideline Refined model AERMOD does not have an explicit treatment of flares. Instead, flares can be modelled as point sources with modified stack parameters (i.e. pseudo-stack parameters) which are selected to ensure the correct plume rise is calculated. Use the following formulas to compute the effective stack height and effective stack diameter:

$$H_e = H_s + (4.56 * 10^{-3}) * Q^{0.478}$$

$$D_e = 0.0122 \sqrt{\frac{T_s * Q * (1 - F)}{g * (T_s - T_a) * V_s}}$$

Where:

H_e = effective stack height (m)

D_e = effective stack diameter (m)

H_s = physical stack height (m)

g = acceleration due to gravity = 9.81 m/s^2

Q = total heat release (cal/s)

F = radioactive heat loss fraction (%)

V_s = effective stack exit velocity (m/s)

T_s = effective stack exit temperature (K)
T_a = ambient temperature (K)

The following is recommended for calculation of pseudo-stack parameters for AERMOD:

- Obtain the total flare heat release, Q (in cal/s), by summing the heat of combustion of the individual flared gas components based on the volume flared in one second.
- Set effective stack exit velocity to 20 m/s. Contact the Ministry for a different value.
- Set effective stack exit temperature to 1273 K. Contact the Ministry for a different value.
- Ambient temperature is typically set to 293 K. Contract the Ministry for a different value.
- Set radioactive heat loss fraction to 55%.

Although the latest version of CALPUFF (version 7.0.0) has a flare source type, it is recommended that flares be modeled by CALPUFF as point sources with those pseudo-stack parameters which are calculated by the formulas above.

8.1.2. INTERMITTENT EMISSION: ABNORMAL (UNSCHEDULED) FLARING

A gas processing facility can flare source gas under abnormal operations: by-pass flaring for plant safety during process upsets, maintenance flaring, or flaring under start-up or shut down conditions. Although such emissions are a relatively rare occurrence, they are an expected part of the operation of a gas processing facility and as such it is important to understand the air quality implications of these different abnormal emission scenarios. Although the probability of abnormal flaring occurring at the same time as poor dispersion conditions may be very small, modelling the worst-case air quality scenario is recommended to show due diligence to protect the environment.

The following is recommended for situations where the emissions associated with these situations *can be quantified:*

- Establish the realistic emission scenarios associated with abnormal emissions (based on the physics/chemistry of the process) and their anticipated duration and frequency of occurrence based on the potential abnormal operation scenarios (example: start up, shut down).
- Apply AERSCREEN to determine the potential worst-case concentration for these scenarios.
- If AERSCREEN-predicted maximum 1-h SO_2 concentrations exceed 450 µg/m^3, additional refined dispersion modeling (AERMOD or CALPUFF) is required.
- For refined modeling, the following is recommended:
    - If the flaring is relatively constant during the flaring period, this type of flaring should be modelled as a continuous source with a representative, constant emission rate and at least one year of meteorological data. o If the flaring is not constant during the flaring period, then follow the steps in the next section for transient emission periods.
- If the predicted 1-hr SO_2 concentrations exceed 450 µg/m^3, then either:

- The heating value should be adjusted by adding fuel gas until the ambient guideline is met, or
- Indicate the potential for exceedances by assessing the probability of the meteorological conditions associated with the predicted worst-case air quality. If this is a planned event (such as scheduled maintenance) then the period of flaring can be based on avoiding the worst-case meteorological conditions or during periods when the likelihood of such conditions is extremely low.

8.1.3. INTERMITTENT, TRANSIENT RELEASES: SCHEDULED PIPELINE BLOW-DOWN FLARING

There are situations when flaring occurs under controlled or scheduled situations such as pipeline blow-down flaring. In these situations a flare stack may be used to depressurize a pipeline (for such scheduled activities such as pipeline repair, testing, abandonment, cleaning) and the flow rate of gas to the flare will be transient (i.e., it will decrease over time). Modelling these scenarios can be difficult since parameters such as duration and flow rates will vary depending on the nature of the event and the design of the flare. In addition, it is not clear what period of the blow-down will result in high ground level concentrations. At the beginning the SO_2 emissions are the greatest, however the plume rise is the highest. At the end, although the SO_2 emissions are low, the plume rise is also low. Thus different periods need to be modelled to determine which part of the blow-down period will yield the maximum ground level concentration. In these cases the following is recommended:

- Given that the dispersion modeling is for scheduled release situations where gas volumes are known, calculate the temporal blow-down profile (emission vs time).
- For multi-hour transient emissions (i.e., blow-downs):
  - Determine hourly average emission rates.
  - Run AERSCREEN for each hourly emission segment. If predicted maximum 1-h concentrations for any of those segments exceed 450 µg/m^3, additional refined dispersion modelling (AERMOD or CALPUFF) is required.
  - For refined modeling, assume a continuous source with emission rates varying on an hourly basis and at least one year of meteorological data.
- For transient emissions (i.e., blow-downs) periods less than one hour:
  - Determine the duration (in minute) of the blow-down.
  - For screening modeling, follow the recommendations below:
    - Divide the blow-down profile into three *n*-minute average emission segments.
    - Run AERSCREEN for each *n*-minute emission segment.
    - Multiply the predicted maximum 1-h concentration by *n*/60 to arrive at the adjusted 1-hr concentration. If the adjusted maximum 1-h concentrations from any of those segments exceed 450 µg/m^3, the SO_2, additional refined dispersion modeling (AERMOD or CALPUFF) is required.

