FINAL REPORT

AN ANALYSIS OF THE ATMOSPHERIC DISPERSION OF RADIONUCLIDES RELEASED FROM THE IDAHO CHEMICAL PROCESSING PLANT (ICPP) (1957-1959)

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EXECUTIVE SUMMARY

This report describes the estimation of air concentrations arising from radionuclide emissions during the 1957-1959 period from Idaho Chemical Processing Plant (ICPP) at Idaho National Engineering Laboratory (INEL). The air concentrations are a component in the assessment of radioactive dose arising from these emissions. The air concentrations were estimated using atmospheric dispersion modeling and incorporated uncertainty analyses to provide quantitative confidence intervals on the estimated air concentrations. The distributions of air concentrations developed from the uncertainty analysis were subsequently used in a pathways analysis and dose assessment.

INEL, established in 1949 as the National Reactor Testing Station, started operating the ICPP in 1953. Radionuclides were released from the ICPP during the Radioactive Lanthanum (RaLa) operations at the ICPP that began on Feb. 1, 1957 with the largest amount of radioactivity released between Feb. 1, 1957 and Dec. 31, 1959. The emission rates generally decreased over this time period.

The emissions from the RaLa operations included more than 130 radionuclides. A previous screening analysis (Kocher 2005a, b) determined that $^{131}$I was by far the most important radionuclide in regard to potential radiation doses to members of the public who resided near INEL during the years 1957-1959. Twelve additional radionuclides of potential concern have also been selected for inclusion in a more detailed dose reconstruction. Air concentrations were estimated using uncertainty analyses for all thirteen radionuclides; however, discussion in this report primarily concerns $^{131}$I.

The CALPUFF/CALMET system of computer codes was used to perform the atmospheric transport calculations due to the complex terrain, and meteorology, in the area and the ability to estimate meteorological conditions with limited measurement data during the 1957-1959 period. There was also good agreement between the estimated air concentrations using CALPUF/CALMET and measured concentrations from recent tracer studies.

Discrete receptors were identified for the uncertainty analysis of air concentrations to support the dose assessment. A systematic grid was established for deterministic modeling of air concentrations and creation of contour plots of the concentrations.

Sources of uncertainty included the emission rates, the selection of options when running the air dispersion model, and the effect of uncertainty in the meteorological conditions during the 1957-1959 period on the estimated air concentrations. Meteorological data are only available for three surface air stations during the 1957-1959 period. This uncertainty was quantified by comparing air dispersion modeling conducted in 1999 using these three stations and air dispersion modeling using a more extensive network of 25 stations, not available in 1957-1959. The uncertainty observed in 1999 was used when conducting uncertainty analyses using the air dispersion modeling with three stations during the 1957-1959 period.
The uncertainty analyses comprised 500 simulations of monthly average air concentrations arising from uncertainty analyses on hourly air dispersion modeling. A review of the results indicated the relative contributions to uncertainty depended on the receptor location and time period. The relative contribution from release rates tended to be higher with longer averaging times. The contribution from meteorological uncertainty was generally higher for averages over shorter time periods and for locations that were infrequently downwind from the ICPP. An interesting outcome was that there were shifts from typical concentrations estimated only with three surface meteorological stations to the values adjusted for the differences if 25 stations were available. There was a tendency for concentrations to increase at some receptors but decrease at others as the result of differences in concentrations predicted with 3 and 25 meteorological stations.
# TABLE OF CONTENTS

Executive Summary ........................................................................................................................................... ES-1

1.0 Introduction ............................................................................................................................................... 1-1

2.0 Modeling Methodology .......................................................................................................................... 2-1
  
  2.1 CALPUFF Modeling System .................................................................................................................. 2-1
  2.2 CALMET Model ..................................................................................................................................... 2-3
    2.2.1 Meteorology ................................................................................................................................. 2-6
    2.2.2 Land Use Data .............................................................................................................................. 2-9
    2.2.3 Terrain Data ............................................................................................................................... 2-11
    2.2.4 CALMET Switches ..................................................................................................................... 2-12
  2.3 CALMET Results ..................................................................................................................................... 2-13
    2.3.1 CALMET Results for the 1957-1959 Period ............................................................................... 2-13
    2.3.2 CALMET Based on 1999 Data ................................................................................................. 2-20
  2.4 CALPUFF Modeling ............................................................................................................................ 2-28
    2.4.1 Stack Parameters ....................................................................................................................... 2-28
    2.4.2 Modeling Locations .................................................................................................................... 2-29
  2.5 CALPUFF Model Options ..................................................................................................................... 2-33
    2.5.1 Deterministic Run ..................................................................................................................... 2-33
    2.5.2 Probabilistic Run ....................................................................................................................... 2-34
    2.5.3 Atmospheric Releases of Radionuclides from the Idaho Chemical Processing Plant ............. 2-35
    2.5.4 Particle Size Distributions ........................................................................................................ 2-40

3.0 Comparison of CALPUFF with Real Time SF₆ Measurements from the Idaho National Engineering Laboratory .......................................................................................................................... 3-1
  3.1 Tracer Test Data ..................................................................................................................................... 3-1
  3.2 Methodology of Validation ................................................................................................................... 3-2
  3.3 CALMET Performance ......................................................................................................................... 3-14
  3.4 Conclusions and Recommendations .................................................................................................. 3-16

4.0 CALPUFF Predicted Iodine-131 Concentrations for Deterministic Run .............................................. 4-1

5.0 Probabilistic Approach ............................................................................................................................ 5-1
  5.1 Approach ................................................................................................................................................ 5-1
  5.2 Sampling Distributions ....................................................................................................................... 5-2
    5.2.1 Emission Rates ............................................................................................................................ 5-2
    5.2.2 Air Dispersion Modeling Scenarios ......................................................................................... 5-2
    5.2.3 Meteorological Uncertainty ...................................................................................................... 5-3
  5.3 Implementation ...................................................................................................................................... 5-8
  5.4 Results .................................................................................................................................................. 5-10
5.4.1 Predicted Air Concentrations ................................................................. 5-10
5.4.2 Contributions to Uncertainty ............................................................... 5-13
5.4.3 Differences by Air Dispersion Modeling Scenario ............................... 5-16
5.4.4 Bias Introduced by Meteorology ......................................................... 5-17

6.0 Conclusions ............................................................................................... 6-1

References ......................................................................................................... R-1

APPENDICES

Appendix A: Sample CALMET Control File
Appendix B: CALMET Results Based on 3 and 25 Surface Stations
Appendix C: Sample CALPUFF Control File
Appendix D: CALMET Wind Fields during Selected Hours of SF6 Experiment
LIST OF TABLES

Table 2.1 Surface, upper air, and precipitation meteorological stations used as input into the CALMET modeling domain for 1957-1959 .................................................... 2-4
Table 2.2 Vertical layers used in CALMET modeling ........................................................ 2-6
Table 2.3 CALMET land use categories based on the U.S. Geological Survey Land Use and Land Cover Classification System ....................................................... 2-10
Table 2.4 Stability class comparison based on CALMET runs ........................................ 2-27
Table 2.5 Locations of offsite and onsite receptors used for dose reconstruction calculations ........................................................................................................ 2-27
Table 2.6 Estimated atmospheric releases of radionuclides from Idaho Chemical Processing Plant during 1957-1959 (Ci) ............................................................ 2-38
Table 2.7 Deterministic monthly emissions (Ci) ............................................................... 2-40
Table 3.1 Tracer test summary (Ref. 1) ............................................................................... 3-2
Table 3.2 SF₆ - CALPUFF model validation ....................................................................... 3-3
Table 3.3 SF₆ - CALPUFF model validation > LOD, and >LOQ ....................................... 3-5
Table 3.4 Maximum hourly model vs. observation results .................................................. 3-8
Table 5.1 Probability for dispersion modeling scenarios ..................................................... 5-3
Table 5.2 Approach to modeling effect of meteorological uncertainty for different categories ........................................................................................................ 5-4
Table 5.3 Probability (%) zero dispersion factor with 25 surface stations when zero dispersion factor with 3 surface stations ........................................................ 5-5
Table 5.4 Average unit dispersion factor (s/m³) for 25 surface stations when zero dispersion factor with 3 surface stations ........................................................ 5-6
Table 5.5 Probability (%) zero dispersion factor with 25 surface stations when dispersion factor with 3 surface stations greater than zero .............................. 5-7
Table 5.6 Specific example of dependency of adjusting with a zero unit dispersion factor when unit dispersion factor from three stations is greater than zero...... 5-7
Table 5.7 Specific example of sampled ratio of unit dispersion factors .............................. 5-8
Table 5.8 Summary of iodine-131 air concentrations (Bq/m³) ............................................. 5-11
Table 5.9 Sources of uncertainty in iodine-131 air concentrations during February 1957 ........................................................................................................ 5-14
Table 5.10 Sources of uncertainty in period average iodine-131 air concentrations ........ 5-15
Table 5.11 Comparison of central estimates of period average iodine-131 air concentrations by dispersion modeling scenario ......................................................... 5-16
Table 5.12 Example of shift in monthly concentrations in 1957 due to meteorological uncertainty with S1 scenario ........................................................................ 5-17
LIST OF FIGURES

Figure 2.1 Surface stations and precipitation stations used as input into CALMET ............2-5
Figure 2.2 Surface stations used in 1999.................................................................................2-8
Figure 2.3 Land use data processed through CALMET with approximate outline of Idaho National Engineering Laboratory property line...........................................2-11
Figure 2.4 Terrain data with Idaho National Engineering Laboratory property line ..........2-12
Figure 2.5 Wind Rose comparison for CFA Meteorological Station...............................2-14
Figure 2.6 Wind Rose comparison for TAN Meteorological Station................................2-15
Figure 2.7 Example of wind flow vectors for July 25, 1958 at 00:00.................................2-16
Figure 2.8 Example of wind flow vectors for July 25, 1958 at 13:00.................................2-17
Figure 2.9 Observations at October 21, 2002 at 15:50 MST – 5 minute averages ...............2-18
Figure 2.10 Observations at October 21, 2002 at 15:55 MST – 5 minute averages ...............2-19
Figure 2.11 Observations at October 22, 2002 at 08:40 MST – 5 minute averages ...............2-20
Figure 2.12 Wind Rose South – CFA, 1999 vs. CALMET (18, 42).................................2-21
Figure 2.13 Wind Rose North – LOFT/TAN, 1999 vs. CALMET (22,51).........................2-22
Figure 2.14 Wind Rose Pocatello – POC, 1999 vs. CALMET (25,26)..............................2-23
Figure 2.15 Wind Rose South – CFA – 1999 vs. CALMET (18, 42) based on 3 stations....2-24
Figure 2.16 Wind Rose North – LOFT/TAN, 1958 vs. LOFT/TAN, 1999 vs. CALMET (22,51) based on 3 stations ...............................................................2-25
Figure 2.17 Wind Rose Pocatello – POC, 1999 vs. CALMET (25,26) based on 3 stations ........................................................................................................2-26
Figure 2.18 Level 4 (110 m) wind speed comparison based on similarity theory and power law interpolation .................................................................2-28
Figure 2.19 Discrete receptors used in dose assessment....................................................2-29
Figure 2.20 Locations used for area average calculations.................................................2-30
Figure 2.21 Activity of iodine-131, barium-149 and strontium-90 released daily into the atmosphere during January 1958 .........................................................2-39
Figure 3.1 Location of the tracer release stack and plume sampling arcs on the Idaho National Engineering Laboratory site.........................................................3-1
Figure 3.2 Scattergram of model performance....................................................................3-8
Figure 3.3 Ratios of maximums as a function of sampling time........................................3-9
Figure 3.4 Ratios of averages > LOD as a function of sampling time...............................3-10
Figure 3.5 Ratios of averages > LOQ as a function of sampling time...............................3-10
Figure 3.6 CALPUFF results .............................................................................................3-11
Figure 3.7 003701 max hour ground level concentration in ug/m$^3$ of SF$_6$ based on emissions of 20.8 g/s.............................................................................3-13
Figure 3.8 Wind fields over Idaho National Engineering Laboratory property and CALPUFF modeling domain.................................................................3-15
Figure 4.1  Predicted annual iodine-131 CALPUFF concentrations for 1957.......................... 4-2
Figure 4.2  Predicted annual iodine-131 CALPUFF concentrations for 1958.......................... 4-3
Figure 4.3  Predicted annual Iodine-131 CALPUFF concentrations for 1959.......................... 4-4
Figure 4.4  Monthly iodine-131 CALPUFF concentrations – February 1957......................... 4-6
Figure 4.5  Monthly iodine-131 CALPUFF concentrations – October 1957.......................... 4-7
Figure 4.6  Monthly iodine-131 CALPUFF concentrations – November 1957...................... 4-8
Figure 4.7  Monthly iodine-131 CALPUFF concentrations – March 1958............................. 4-9
Figure 4.8  Monthly iodine-131 CALPUFF concentrations – May 1958............................... 4-10
Figure 4.9  Monthly iodine-131 CALPUFF concentrations – June 1958............................... 4-11
Figure 5.1  Summary of probabilistic sampling of air concentrations................................. 5-9
Figure 5.2  Estimated concentration of iodine-131 in air in Atomic City, Idaho, due to releases from the Idaho Chemical Processing Plant operations.......................... 5-12
Figure 5.3  Concentration of iodine-131 in air averaged over the period of release (February 1958 – December 1959)................................................................. 5-13
1.0 INTRODUCTION

The Idaho National Engineering Laboratory (INEL), established in 1949 as the National Reactor Testing Station, started operating the Idaho Chemical Processing Plant (ICPP) in 1953, for recovering uranium from spent nuclear fuel. The Radioactive Lanthanum (RaLa) operations at the ICPP began on Feb. 1, 1957. The RaLa process was designed to extract lanthanum-140 (\(^{140}\text{La}\); half-life of 40.2 hours) from irradiated reactor fuel, an isotope used to evaluate the implosion process of a nuclear weapon. The short half-lives of \(^{140}\text{La}\) and its radioactive precursor \(^{140}\text{Ba}\) (12.9 days) required a chemical process in which fuel elements irradiated in a nuclear reactor were dissolved shortly after irradiation.

Gases and aerosol particles generated during RaLa dissolution and extraction processes were captured by an off-gas system, and then passed through a series of scrubbers and charcoal beds to a temporary 10,000-ft\(^3\) storage tank. Before gases and aerosols were released to the atmosphere through the 250-ft ICPP stack, they were diluted by mixing with large amounts of the air from the ICPP building ventilation system, which created a total output flow rate of about 100,000 ft\(^3\) per minute.

Due to the short decay time after irradiation of the fuel, the gases and aerosol particles from RaLa operations carried more than 130 radionuclides, which were released into the atmosphere. The largest amount of radioactivity released from the RaLa operations occurred from February 1957 to December 1959. During this period, essentially all releases from the ICPP were due to RaLa process operations.

A screening analysis (Kocher 2005a, b) determined that \(^{131}\text{I}\) was by far the most important radionuclide in regard to potential radiation doses to members of the public who resided near INEL during the years 1957-1959. Twelve additional radionuclides of potential concern were also selected for inclusion in a more detailed dose reconstruction.

This report describes the analysis of the atmospheric dispersion of the radionuclides released from the ICPP from 1957 to 1959. This analysis was performed as part of the effort of estimating radiation doses for members of the public living around INEL during the years of release. Due to overwhelming importance of \(^{131}\text{I}\) as compared to the other radionuclides released from the ICPP from 1957 to 1959, this analysis focuses on estimation of the concentration of \(^{131}\text{I}\) in air at selected locations in the INEL extended region. The modeling of the atmospheric transport for other radionuclides is only described very briefly.