- For refined modeling, assume a continuous source with emission rates varying on a sub-hourly basis and at least one year of meteorological data.

- For those emission segments where exceedances are predicted, then either:
    - adjust the heating value by adding fuel gas until the ambient guidelines is met, or
    - indicate the potential for exceedances by assessing the probability of the "worst-case" meteorological conditions associated with these exceedances. For transient emissions that are scheduled, the time of release can be based on avoiding the worst-case meteorological conditions or during periods when the likelihood of such conditions is extremely low.

8.1.4. WELL TEST FLARING

The operator must conduct an air quality assessment for flaring sour gas in situations where the H_2S concentration ≥ 1 mole percent.

Depending on the maximum predicted concentration, the operator must submit a Level 1 Assessment and in some situations, a Level 2 or 3 Assessment. These are described in the following sections.

10.1.4.1. LEVEL1 ASSESSMENTS

AERSCREEN (with default heat loss fraction of 55% and user-specified surface characteristics) must be used for the Level 1 Assessment. A Level 2 or 3 Assessment is required if:

- Well-test flaring is planned between April and September inclusive and AERSCREEN predicts an exceedance of 450 $\mu g/m^3$.
- Well-test flaring is planned between October and March inclusive and AERSCREEN predicts an exceedance of 900 $\mu g/m^3$.

Options for reducing the air quality impact can be considered such as: reducing the flaring rate and/or increasing the flare stack height, delay until winter (October - March) or directing the flow into a pipeline. These options can be assessed by re-doing the Level 1 Assessment.

10.1.4.2. LEVEL2 ASSESSMENTS

AERMOD or CALPUFF must be used for the Level 2 Assessment. The area to be modeled should have a minimum radius of 10 km from the flare site. Either polar or Cartesian coordinate systems can be used.

- If the Cartesian coordinate system is used, gridded receptors should be placed at no more than 100 m apart for the first 4 km from the flare, and at no more than 250 m apart (for extreme complex terrain) for distances from 4 to 10 km from the flare site.
- For the polar coordinate system, gridded receptors should be placed at no more than ten degree intervals and at no more than 100 m apart for the first 4 km, and at no more than 250 m apart for distances from 4 to 10 km from the flare site. The source of terrain information must be specified.

If predicted maximum 1-hr SO_2 concentrations exceed 450 $\mu g/m^3$, the operator may wish to redesign the test parameters (e.g., modify the flare rates, increase the stack height, and wait until winter season).

10.1.4.3. HUMAN HEALTH: ASSESSMENT, MITIGATION AND MONITORING

In order to address the risk to human health based on the Level 2 or 3 Assessments, if the maximum predicted 1-h SO_2concentration exceeds 900 µg/m^3 at any residences, then:

- The applicant must submit a plan to continuously monitor ambient SO_2 levels at the affected residences throughout the flaring operation, and
- The operator must indicate that flaring will be suspended if ambient hourly levels exceed 900 µg/m^3 at the residential monitoring location.

10.1.4.4. VEGETATION: ASSESSMENT, MITIGATION AND MONITORING

In order to address vegetation effects, the operator must submit predictions for potential "visible foliar injury":

- If well-test flaring is planned between April and September inclusive and the Level 2 or 3 maximum predicted SO_2concentration exceeds 450 µg/m^3.
- If well-test flaring is planned between October and March inclusive and the Level 2 or 3 maximum predicted SO_2concentration exceeds 900 µg/m^3.

"Visible foliar injury" is determined using the concentration versus duration equations developed by Legge (1995) (see Table 10.1). The duration values in the Legge (1995) vegetation effects equations are based on four categories:

- start of growing season (spring)
- growing season (summer)
- dormant stage (winter)
- nighttime (spring and summer)

Table 10.1 The Legge SO_2 Concentration Criteria for the Onset of Acute Visible Foliar Injury

Number of consecutive hours with concentration above given level	Apr – Jun (daytime) (µg/m^3)	Jul – Sep (daytime) (µg/m^3)	Apr – Sep (nighttime) (µg/m^3)	Oct – Mar (all hours) (µg/m^3)
1	1306	1741	4724	7086
2	832	1110	3025	4538
3	639	852	2331	3496
4	530	707	1937	2906
5	459	612	1678	2517
6	408	543	1493	2239
7	369	491	1352	2028
8	338	451	1241	1861

9	313	417	1150	1725
10	292	390	1075	1612
11	275	366	1011	1516
12	260	346	956	1434

The vegetation sensitivity to SO_2 is dependent on the season and time of day that influences when vegetation is susceptible. Table 10.1 shows that calculated hourly concentration (µg/m^3) required for each group of consecutive hours (e.g., for the daytime period in May, hourly concentrations over 459 µg/m^3 for five consecutive hours can result in visible foliar injury).

For application of the foliar damage assessment, receptors should be set at the height of the vegetation canopy in the region of the flare. Typically, this would be a flagpole height of 15 m.

Along with this analysis, based on the predicted hourly SO_2 the operator must submit:

- Figures that show the spatial distribution of the number of hourly exceedances above concentrations of 900, 1300, 1700, 4700 and 7000 µg/m^3,
- A figure that shows the maximum concentration predicted at each receptor point, and
- Any areas where visible foliar injury is predicted to occur.

With regards to the physical environs around the flare, the operator must also:

- Submit a map showing the elevation contours and location of any residence or areas that may have people (i.e., camp sites, coal mines),
- The elevation and location (either lat./long. or UTM coordinates) of the flare site,
- The expected flare date, flow rate, stack height, gas composition,
- A wind rose of the meteorological data used, and
- Emission parameters (including pseudo-stack parameters) used in the modelling.

If there is a potential of acute visible foliar injury, then the operator must provide:

- The meteorological conditions to avoid during flaring, which may cause the acute visible foliar injury.

Where potential for significant vegetation damage has been predicted prior to the test, then:

- Subsequent re-modeling of the well test using the site-specific meteorological and well-test data is required.

8.2. STAGNATION CONDITIONS

Light wind conditions can lead to high concentrations as emissions can build up in an area or transport slowly downwind with very little mixing and impinge on the side of a hill, resulting in high concentrations in a localized zone.

Stagnation occurs when a light wind or no-wind condition (meteorological calm) and variable wind directions for these periods persist for many hours or days. This commonly occurs in valleys, especially during the winter. With stagnation, contaminant dispersion is minimal due to limited turbulence and transport of the emissions from the area (accumulation), as well as contaminant recirculation.

If a site is subject to frequent and prolonged stagnations, straight-line Gaussian models such as AERMOD have limited value since calms treatment methods (wind speed = 0.0) eliminate these important periods (see Section 5.8.2) Furthermore, causality effects are not handled which are important during light wind, variable wind direction periods. In such cases consider the following:

- Although AERMOD has a low wind speed limit of approximately 0.3 m/s which should capture many low wind periods, the anemometer starting threshold may be much higher, leading to frequent periods of zero wind speeds and many skipped hours.
- Use CALPUFF since it can treat zero wind speeds and causality explicitly.

Use NWP output to provide wind speeds for periods where measurements indicate a calm.

8.3. SHORE / COASTAL EFFECTS

Near the shore of a large body of water, or along the coast, complex winds and turbulence are generated as a result of the difference in surface roughness and differential heating between land and water. A sea breeze (onshore breeze) can develop during the day, and at night, the opposite can occur (a land breeze or offshore breeze). The localized wind flow and turbulence can have significant effects on the dispersion of emission sources.

Coastal fumigation can occur when a tall stack located on a shoreline emits a plume towards the land into a stable (or neutral) air regime and is then intercepted by a thermal internal boundary layer over the land (TIBL). These boundary layers over the land create considerable convective or mechanical mixing and can generate high ground- level concentrations as the plume is pulled towards the ground.

In situations where these shore/coastal effects are important, CALPUFF in Hybrid mode is recommended. The NWP model output blended with observations in CALMET is an effect way to include the 3-D sea and land breeze effects in the meteorological fields. In order to properly treat the coastal effects, overwater meteorological data are required (air-sea temperature different, relative humidity, air temperature, and overwater mixing height). In addition, if the effects of the TIBL on the plumes are occurring at scales smaller than the CALMET grid spacing, then a sub-grid scale treatment can be invoked. This treatment requires the X, Y coordinates of one or more coastlines in an optional file called COASTLN.DAT. The purpose of this file is to better resolve the relationship between the coastline and source locations during periods conducive to onshore fumigation events. Further instructions on the treatment of coastline effects and the required data are found in TRC (2011b).

8.4. HORIZONTALLY ORIENTED STACKS AND STACKS WITH RAIN CAPS

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.

AERSCREEN and AERMOD can handle this situation explicitly through the selection of options, POINTCAP and POINTHOR for treating capped and horizontal plumes respectively. The source parameters are input as if it were a vertically oriented stack and the model applies adjustments internally to account for these types of orientations. For plumes with little or essentially no buoyancy, users can specify a stack gas exit temperature = 0.0 K which automatically sets the exit temperature to the ambient temperature.