The CALPUFF/CALMET system of computer codes was used to perform the atmospheric transport calculations. The CALPUFF/CALMET systems are described in Chapter 2.0. Site-specific meteorological data was collected from the National Oceanic and Atmospheric Administration (NOAA) for 1957-1959, and also for 1999 (See Chapter 2.2.1). The more abundant data for 1999 was used to demonstrate the capability of CALMET, with a limited number of surface stations as input, to generate three dimensional wind fields. Once the comparison was done, CALMET was applied for the periods of interest as described in Section 2.3.2.
To insure that the CALPUFF/CALMET computer codes are able to accurately predict the air concentration in the INEL environment, a validation exercise was performed using data collected in 1999 during an exercise in which sulfur hexafluoride tracer (SF₆) was released on the INEL site under controlled conditions. The results of the validation exercise indicate a very good performance of the CALPUFF/CALMET system for the time-averaged air concentrations, which are needed for estimation of radiation dose to the members of the public. The SF₆ tracer study and CALPUFF results are described in Chapter 3.0.
2.0 MODELING METHODOLOGY

The U.S. Environmental Protection Agency (U.S. EPA) Guideline on Air Quality Models (40 CFR 51, Appendix W) currently recommends the Industrial Source Complex Short-Term (ISCST3) model for simple terrain settings. Recently, the U.S. EPA has approved the CALPUFF modeling system, for use as a regulatory model for long-range transport and complex wind situations (e.g., complex terrain). The CALPUFF model has been developed using more up-to-date mathematical formulations for atmospheric dispersion and deposition.

Considering the location and the complex terrain around the INEL site, the alternative model (CALMET/CALPUFF) is more suitable in this kind of study than the simple Gaussian Model. The limited input of meteorological data for 1957-1959 period suggested use of the more extensive Meso-West network for 1999 to validate the performance of CALMET wind field creation with limited surface observations as an input. Comparison of these wind fields provides an indication of the uncertainty present in wind fields during 1957-1959 when only 3 surface air stations are available.

2.1 CALPUFF MODELING SYSTEM

CALPUFF is a non-steady-state air quality modeling system developed by Sigma Research Corporation (now part of Earth Tech, Inc.). The CALPUFF modeling system consists of three sub-systems: 1) a meteorological modeling package (CALMET) which includes a diagnostic wind field generator; 2) a Gaussian puff dispersion model (CALPUFF) with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation, and other effects; and, 3) post-processing programs (CALPOST) for the output of meteorological data, concentration and deposition fluxes.

The original development of the CALMET/CALPUFF models was sponsored by the California Air Resources Board (CARB) and is supported by the U.S. Environmental Protection Agency (U.S. EPA). Both the CALMET and CALPUFF models have been enhanced as part of work conducted for the Interagency Workgroup on Air Quality Modeling (IWAQM), the U.S. EPA, the U.S. Forest Service, the U.S. National Park Service, the U.S. Fish and Wildlife Service, and private industry in the United States and abroad. In June 2000, the U.S. EPA proposed including the CALPUFF modeling system as a Guideline model for regulatory applications involving long range transport and on a case-by-case basis for near-field applications where non-steady-state effects (i.e., situations where factors such as spatial variability in meteorological fields, calm winds, fumigation, re-circulation or stagnation, and terrain or coastal effects) may be important.

The CALPUFF modeling system was designed to address the following specifications:

- The capability to treat time-varying point and area sources
- Suitability for modeling domains from tens of meters to hundreds of kilometers from a source
• Predictions for averaging times ranging from one-hour to annual

• Applicability to model inert pollutants and those subject to linear removal and chemical conversion mechanisms

• Applicability to rough or complex terrain

The CALMET model is a meteorological model which includes a diagnostic wind field generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects, a divergence minimisation procedure, and a micrometeorological model for over land and over water boundary layers. CALMET develops hourly wind and temperature fields on a three-dimensional gridded modeling domain, which incorporates the effects of terrain on wind, flow. Associated two-dimensional fields such as mixing heights, surface characteristics and dispersion properties are also included in CALMET. The three-dimensional (3-D) wind field can be developed in CALMET using observations from several meteorological monitoring stations in the vicinity of the emission source. Alternatively, if there are no suitable surface-monitoring data available for the area, CALMET has the option to import prognostic wind field data produced by the MM5/MM4 (Penn State/NCAR Mesoscale Model) models.

CALPUFF is a transport and dispersion model that advects a discrete number of packets of pollutant material (i.e., “puffs”) emitted from modeled sources to represent the continuous plume, simulating dispersion and transformation processes along the way. Temporal and spatial variations in the meteorological fields derived from CALMET are explicitly incorporated in the resulting distribution of puffs throughout the simulation period. Alternatively, CALPUFF can be run with meteorological data from a single monitoring station as with other commonly available regulatory Gaussian plume dispersion models. In a situation where wind direction would carry a plume from the source towards a receptor on a hill, the 3-D wind field in CALPUFF would determine whether that puff release will be carried over or around the hill, while a standard Gaussian plume model, using wind direction derived from a single meteorological monitoring site, would predict the flow to be over the hill in all cases.

The use of CALPUFF for this application is, according to the proposed U.S. EPA Guideline, an alternative refined model use. The use of the CALPUFF model is considered appropriate because:

• The CALPUFF model has the ability to develop three-dimensional, regional wind fields from the limited surface observation data in a complex terrain setting. CALPUFF has received considerable peer review both in a formalised U.S. EPA process (Allwine et al., 1998) and in statements made at the 7th Modeling Conference (June 2000). Each of the reviews urged the use of CALPUFF for modeling impacts at distances shorter than 50 kilometers.
• On a theoretical basis, CALMET and CALPUFF are applicable to the flat and complex terrain setting in the vicinity of the INEL site, and the model produces results that are comparable to the ISCST3 model, which is currently the regulatory model of choice.

(1) The relatively few available comparisons between ISCST3 and CALPUFF for short-range applications have shown that CALPUFF often predicts higher concentrations than ISCST3. The higher predicted ambient concentrations result from the CALPUFF model’s treatment of calm winds and stagnation conditions, which lead to higher ambient concentrations. Therefore, it can be expected that the CALPUFF model would not underestimate air quality impacts in the current application.

2.2 CALMET MODEL

A major reason for selecting the CALMET/CALPUFF modeling system to model emissions of $^{131}$I from the INEL was that CALMET can produce a reasonable wind field based on a limited amount of surface observation data in the modeling domain. The CALMET model uses all available meteorological data within a defined modeling domain to compute gridded wind fields. CALMET requires, at a minimum, one surface station and one upper air (sounding) station with at least two upper air soundings each day. There must also be wind and temperature data at the bottom and top layer of the modeling domain.

For the current analysis, the CALMET model was used to develop a one-year data set - 1999 of hourly wind fields for the comparison of the wind fields with the yearly data sets for 1957, 1958 and 1959 to be used in the CALPUFF dispersion model.

The CALMET model was run in a coarse grid resolution (4km grid spacing) for a 320 x 320 km modeling domain around INEL site. This grid was used for developing contour plots (isopleths) of air concentration. Discrete receptors were identified for the purposes of dose estimation. Table 2.1 shows the hourly surface meteorological stations, the upper air stations and precipitation stations used in analysis of the 1957-1959 data sets. The dispersion modeling domain is depicted in Figure 2.1 along with locations of surface and precipitation data available in 1957-1959.