CALPUFF can also handle these sources through the use of the adjustable vertical momentum flux factor (FMFAC) for point sources with constant emissions which ranges from 1 (corresponding to a vertically oriented stack) to 0 (corresponding to a horizontal or capped stack with no vertical momentum). If time varying point source emissions are applied, in the PTEMARB.DATE file, set TIDATA(7) (the vertical momentum flux) = 0.

8.5. LIQUID STORAGE TANKS

There are two types of liquid storage tanks. One has a fixed roof where most vapours are emitted through a single vent to top of the tank. The other type has a floating roof, where most of the emissions occur from between the wall and the floating cover i.e., through the seal between the two.

For these two types, the following is recommended:

- For fixed roof tanks, treat the vent as a point source and consider the tank as a building where downwash effects are included.
- For floating roof tanks, treat the emissions as at least 8 point sources (where the emissions are distributed equally) positioned equidistant around the perimeter of the tank, and consider the tank as a building where downwash effects are included.

Note that if the emissions from these sources have no plume rise, so treating them as point sources as recommended above means that both the momentum and buoyancy should be set to zero through the inputting of the following:

- exit velocity = 0.001 m/s
- exit diameter = 0.001 m
- exit temperature = ambient

These apply for all the models recommended in this Guideline. For AERSCREEN and AERMOD, if the stack gas exit temperature = 0 K, the exit temperature is automatically set equal to the ambient temperature.

8.6. PLUME CONDENSATION (FOGGING) AND ICING

For fog assessments where the distances of a condensed visible plume or where areas of potential icing need to be identified, CALPUFF with the FOG algorithm is recommended (MFOG=1). The FOG module in CALPUFF has two modes: the Plume mode (provides the length and height of the visible plume due to condensation) and the Receptor mode (indicates whether there is ground based fog or ice occurring at each receptor). To assess the length andheight of visible plumes, CALPUFF is used with a single location hourly “ISCMET” meteorological data file that includes hourly wind speed, direction, temperature, stability class, mixing height, etc..

There are two source emission preprocessors: one for cooling tower plumes (CTEMISS) and one for combustion turbines (FGEMISS). These pre-processors create CALPUFF-ready PTEMARB.DAT variable water vapour emission files as input to the CALPUFF-ISC fog model. In addition, these preprocessors can work only with the Schulman-Scire building downwash algorithm.

8.7. WET AND DRY SULPHUR AND NITROGEN DEPOSITION

CALPUFF is recommended for regional scale estimates of sulphur and nitrogen deposition. There are several chemical transformation options available, and CALPUFF V6.42 includes the more advanced RIVAD/ISORROPIA chemical mechanism. Based on two plume studies, Scire, et al. (2012) reports that it performs better, avoids the large over prediction bias in nitrate concentrations associated with the old methods, and has improved NO_x and sulphate transformation rates.

For this reason, the Guideline recommends the RIVAD/ISORROPIA mechanism (MCHEM=6) for regional scale wet and dry deposition estimates. As such, Table 10.2 provides the corresponding options and settings for this selection.

If aqueous phase chemistry is selected (MAQCHEM=1) then MLWC=1 is recommended in order to get full 3dimensional, gridded cloud liquid water content from MM5/WRF through CALMET. CALMET must be set up to output additional auxiliary “calmet.dat.aux” file.

Finally, the post processor POSTUTIL has been updated to include the ISORROPIA gas/particle partitioning scheme. For the RIVAD/ISORROPIA chemistry treatment (MCHEM=6), then in POSTUTIL select MEQPHASE=2 (ISORROPIA scheme for nitrate partitioning).

Table 10.2 Recommended CALPUFF Input Group 11a, 11b RIVAD/ISOROPPIA Chemistry Parameters (TRC Environmental Corporation, 2010) (Lawrence, 2012)

Black (do not touch)Dark Grey (recommended default)Light Grey (expert judgement required)White(user specified values)

Option	Parameter	Value	Explanation & Justification
Ozone data input option	MOZ	0	(0) use a monthly background ozone value
Monthly ozone concentrations	BCKO3		For MOZ = 0 specify 12 ozone values for each month in ppb (default: 12*80.0)
Monthly ammonia data input option	MNH3	0	(0) use a monthly background ammonia value for all layers
Ammonia vertical averaging option	MAVGNH3	1	Not used if MNH3 = 0
Monthly ammonia concentrations	BCKNH3		used only if MCHEM = 1, 3, 6, or 7 and MNH3 = 0 Specify 12 ammonia values for each month in ppb (default: 12*10.0)

Nighttime SO2 loss rate in %/hour	RNITE1	0.2	Used for day and night for MCHEM = 6 or 7. Use default
Nightime NOx loss rate in %/hour	RNITE2	2.0	Used only if MCHEM = 1
Nightime HNO3 loss rate in %/hour	RNITE3	2.0	Used only if MCHEM = 1
H2O2 data input option	MH2O2	0	Used only if MCHEM = 6 or 7 and MAQCHEM = 1 (0) monthly background H_2O_2 value (1) read hourly H_2O_2 concentrations from the H2O2.DAT data file
Monthly H2O2 concentrations in ppb	BCKH2O2		Used only if MAQCHEM = 1 and either MH2O2 = 0 or MH2O2 = 1 and all hourly H_2O_2 data missing Specify 12 H_2O_2 values for each month in ppb (default 12*1.)