The input to the CALMET model requires a control file that defines the wind field grid parameters and model option switches, surface and upper air meteorological data, land use data and terrain data.
### Table 2.1  Surface, upper air, and precipitation meteorological stations used as input into the CALMET modeling domain for 1957-1959

<table>
<thead>
<tr>
<th>No.</th>
<th>Station</th>
<th>Station No.</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Surface Stations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>North- LOFT/TAN</td>
<td>10000*</td>
<td>43.859</td>
<td>112.730</td>
</tr>
<tr>
<td>2</td>
<td>South – CFA</td>
<td>10055*</td>
<td>43.532</td>
<td>112.948</td>
</tr>
<tr>
<td>3</td>
<td>Pocatello</td>
<td>24156</td>
<td>42.917</td>
<td>112.600</td>
</tr>
<tr>
<td></td>
<td><strong>Upper Air Stations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Boise</td>
<td>24131</td>
<td>43.57</td>
<td>116.22</td>
</tr>
<tr>
<td>2</td>
<td>Lander</td>
<td>24021</td>
<td>42.82</td>
<td>108.73</td>
</tr>
<tr>
<td>3</td>
<td>Salt Lake City</td>
<td>24127</td>
<td>40.77</td>
<td>111.97</td>
</tr>
<tr>
<td></td>
<td><strong>Precipitation Stations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Idaho Falls – 2ESE</td>
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<tr>
<td>2</td>
<td>Idaho Falls – 46W</td>
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<td>43.553</td>
<td>112.950</td>
</tr>
<tr>
<td>3</td>
<td>Pocatello Municipal Airport</td>
<td>24156</td>
<td>42.917</td>
<td>112.600</td>
</tr>
</tbody>
</table>

Note: * - assigned  
n/a - not assigned
Figure 2.1 Surface stations and precipitation stations used as input into CALMET

Figure 2.1a: Surface Stations

Figure 2.1b: Precipitation Stations

Note: SW Corner of the domain is at (lat=41.96 deg., long=113.89 deg) of UTM Coordinates (Easting = 260,000 km, Northing = 4650,000 km, UTM Zone=12). Axis values are in kilometres.
2.2.1 Meteorology

Meteorological data for 1957-1959 from the two weather stations located within the INEL borders were obtained from the National Oceanic and Atmospheric Administration (NOAA) in Idaho Falls (Clawson 2002). Hourly data are reported for wind speed, wind direction, and temperature. The more complete data are from the weather station at the Central Facilities Area (CFA), which is near the ICPP (labeled the South station). The second (North) station is for the Test Area North (TAN), at the IET site. The data were collected at elevations of 20’ and 250’ at the South station and at 20’ and 150’ at the North station. In addition to these two stations, meteorological data for the years of interest were obtained for Pocatello and Idaho Falls, as well as from stations at Boise, Lander and Salt Lake City for upper atmosphere data.

Table 2.1 shows the hourly surface meteorological stations, the upper air stations and precipitation stations used in analysis of the 1957-1959 data sets.

Ten vertical layers were included for the development of the 3-D wind field. The layer heights considered are shown in Table 2.2.

<table>
<thead>
<tr>
<th>Vertical Height of Layer (metres)</th>
<th>Height at Top of Layer (metres)</th>
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<tbody>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
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<td>3000</td>
</tr>
<tr>
<td>500</td>
<td>3500</td>
</tr>
</tbody>
</table>

This pattern of rising layers follows the guidance from the CALMET user’s manual in terms of gradually increasing layer depth with height. Mixing heights developed by SENES using the CALMET model\(^1\) for upper air monitoring stations at Boise, Lander, and Salt Lake City were reviewed to ensure that the top of the 3-D wind field grid was well above climatological mixing heights.

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A complete set of meteorological data for 1999 was obtained from NOAA (Clawson 2002) for 25 stations in and around the INEL site. This data was used for validation of CALPUFF with tracer study data from 1999 and to quantify the uncertainty in air dispersion modeling present if only three stations are available as was the case in 1957-1959. The locations of these stations are shown in Figure 2.2 and include the locations of the three stations with data in 1957-1959 (number 1 to 3 on the figure). The data contains hourly data (when available) of mean wind speed, mean (vector) wind direction, mean temperature, and total precipitation during the year 1999.
Figure 2.2   Surface stations used in 1999

<table>
<thead>
<tr>
<th>Station</th>
<th>ID</th>
<th>SENES-No</th>
<th>Map No</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA-Building 69C</td>
<td>CFA</td>
<td>10000</td>
<td>1</td>
</tr>
<tr>
<td>LDF/TAN</td>
<td>TAN</td>
<td>10080</td>
<td>2</td>
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<tr>
<td>Fort Colville</td>
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<td>24165</td>
<td>3</td>
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<tr>
<td>Fort Hall</td>
<td>FOR</td>
<td>10004</td>
<td>4</td>
</tr>
<tr>
<td>Blue Dome</td>
<td>BLD</td>
<td>10020</td>
<td>5</td>
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<tr>
<td>Dubois (EUB)</td>
<td>EUB</td>
<td>10030</td>
<td>6</td>
</tr>
<tr>
<td>BBR2</td>
<td>BBR2</td>
<td>10040</td>
<td>7</td>
</tr>
<tr>
<td>Howie</td>
<td>HOW</td>
<td>10050</td>
<td>8</td>
</tr>
<tr>
<td>Idaho Falls</td>
<td>IDF</td>
<td>10060</td>
<td>9</td>
</tr>
<tr>
<td>Kettle Butte</td>
<td>KET</td>
<td>10070</td>
<td>10</td>
</tr>
<tr>
<td>Naval Reactor Fac</td>
<td>NRF</td>
<td>10080</td>
<td>11</td>
</tr>
<tr>
<td>Roberts</td>
<td>ROB</td>
<td>10100</td>
<td>12</td>
</tr>
<tr>
<td>Rover</td>
<td>ROV</td>
<td>10110</td>
<td>13</td>
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<tr>
<td>RWMC</td>
<td>RWMC</td>
<td>10120</td>
<td>14</td>
</tr>
<tr>
<td>Sand Downs</td>
<td>SDO</td>
<td>10130</td>
<td>15</td>
</tr>
<tr>
<td>Sugar City</td>
<td>SUG</td>
<td>10140</td>
<td>16</td>
</tr>
<tr>
<td>Tabler</td>
<td>TAB</td>
<td>10150</td>
<td>17</td>
</tr>
<tr>
<td>Terrebonne</td>
<td>TEB</td>
<td>10160</td>
<td>18</td>
</tr>
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<td>Arco</td>
<td>ARCO</td>
<td>10011</td>
<td>19</td>
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<tr>
<td>Mimbahao</td>
<td>MNS</td>
<td>10039</td>
<td>20</td>
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<tr>
<td>CRID3</td>
<td>RID</td>
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<td>21</td>
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<tr>
<td>Aninderan</td>
<td>ABD</td>
<td>10012</td>
<td>22</td>
</tr>
<tr>
<td>Big Southern Butte</td>
<td>BSB</td>
<td>10013</td>
<td>23</td>
</tr>
<tr>
<td>Craters of the Moon</td>
<td>COM</td>
<td>10021</td>
<td>24</td>
</tr>
<tr>
<td>Deadfoot</td>
<td>DFO</td>
<td>10014</td>
<td>25</td>
</tr>
</tbody>
</table>
2.2.2 Land Use Data

The data for the fine modeling domain were based on the land cover data obtained from USGS based on ~900 m resolution GTOPO data set.

The land use categories for use in CALMET are based on the USGS land use classification system. These categories are listed in Table 2.3, below. The land use data, after processing by CALMET, are presented in Figure 2.3.
### Table 2.3 CALMET land use categories based on the U.S. Geological Survey Land Use and Land Cover Classification System (52-category system)

<table>
<thead>
<tr>
<th>Level</th>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Urban or Built-up Land</td>
<td>Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Commercial and Services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transportation, Communications and Utilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial and Commercial Complexes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed Urban or Built-up Land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Urban or Built-up Land</td>
</tr>
<tr>
<td>20</td>
<td>Agricultural Land — Unirrigated</td>
<td>Cropland and Pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Confined Feeding Operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Agricultural Land</td>
</tr>
<tr>
<td>! 20</td>
<td>Agricultural Land — Irrigated</td>
<td>Cropland and Pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Confined Feeding Operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Agricultural Land</td>
</tr>
<tr>
<td>30</td>
<td>Rangeland</td>
<td>Herbaceous Rangeland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shrub and Brush Rangeland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed Rangeland</td>
</tr>
<tr>
<td>40</td>
<td>Forest Land</td>
<td>Deciduous Forest Land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evergreen Forest Land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed Forest Land</td>
</tr>
<tr>
<td>50</td>
<td>Water</td>
<td>Streams and Canals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lakes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reservoirs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bays and Estuaries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oceans and Seas</td>
</tr>
<tr>
<td>60</td>
<td>Wetland</td>
<td>Forested Wetland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-forested Wetland</td>
</tr>
<tr>
<td>70</td>
<td>Barren Land</td>
<td>Dry Salt Flats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sandy Areas Other than Beaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bare Exposed Rock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strip Mines, Quarries, and Gravel Pits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transitional Areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed Barren Land</td>
</tr>
<tr>
<td>80</td>
<td>Tundra</td>
<td>Shrub and Brush Tundra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Herbaceous Tundra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bare Ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wet Tundra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mixed Tundra</td>
</tr>
<tr>
<td>90</td>
<td>Perennial Snow or Ice</td>
<td>Perennial Snowfields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glaciers</td>
</tr>
</tbody>
</table>
2.2.3 Terrain Data

The GTOP digital elevation maps (DEM’s) (~900 m spacing) were downloaded from the USGS Web Site and used for the coarse wind field grid. The digital elevation model (DEM) data were processed to conform to CALMET formats using the terrain-processing program, TERREL that is provided with the CALMET/CALPUFF modeling system. A depiction of terrain data used in this analysis is presented in Figure 2.4.
2.2.4 CALMET Switches

The CALMET dispersion model has optional algorithms and approaches for meteorological processing that are specified in the control file. Options, or algorithms, are specified as “switches” in the control file. Switch settings for the deterministic run are provided in Section 2.5.1 and switch settings for the probabilistic runs are provided in Section 2.5.2.

A sample CALMET input file with similarity theory for vertical wind extrapolation for January 1957 is presented in Appendix A.
Computer Hardware and Operating System

The operating system is Linux – Mandrake 8.2 installed on the Pentium IV, 1.7 GHz personal computer. The CALMET/CALPUFF model was compiled with Portland Group Fortran Compiler (PGF) with the Optimization Zero. An advantage of the Linux/PGF system is the handling of the large file sizes developed in this project.

Selected results from the Linux model runs were compared against Windows based CALMET/CALPUFF to ensure the same results were produced.

2.3 CALMET RESULTS

2.3.1 CALMET Results for the 1957-1959 Period

CALMET runs were executed for the entire period 1957-59 and the results are presented in this Chapter. As an example, to illustrate the capabilities of the model, 1958 was chosen for more detailed presentation of results.

Actual meteorological observations were compared to CALMET predictions at the closest CALMET grid points. Figure 2.5 presents comparison for the South – CFA meteorological station and grid point (18,42) for 1958. Figure 2.6 shows similar comparison for the North – TAN meteorological station and grid point (22,51) for 1958.

Figures 2.7 and 2.8 show examples of the hourly snap shots of the wind fields predicted by CALMET. Figure 2.7 shows an hour with complex wind patterns where winds “drain” from many directions into the basin with flow generally towards the southwest. Figure 2.8 shows an hour where the wind fields are predicted to be uniformly towards the northeast throughout the modeling domain.

Examples of measured wind flow patterns are presented in Figures 2.9, 2.10 and 2.11. These examples were selected to demonstrate the complexity of the wind flow around the INEL site and to confirm the complexity of wind fields predicted using CALMET.
Figure 2.5  Wind Rose comparison for CFA Meteorological Station

Wind Rose
South - CFA, 1958 vs. CALMET Grid Point (18,42)

Wind Direction Frequency (%)

South-CFA  CALMET(18,42)

Average Wind Speed (m/s)

Wind Speed (m/s)  CALMET(18,42)
Figure 2.6  Wind Rose comparison for TAN Meteorological Station

Wind Rose
North - LOFT/TAN, 1958 vs. CALMET Grid (22.51)
Figure 2.7  Example of wind flow vectors for July 25, 1958 at 00:00

CALMET SIMULATION - Jul 25, Hour 01:00 AM, 1958
Figure 2.8  Example of wind flow vectors for July 25, 1958 at 13:00

CALMET SIMULATION - Jul 25, Hour 01:00 AM, 1958
Figure 2.9  Observations at October 21, 2002 at 15:50 MST – 5 minute averages
Figure 2.10 Observations at October 21, 2002 at 15:55 MST – 5 minute averages
2.3.2 CALMET Based on 1999 Data

CALMET predictions were made for 1999 in two scenarios; first was using the full network and, second, was using only the three stations that were also available in 1957-1959. The results of the two scenarios can be compared to show the uncertainty present using three stations as compared to the more complete meteorological information. Comparisons of these two scenarios are provided in this chapter.

Wind roses of observations and CALMET predictions at the closest grid point at three stations that were produced for both scenarios (CALMET with 25 stations and CALMET with three surface stations) are presented in Figures 2.12 through 2.17. Figures 2.12 through 2.14 show wind roses based on 25 meteorological stations.
Figure 2.12  Wind Rose South – CFA, 1999 vs. CALMET (18, 42)
Figure 2.13  Wind Rose North – LOFT/TAN, 1999 vs. CALMET (22,51)
Figure 2.14  Wind Rose Pocatello – POC, 1999 vs. CALMET (25,26)
Figures 2.15 through 2.17 show the wind roses based on 3 meteorological stations.

Figure 2.15  Wind Rose South – CFA – 1999 vs. CALMET (18, 42) based on 3 stations

---

Wind Direction Frequency (%)

---

CFA-99  CALMETF(18,42)

---

Average Wind Speed (m/s)

---

Wind Speed (m/s)  CALMETF(18,42)
Figure 2.16  Wind Rose North – LOFT/TAN, 1958 vs. LOFT/TAN, 1999 vs. CALMET (22,51) based on 3 stations
Based on these comparisons of the wind roses, it was concluded that CALMET performance with the limited number of stations (3 vs. 25) was reasonable for prediction of meteorological conditions at selected locations.
Table 2.4 summarizes the stability class distribution for CALMET based on 25 stations and 3 stations at the stack location as well as at Idaho Falls using similarity theory. CALMET was performed using similarity theory and power law for vertical profiles as part of the probabilistic assessment. Wind speeds generally increase with height in the atmosphere. To determine the speed at different levels normally the power-law equation is used: \( u_1/u_2=(z_1/z_2)^p \). The coefficient \( p \) varies from 0.4 in urban environment, with scaling down to 0.16 over water surfaces.

The vertical profile of the wind can also be calculated based on the boundary layer physics and the parameters which represents the layer: surface roughness, surface friction velocities, Monin-Obukhov length, stable and unstable boundary layer heights, sensible heat flux etc. This approach is often called a similarity theory approach in air dispersion modeling. One of the advantages of the CALMET/CALPUFF system is the ability to simulate the atmosphere in both ways. The distribution of stability class did not change substantially between the two methods.

<table>
<thead>
<tr>
<th>Stability</th>
<th>At The Stack</th>
<th>Idaho Falls - Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>A</td>
<td>0.8</td>
<td>1.6</td>
</tr>
<tr>
<td>B</td>
<td>10.7</td>
<td>12.6</td>
</tr>
<tr>
<td>C</td>
<td>14.5</td>
<td>14.4</td>
</tr>
<tr>
<td>D</td>
<td>37.8</td>
<td>33.8</td>
</tr>
<tr>
<td>E</td>
<td>9.2</td>
<td>7.0</td>
</tr>
<tr>
<td>F</td>
<td>26.9</td>
<td>30.5</td>
</tr>
</tbody>
</table>

Wind speed and directions at 10 m levels are the same for similarity theory or power law vertical profile. To demonstrate the difference, the wind speeds at level 4 (110m) were processed for January 1999 for scenario 1 (25 stations with similarity theory and power law interpolation). A graph of wind speed differences is presented in Figure 2.18.
Figure 2.18  Level 4 (110 m) wind speed comparison based on similarity theory and power law interpolation

Based on this comparison at higher levels, there were higher wind speeds using the similarity theory than using power law profiles. These differences are expressed through the probabilistic approach, and the speed difference at different levels determines different concentration predictions at different locations. As the speed at ground level (10m) stays the same, it would be difficult to explain the concentration predictions without direct comparisons of concentrations using two different approaches.

Figures B1 through B12 presented in Appendix B demonstrate monthly wind vectors based on 3 and 25 meteorological stations used as an input to generate three-dimensional CALMET wind fields. Visually, differences in wind field difference do no appear large; however, there is a tendency for winds to be shifted slightly counter-clockwise based on the 25 stations compared to the wind fields with three stations.