8.8. POINT SOURCE PLUME: SECONDARY PM $_{2.5}$ AND O_3

Predicting secondary $PM_{2.5}$ and O_3 has been the exclusive domain of regional photochemical grid based models, where models such as CMAQ are applied over large domains that include urban areas that include thousands of sources of various types. However, for assessing the contribution of a single point source (or sources in a limited area), predicting the secondary pollutants is problematic since the plumes from these sources cannot be resolved by the grid. As a way to treat this, plume-in-grid (PIG) methods have been used, so sub-grid processes such as dispersion and chemical transformation can be applied.

There are other methods that can treat point-source plume chemical transformation. For example, CALPUFF (Beginning with Version 6.0) includes the RIVAD/ISORROPIA chemical mechanism (the same mechanism used in CMAQ), which provides the ability to calculate secondary $PM_{2.5}$ for regional scale applications.

Currently there are no methods/models that are preferred for this purpose. If this is a critical issue in the assessment, methods should be discussed with the Ministry and included in the Dispersion Modelling Plan.

9. MODEL RESOURCES

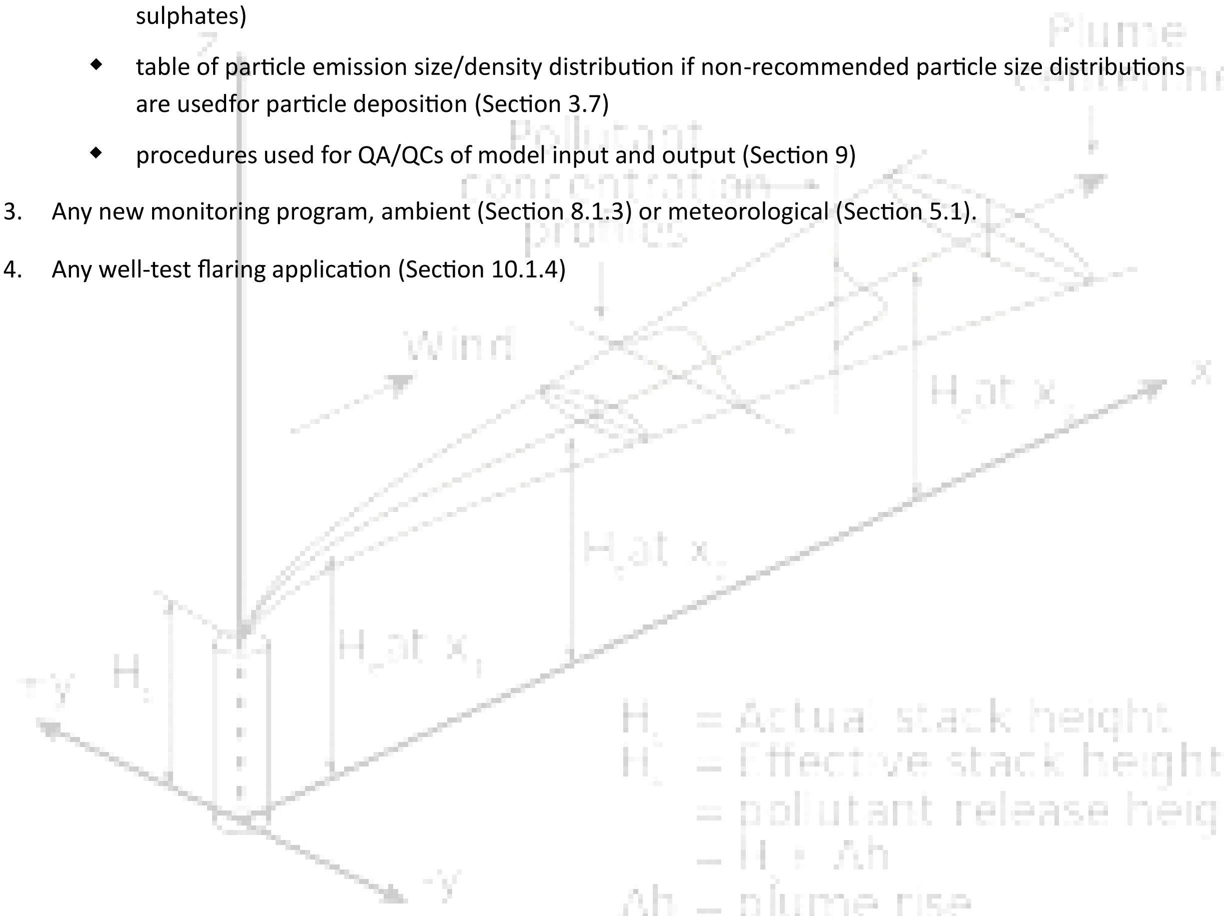
9.1. A SUMMARY OF MINISTRY RECOMMENDED ACCEPTANCE ITEMS

Throughout this the Guideline, there are references made to the need for Ministry review and feedback on certain proposed choices and actions. These are summarized here.