2.4  CALPUFF MODELING

The CALPUFF model was run for two purposes; first were deterministic runs to develop contour plots (isopleths) over the modeling domain. The second was to provide unit dispersion factors to address the uncertainty in CALPUFF modeling approaches on the air concentrations. This section describes parameter values used in the CALPUFF modeling.

2.4.1 Stack Parameters

For this study, the point source was placed close to the GRID3 meteorological station (lat.: 43.572° North and long.: 112.93° West). Stack parameters were: height=76.2m, diameter=3.3m, exit velocity=5.5m/s – corresponding to 100,000 ft³/min and exit temperature=293°K.
2.4.2 Modeling Locations

A grid was established over the modeling domain for deterministic analysis and description of overall patterns in air concentration described in Chapter 4.

For the purpose of dose reconstruction, discrete receptors were identified at off-site locations and at two sites on the INEL property. Modeling locations were also identified for the calculation of average concentrations over the INEL property and for average concentrations over the area of commercial milk production. Table 2.5 summarizes the locations of discrete receptors and Figure 2.19 presents their locations. Figure 2.20 shows the locations used to calculate average air concentrations for the INEL property and for the commercial milk production area.
Table 2.5  Locations of offsite and onsite receptors used for dose reconstruction calculations

<table>
<thead>
<tr>
<th>Community or town</th>
<th>Receptor No</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Junction</td>
<td>1</td>
<td>43.223</td>
<td>112.470</td>
</tr>
<tr>
<td>Arco*</td>
<td>2</td>
<td>43.637</td>
<td>113.299</td>
</tr>
<tr>
<td>Atomic City*</td>
<td>3</td>
<td>43.445</td>
<td>112.812</td>
</tr>
<tr>
<td>Basalt</td>
<td>4</td>
<td>43.316</td>
<td>112.168</td>
</tr>
<tr>
<td>Blackfoot*</td>
<td>5</td>
<td>43.191</td>
<td>112.344</td>
</tr>
<tr>
<td>Butte City*</td>
<td>6</td>
<td>43.610</td>
<td>113.243</td>
</tr>
<tr>
<td>Dubois</td>
<td>7</td>
<td>44.176</td>
<td>112.230</td>
</tr>
<tr>
<td>Firth</td>
<td>8</td>
<td>43.305</td>
<td>112.182</td>
</tr>
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<td>Fort Hall</td>
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<td>43.033</td>
<td>112.438</td>
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<td>Grandview</td>
<td>10</td>
<td>43.053</td>
<td>112.788</td>
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<td>Hamer</td>
<td>11</td>
<td>43.927</td>
<td>112.205</td>
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<tr>
<td>Howe*</td>
<td>12</td>
<td>43.784</td>
<td>113.004</td>
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<td>43.689</td>
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<tr>
<td>Mackay</td>
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<td>43.915</td>
<td>113.613</td>
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<td>43.721</td>
<td>111.989</td>
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<td>Moore</td>
<td>18</td>
<td>43.736</td>
<td>113.366</td>
</tr>
<tr>
<td>Montevideo*</td>
<td>19</td>
<td>43.972</td>
<td>112.536</td>
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<td>Mud Lake*</td>
<td>20</td>
<td>43.842</td>
<td>112.475</td>
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<tr>
<td>Roberts*</td>
<td>21</td>
<td>43.720</td>
<td>112.126</td>
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<tr>
<td>Shelley</td>
<td>22</td>
<td>43.381</td>
<td>112.123</td>
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<tr>
<td>Spencer</td>
<td>23</td>
<td>43.361</td>
<td>112.186</td>
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<tr>
<td>Terreton</td>
<td>24</td>
<td>43.842</td>
<td>112.436</td>
</tr>
</tbody>
</table>

ON-SITE LOCATIONS

<table>
<thead>
<tr>
<th>Location</th>
<th>Receptor No</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA @ 250 ft Met Tower location</td>
<td>25</td>
<td>43.533</td>
<td>112.950</td>
</tr>
<tr>
<td>Big Lost River sink area - 12 km (8 miles) East-South-East of Howe, about 2-3 miles inside the INEL border.</td>
<td>27</td>
<td>43.775</td>
<td>112.866</td>
</tr>
</tbody>
</table>

Note:
* Previously modeled locations (DOE 1991)
Receptor #26 was not used in dose reconstruction.
Sources: USGS maps and factfinder.census.gov; www.digital-neighbors.com/city/id
Figure 2.19  Discrete receptors used in dose assessment
Figure 2.20  Locations used for area average calculations

Blue grid points are used for the area average over the INEL property.  
Red points are used for the area average over commercial milk production areas  
Spacing between the grid points is 10 km.
2.5 CALPUFF MODEL OPTIONS

Options for algorithms and modeling approaches are specified for the CALPUFF model. This section describes the set-up of these approaches.

2.5.1 Deterministic Run

The CALMET model was run, as described above, using similarity theory to estimate the vertical wind profile. The CALPUFF model provides multiple options for evaluating modeling scenarios. For the deterministic analysis, the model was run using model default settings for most parameters. Pasquill-Gifford stability classes were used in CALPUFF to determine the dispersion coefficients (MDISP=3).

Other important model switches included:

- **INPUT Group 1**
  - (a) NSPEC and NSE were set to run one pollutant at a time to conserve computer resources.

- **INPUT Group 2**
  - (a) MCTADJ = 3 was set to use the CALPUFF type terrain adjustment as the default.
  - (b) MSLUG was set to the default (i.e., slug model not used).
  - (c) MTRANS was set to 1, the default, because the proximity of the terrain may make transitional plume rise important.
  - (d) MTIP is set to the default of 1, although stack tip downwash is not expected at reasonable windspeeds.
  - (e) MSHEAR has been selected so that vertical wind shear was not modeled.
  - (f) MCHEM=0 (no chemical reactions), MWET and MDRY were all set so that wet and dry removal are considered to reduce plume concentration.
  - (g) MDISP was described above, and MTURBV was set accordingly.
  - (h) MROUGH was set to default (i.e., no surface roughness credit is being taken in calculating diffusion parameters).
  - (i) MTINV was set to default so that inversions are computed from gradients only.
  - (j) MPDF was set to default, therefore not adding PDF dispersion.
  - (k) MSGTIBL was set to default, no shoreline dispersion calculated.

- **INPUT Group 3**
  - One Species $^{131}$I modeled as a gas

- **INPUT Group 4**
  - LSAMP = T Discrete receptors used

- **INPUT Group 5**
  - Output Options
• INPUT Group 6  No hills are added as complex terrain inputs
• INPUT Group 7–10 Deposition to be used
• INPUT Group 11  No chemistry used
• INPUT Group 12
• INPUT Group 13 Stack data entry (emissions modeled as daily variable emission (daily numbers are divided on 24 equally distributed hours Ci/s)
• INPUT Group 14  No area sources
• INPUT Group 15  No line sources
• INPUT Group 16  No volume sources
• INPUT Group 17 discrete receptors used in probabilistic run

An example of the CALPUFF input file for the deterministic run of 1957 concentrations is provided in Appendix C.

2.5.2 Probabilistic Run

The sources of uncertainty in the probabilistic runs were:

(a) Uncertainty in emission rates
(b) Model uncertainty related to methods for calculating vertical wind profile (in CALMET), terrain adjustment methods (in CALPUFF) and dispersion coefficients (in CALPUFF)
(c) Meteorological uncertainty due to complex terrain and only 3 stations during the time period of interest (1957-1959)

The uncertainty in unit air dispersion modeling is addressed by considering two methods for calculating the vertical wind profile, two methods for terrain adjustment and two methods for calculating dispersion coefficients. There are therefore eight discrete combinations of dispersion methods identified to reflect the modeling uncertainty. Probabilities for each combination were developed based on experience.

The specific choices for the methods are:
(a) For vertical wind profile within the CALMET processor, the methods are:
   1. IEXTRP=4 for use of similarity theory and
   2. IEXTRP=2 for use of power law extrapolation

(b) For terrain adjustment with the CALPUFF model, the methods are:
   3. MCTADJ=2 for simple CALPUFF type of terrain analysis and
   4. MCTADJ=3 for partial plume path adjustment

(c) For dispersion coefficients (i.e. sigma) within the CALPUFF model, the methods are:
   5. MDISP2=3 for PG dispersion coefficients and
   6. MDISP2=2 for dispersion coefficients from internally calculated sigma v and
      sigma w using micrometeorological variables (v*, w*, L, etc.)

The selection of these methods for consideration is based on expert opinion applicable to this dispersion analysis.

The CALPUFF model was run for each combination for each of the three years during the 1957-1959 period for a total of 24 model runs. The unit dispersion factors were stored in a database with identification by the model uncertainty (i.e. the methods used for CALMET AND CALPUFF).

The uncertainty of using only 3 surface air stations during the 1957-1959 period was quantified from a comparison of unit air dispersion factors calculated for 1999 when 25 air stations are available. The unit dispersion factors determined with 25 air stations were considered the standard (i.e. providing “accurate” meteorological data after CALMET processing).

The CALPUFF unit dispersion factors were calculated for the eight combinations of model uncertainty at the 27 discrete receptor locations. This was done twice; once with the 3 surface air stations and once with the 25 air stations resulting in a total of 16 CALPUFF runs. The difference between the air dispersion factors using 3 stations and the air dispersion factors with the 25 meteorological stations reflect the uncertainty due to uncertainty in meteorological conditions. These distributions were developed for each of the 27 discrete receptor locations and may be further classified according to broad meteorological condition (e.g. stability, wind speed, direction).

This information is stored in a database with identification by model uncertainty (i.e., the methods used for CALMET and CALPUFF).

2.5.3 Atmospheric Releases of Radionuclides from the Idaho Chemical Processing Plant

The Radioactive Lanthanum (RaLa) process was designed to extract $^{140}\text{Ba}$ (half-life of 12.9 days), which decays to $^{140}\text{La}$ (40.2 hours), from irradiated reactor fuel. The latter isotope is an intense source of high-energy gamma rays and was used to evaluate the implosion process of
a nuclear weapon. The short half-lives of $^{140}\text{Ba}$ and $^{140}\text{La}$ required the design of a process in which fuel elements irradiated in a nuclear reactor were dissolved shortly after irradiation.

The RaLa process at the ICPP used fuel elements irradiated in the Material Testing Reactor (MTR) located on-site at INEL. A total of 36 RaLa runs took place at the ICPP between February 1957 and December 1959. Additional releases of radionuclides occurred as a result of a criticality accident on October 16, 1959, when highly enriched uranium solution was inadvertently transferred to a waste tank not designed to hold such a solution.

Essentially all releases from the ICPP during the years 1957-1959 were due to RaLa process operations. Gases and aerosol particles generated during RaLa dissolution and extraction processes were captured by an off-gas system, and then passed through a series of scrubbers and charcoal beds to a temporary 10,000-ft$^3$ storage tank. The number and type of filters changed with time during the period of operations. Before gases and aerosols were released to the atmosphere through the 250-ft ICPP stack, they were diluted by mixing with large amounts of the air from the ICPP building ventilation system, which created a total output flow rate of about 100,000 ft$^3$ per minute.

As part of the present study, Wichner et al. (2005a, b) estimated the activity of more than 130 radionuclides that were released to the atmosphere from RaLa process operations at the ICPP during the years 1957-1959, based on information obtained from historical Stack Monitoring Datasheets, from official RaLa project reports, progress reports, operational logs, calculation sheets, and contemporary project letters. On the basis of a screening analysis (Kocher 2005a, b), $^{131}\text{I}$ was determined to be by far the most important radionuclide in regard to potential radiation doses to members of the public who resided near INEL during the years 1957-1959. Twelve additional radionuclides of potential concern were also selected for inclusion in a more detailed dose reconstruction. This section summarizes the estimated releases of radionuclides that were found to be important in regard to potential exposures of the public.

Two isotopes of iodine were released in sufficiently large quantities to be of concern in regard to potential off-site exposures of the public: $^{131}\text{I}$ (half-life of 8.04 days) and $^{133}\text{I}$ (20.8 hours). Releases of radioactive isotopes of iodine were estimated using measurements of $^{131}\text{I}$ in samples of air from the ICPP stack, as reported in Stack Monitoring Datasheets; a method that is considered more reliable than theoretical modeling of the RaLa dissolving, extraction, storage, and off-gas systems. Iodine in stack air was collected during a 24-hour period (midnight to midnight) in a one-liter scrubber liquid sampler, which was later analyzed using a NaI crystal scintillation counter set to record the principal $^{131}\text{I}$ emissions. After removal of iodine from the liquid, a gross beta (i.e., beta minus iodine; $\beta$-I) and a gross-alpha ($\alpha$) reading were taken and recorded.

Since estimated releases of $^{131}\text{I}$ following the criticality accident are similar to releases during a normal RaLa run, and since they occurred over a number of days, the criticality accident can be considered in the same way as a routine RaLa run from the point of view of modeling the transport of $^{131}\text{I}$ into the atmosphere. In this report, the $^{131}\text{I}$ air concentrations were estimated including all normal (routine) releases from the ICPP during the years 1957-1959, and the
releases following the criticality accident. A separate analysis of the criticality accident is not performed. As summarized in Table 2.7, about 3,200 Ci (95% C.I. = 2,400 – 5,100 Ci) of $^{131}$I were released from the ICPP as a result of normal RaLa operations during 1957-1959 and the 1959 criticality accident.

Daily records of total beta minus iodine ($\beta-I$) activity and $\alpha$ activity provided by ICPP Stack Monitor Datasheets indicate that non-gaseous radionuclides were emitted from ICPP operations. Those radionuclides were attached to very small particles (aerosols), which were transported through the off-gas system and released to the atmosphere. Of the 115 radionuclides attached to aerosols that were assumed to be released to the atmosphere from the ICPP, the screening analysis resulted in selection of ten $\beta/\gamma$-emitting radionuclides ($^{89}$Sr, $^{90}$Sr, $^{91}$Y, $^{95}$Zr, $^{95}$Nb, $^{103}$Ru, $^{140}$Ba, $^{141}$Ce, $^{144}$Ce, and $^{143}$Pr) and one $\alpha$-emitting radionuclide ($^{238}$Pu) for inclusion in a detailed dose reconstruction. Of the ten $\beta/\gamma$-emitting radionuclides of potential concern, $^{140}$Ba has the shortest half-life (12.7 days), while $^{90}$Sr has the longest half-life (29.2 yrs). The one alpha-emitter of potential concern ($^{238}$Pu) is long-lived (87.7 years). All the radionuclides of concern for the ICPP releases have a long enough half-lives as compared to the travel time of the plume from the ICPP stack to the location of the receptors, so the loss of activity due to radioactive decay during atmospheric transport has a minimal effect.

Estimated releases of radionuclides attached to aerosols during the years 1957-1959 are presented in Table 2.6. As in the case of releases of iodine discussed above, releases of radionuclides in aerosol form following the criticality accident are similar to releases during a normal RaLa run, and the two types of releases are combined in estimating the air concentrations. The atmospheric dispersion calculations presented in this report are based on the estimated daily releases of radionuclides. As an example, Figure 2.21 shows the estimated activities of $^{131}$I, $^{140}$Ba and $^{90}$Sr released daily during January 1958 (RaLa Run #9).