1. Use of an alternate model or modifications to a Guideline model (Section 2.3.1 and 2.3.2)
2. Dispersion modeling plan should include:
   - general approach (Section 1.5)
   - project description and geographic setting
   - model selected (Section 2), model domain (Section 6.4.2 and 7.1), model switch settings (Section 6.4.3, 7.7 and 7.8) and receptor grid (Section 7.2 and 7.4)
   - planned model output (Section 8.3)

- method used to establish source emission rates (Section 3.3 and 3.4)
- method used to establish baseline concentrations (Section 8.1)
- building information for downwash if applicable (Section 7.6)
- the source of the geophysical data and data treatment (Section 4)
- meteorological data input sources (Section 5), including NWP model output if applicable and how they areused in AERMOD and CALPUFF its application if applicable. (Section 6.1 and 6.3)
- if applicable, the method used to determine NO_2 concentrations (Section 8.2)
- if applicable, the method used for chemical transformation and its detailed inputs (e.g., ammonia, ozone,hydrogen peroxide concentrations, and nighttime loss and formation rates for nitrates and sulphates)
- table of particle emission size/density distribution if non-recommended particle size distributions are usedfor particle deposition (Section 3.7)
- procedures used for QA/QCs of model input and output (Section 9)

3. Any new monitoring program, ambient (Section 8.1.3) or meteorological (Section 5.1).
4. Any well-test flaring application (Section 10.1.4)



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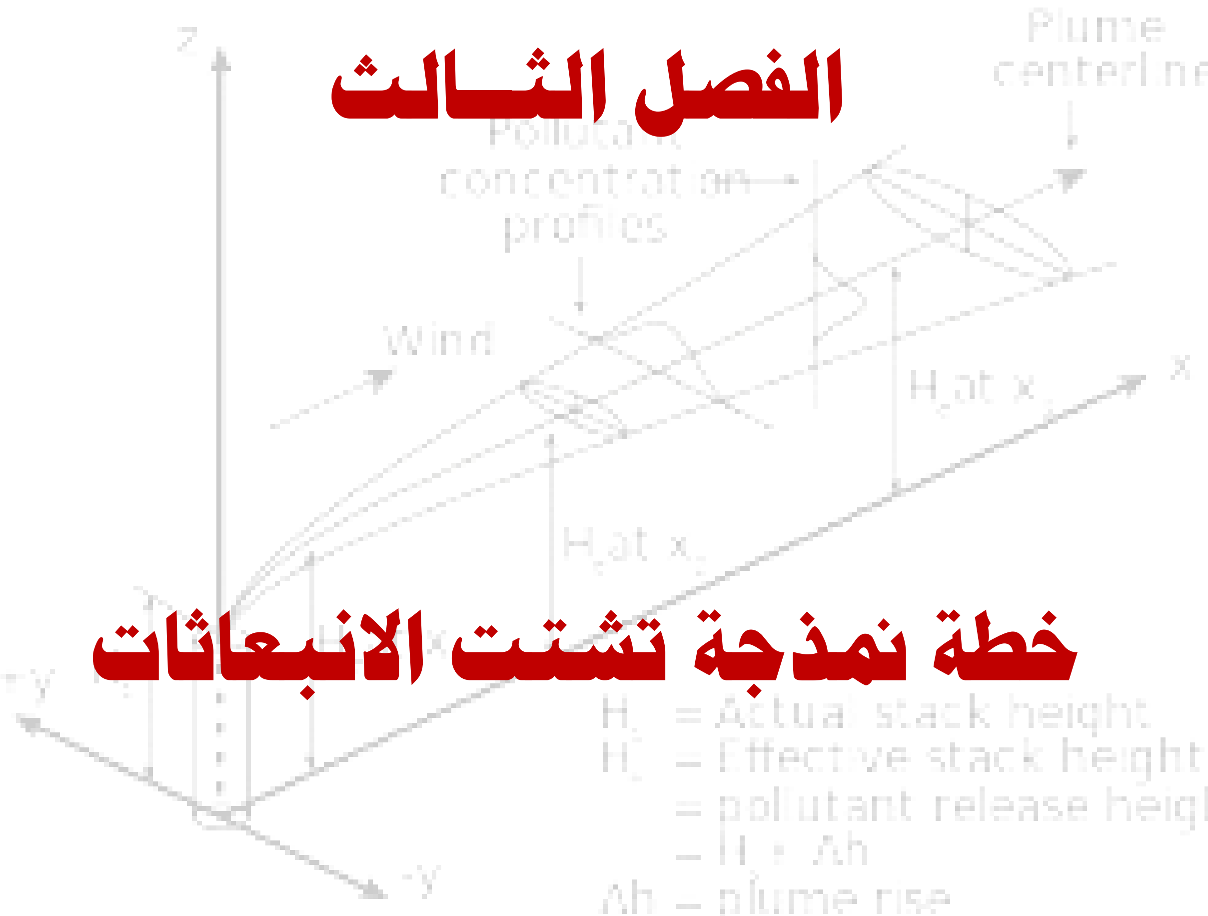
الفصل الثـــالث

خطة نمذجة تشتت الانبعاثات



خطة نمذجة تشتت الإنبعاثات

عمل خطة لتوضيح خطوات نمذجة تشتت الإنبعاثات هي خطوة مهمة من أجل وضع معايير عامة يسهل اتباعها من منفذي دراسة التشتت وبالتالي تجنب سوء الفهم والتأخير.

مكونات خطة نمذجة تشتت الانبعاثات:

١- **بيانات عامة**

- تاريخ الخطة
- اسم المنشأة / الشركة
- الموقع / الاحداثيات (خط الطول ، خط الطول)
- الاستشاري البيئي المسئول عن النمذجة واسم جهة الاتصال
- رقم الاعتماد للاستشاري وتاريخه (يرفق صورة من شهادة الاعتماد)
- اسم جهة الاتصال بالوزارة
- مستوى التقييم (أولى ومتقدم أو متخصص) وكذلك أذكر الأسباب المنطقية لاختيارك لمستوى التقييم المقترح (يمكن الرجوع الى البند ٢ في الدليل الإرشادي)

٢- **وصف المشروع والإعدادات الجغرافية :**

- قدم نظرة عامة على وصف المشروع، بما في ذلك وصف خطوات النمذجة والغرض من دراسة نمذجة التشتت (لا يتعدى صعدد صفحة).
- قدم وصفًا لما يلي:

– خصائص التضاريس داخل منطقة الدراسة: هل التضاريس مستوية أو التضاريس غير المستوية (توجد مناطق أعلى من مصدر الانبعاث او في مستواها في الارتفاع (**complex terrain**)) .

– الغطاء الأرضي السائد: حضري ، ريفي ، صناعي ، صحراوي ، زراعي ، مشجر ، صخري ، مائي ، مراعي .

٣- نموذج التشتت

اذكر النموذج المستخدم (النماذج) – رقم الاصدار والإصدار الذي سيتم استخدامه (انظر البند٢ في الدليل الإرشادي)، لا يسمح باستخدام اصدارات قديمة، يسمح باستخدام الاصدار الاخير أو قبل الاخير فقط من نموذج التشتت .

٤- برنامج إدارة الجودة

- بيانات إدخال النموذج (حدد الاختبارات التي سيتم إجراؤها لضمان جودة المدخلات).
- ببيانات المدخلات الجيوفيزيائية (رسم خريطة كونتورية للتضاريس الخاصة بمنطقة الدراسة، رسم خرائط توضح تصنيف الاراضى وطبيعتها (**land use and land cover**) .
- ببيانات الأرصاد الجوية:
  - ➢ رسم وردة الرياح (السنوية و/ أو الموسمية) .
  - ➢ رسم يوضح توزيع ترددات سرعات الرياح السطحية(السنوية و / أو الموسمية) .
  - ➢ رسم يوضح متوسط درجات الحرارة الساعية (سنوية و / أو موسمية) .
- عند استخدام **CALMET/CALPUFF**، قدم قائمة بالاختبارات التي أجريت للتأكد من جودة مخرجات النموذج (ملفات ما قبل المعالجة المتوسطة وتوقعات التركيز / الترسيب).

وفيما يتعلق بالملفات المعالجة مسبقاً التي يتم إعدادها لإدخال **CALPUFF** ، هناك العديد من الاختبارات التى سيتم تحديدها من قبل الوزارة للتحقق من المخرجات من البرامج التي يتم استخدامها لإعداد بيانات مدخلات **CALPUFF** قبل المعالجة للتأكد من أنها قد تمت معالجتها بشكل صحيح. وهذه تتعلق بالتحقق مما يلي:

- التضاريس، والأراضي المستخدمة (**land use**)
- المصادر (المواقع والارتفاعات) وخصائص الانبعاث
- بيانات الأرصاد الجوية (المواقع) والاختبارات للتأكد من المعالجة السليمة لبيانات الأرصاد الجوية الخام (الوحدات والعناصر
- مواقع المستقبلات والارتفاعات

وبالنسبة لمخرجات **CALMET**، هناك عدة اختبارات (لابد من مراجعة الوزارة) لاختبار نوعية بيانات الأرصاد الجوية المولدة. وهي تتعلق باستعراض ما يلي:

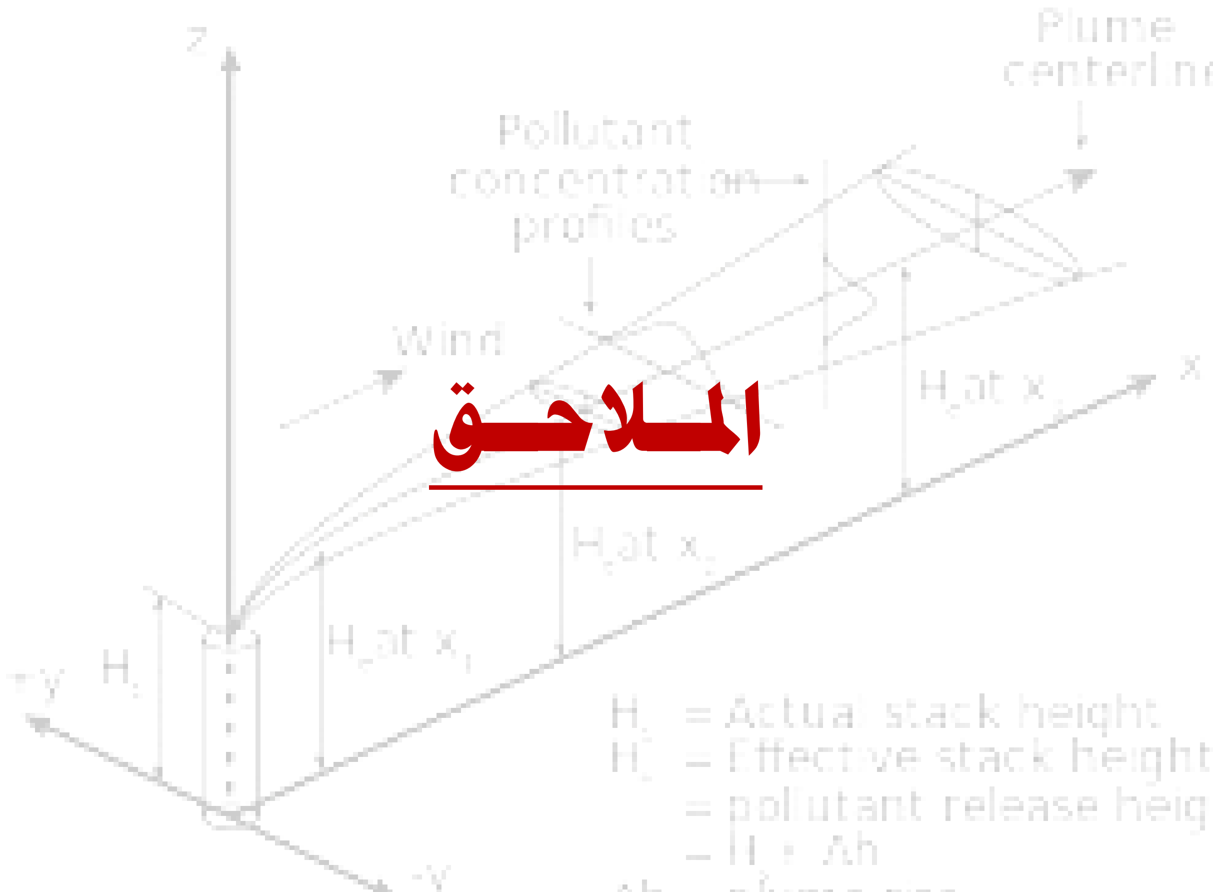
- خرائط الرياح (سطحية وعلى ارتفاعات مختلفة) لفترات محددة حيث تكون التأثيرات الطبوغرافية (التدفقات الحرارية المسببة لحركة الرياح) واضحة .
- وردة الرياح لمواقع مختارة وارتفاعات مختارة (السنوية والموسمية) .
- توزيعات التكرارات لمختلف عناصر الأرصاد الجوية (السنوية والموسمية) .

٥- <u>الملفات الإلكترونية</u>

- قائمة ووصف الملفات الإلكترونية
- الملفات الإلكترونية المطلوبة لتقديمها مع التقرير
- ملفات الإدخال والإخراج للنموذج المستخدم .
- ملفات الإدخال والإخراج للمعالجات السابقة (إن وجدت) .
- ملفات الإدخال والإخراج لمرحلة ما بعد المعالجات (إن وجدت) .
- ملفات وخرائط التضاريس الرقمية .
- الملفات الرسومية المختلفة .
- التقرير النهائي .

ملاحظة: يجوز للوزارة أن تطلب تقديم جميع ملفات الكمبيوتر المرتبطة بالنمذجة عند الطلب.

الملاحق


Plume
centerline
Pollutant
concentration
profiles
Wind
z
x
-y
+y
H_s
H_e at x_1
H_e at x_2
H_e at x_3
H_s = Actual stack height
H_e = Effective stack height
= pollutant release heigl
= $H_s + \Delta h$
Δh = plume rise