For the probabilistic runs, the unit emission rate of 1Ci/s was used to estimate unit dispersion factors and these unit dispersion factors were stored in a database. Probabilistic air concentrations were calculated by multiplying probabilistically simulated emission rates by the unit dispersion factors. The emission rates for the uncertainty analyses are described later. Table 2.7 summarizes the central estimate of $^{131}$I concentrations used in the deterministic assessment.
Table 2.6  Estimated atmospheric releases of radionuclides from Idaho Chemical Processing Plant during 1957-1959 (Ci)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Lower bound</th>
<th>Central Estimate</th>
<th>Upper Bound</th>
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<td>2,400</td>
<td>3,200</td>
<td>5,100</td>
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<td>$^{133}$I</td>
<td>340</td>
<td>470</td>
<td>730</td>
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<td>$^{143}$Pr</td>
<td>174</td>
<td>344</td>
<td>886</td>
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<td>$^{141}$Ce</td>
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<td>873</td>
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<td>$^{140}$Ba</td>
<td>165</td>
<td>327</td>
<td>841</td>
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<tr>
<td>$^{95}$Zr</td>
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<td>292</td>
<td>751</td>
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<tr>
<td>$^{91}$Y</td>
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<td>723</td>
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<tr>
<td>$^{89}$Sr</td>
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<td>237</td>
<td>611</td>
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<tr>
<td>$^{95}$Nb</td>
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<td>195</td>
<td>502</td>
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<tr>
<td>$^{103}$Ru</td>
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<td>166</td>
<td>428</td>
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<tr>
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<td>81</td>
<td>208</td>
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<tr>
<td>$^{90}$Sr</td>
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<td>2.6</td>
<td>6.6</td>
</tr>
<tr>
<td>$^{238}$Pu</td>
<td>0.50</td>
<td>0.98</td>
<td>2.5</td>
</tr>
</tbody>
</table>

* The reported activities are in Curies (Ci). 1 Ci = $3.7 \times 10^{10}$ Bq (Becquerel)
Figure 2.21  Activity of iodine-131, barium-149 and strontium-90 released daily into the atmosphere during January 1958
Table 2.7  Deterministic monthly emissions (Ci)

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<th>Month</th>
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<th>1959</th>
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<td>110.6</td>
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<td>APR</td>
<td>86.4</td>
<td>56.0</td>
<td>8.9</td>
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<td>MAY</td>
<td>50.6</td>
<td>314.3</td>
<td>3.5</td>
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<td>JUN</td>
<td>163.1</td>
<td>241.9</td>
<td>2.7</td>
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<tr>
<td>JUL</td>
<td>26.5</td>
<td>1.7</td>
<td>11.5</td>
</tr>
<tr>
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<td>4.4</td>
</tr>
<tr>
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<td>38.4</td>
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<td>9.2</td>
</tr>
<tr>
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<td>316.7</td>
<td>125.1</td>
<td>17.1</td>
</tr>
<tr>
<td>NOV</td>
<td>257.5</td>
<td>39.9</td>
<td>15.2</td>
</tr>
<tr>
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<td>2.9</td>
<td>4.4</td>
<td>2.1</td>
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<tr>
<td>YEAR</td>
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<td>256.1</td>
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</table>

Note: 50th percentile of the probability distribution function obtained from the uncertainty analysis.

2.5.4  Particle Size Distributions

Iodine-131 and $^{133}$I were modeled as gases with plume depletion. When released, the other radionuclides were attached to very small particles, which behave similarly to gases and will also have small depletion from the plume. Therefore, unit air dispersion factors based on dispersion modeling as a gas were used for all radionuclides.
3.0  COMPARISON OF CALPUFF WITH REAL TIME SF$_6$ MEASUREMENTS FROM THE IDAHO NATIONAL ENGINEERING LABORATORY

This chapter provides a description of the validation of CALPUFF predictions compared to the results of a tracer study done by the Air Resources Laboratory Field Research Division (ARLFRD) for the emergency response at INEL. Based on these comparisons, CALPUFF was considered appropriate for air dispersion modeling of radionuclides.

3.1  TRACER TEST DATA

To test the validity of estimates of airborne concentrations of radionuclides, CALPUFF was evaluated using data collected in 1999 as part of an atmospheric tracer experiment. In that experiment, sulfur hexafluoride (SF6) was released from a 21-m stack in the INEL site in April and May 1999 during six 4-hour and one 2-hour tests. Two mobile real-time SF6 detectors were placed in vans and deployed during each test. The SF6 air concentrations were measured using detectors in the vans and detectors at fixed locations along three sampling arcs located 15 to 50 km northeast of the release (i.e., downwind). The number of sampling points per test varied from 520 to 12,478, and 54 sets of measurements were generated. The complete set of data, including release information, meteorological information, and measured air concentrations, was provided by Dr. Kirk Clawson of NOAA, one of the organizers of the experiment (Clawson 2003). The details of the experiment and measurements are described in a paper, “Comparison of a Puff Trajectory Model with Real Time Tracer Measurements” by Kirk L. Clawson et al. (2002).

Figure 3.1 adapted from Kirk L. Clawson et al. shows the location of the tracer release stack and plume sampling arcs on the INEL site. The distances to the arcs are: Arc A – about 15 km; Arc B – about 30 km; Arc C – about 50 km; and Arc D – about 15 – 20 km. Table 3.1 summarizes the tracer test results.

Figure 3.1  Location of the tracer release stack and plume sampling arcs on the Idaho National Engineering Laboratory site
Table 3.1  Tracer test summary (Ref. 1)

<table>
<thead>
<tr>
<th>Test #</th>
<th>Date</th>
<th>Release</th>
<th>Plume Tracking</th>
<th>Meteorology</th>
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<tr>
<td></td>
<td></td>
<td>Start Time (MDT)</td>
<td>End Time (MDT)</td>
<td>Wind Direction (degrees)</td>
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<tr>
<td>1</td>
<td>19-Apr</td>
<td>1400</td>
<td>1600</td>
<td>1700</td>
</tr>
<tr>
<td>2</td>
<td>23-Apr</td>
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<td>1700</td>
<td>1745</td>
</tr>
<tr>
<td>3</td>
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<td>1245</td>
<td>1645</td>
<td>1745</td>
</tr>
<tr>
<td>4</td>
<td>27-Apr</td>
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<td>1650</td>
<td>1740</td>
</tr>
<tr>
<td>5</td>
<td>02-May</td>
<td>1230</td>
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<tr>
<td>6</td>
<td>07-May</td>
<td>1300</td>
<td>1700</td>
<td>1800</td>
</tr>
<tr>
<td>7</td>
<td>07-May</td>
<td>2215</td>
<td>0215</td>
<td>0345</td>
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</tbody>
</table>

SENES Consultants Ltd. has attempted validation for all seven tracer tests. Each tracer test had a set of measurements and all measurements are included in the validation for all but Tracer test 5 and Tracer test 7, which each had 22 sets of measurements. For these tracer tests, we validated 6 of the 22 sets of measurements.

### 3.2 METHODOLOGY OF VALIDATION

Tracer measurements were done by instrumenting two vans. The time and location of each van were recorded, as well as the measured SF₆ concentrations. The number of sampling points per test varied from 520 to 12,478. All of the points in a particular test are taken into account during the validation. All lat-long coordinates for the measurements were converted to Lambert-Conformal coordinates and incorporated into the CALPUFF input files. Thus, wherever the measurements were taken there is a corresponding model prediction.

Excel spreadsheets were developed for each test and set of measurements and predictions. Based on these results the model performance statistics were developed. The summary of all the measurements and predictions is presented in Table 3.2.

Due to the characteristics of the model, all predictions are made on an hourly basis. Thus, the model results represent the hourly estimates. The maximum hourly results referred to in Table 3.2 are selected from all locations. The sample results represent the plume concentrations at the moment (few seconds) of the van passing through the plume at a specific location.

After the first round of validation, it was discovered that the measured averaged values were far below the predicted averages. This led to a review of NOAA’s original work (K.L. Clawson, 1999). From this, it was discovered that the values between limit of detection (LOD) and the limit of quantification (LOQ) were (very much) less certain than measurements reported as above the LOQ. NOAA defines the LOQ as 10 times the baseline noise and it is the level above which quantification may be performed with “reasonable” certainty.
After revising the measurement data and considering the exclusion of data below LOD and LOQ the model performance has improved. Nonetheless, the best agreement between the modeling and observation was still achieved with the maximum observed numbers. This is perhaps not surprising considering, the variety of factors that affect confidence in measuring and predicting concentrations over short times.

Table 3.2  SF6 - CALPUFF model validation

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<tr>
<th>Test</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ.(µg/m³)</th>
<th>Average Peak of Observ.(µg/m³)</th>
<th>1 Hour Obs. (µg/m³)</th>
<th>Model Prediction(µg/m³)</th>
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<th>Model Prediction(µg/m³)</th>
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<td>003-4-02</td>
<td>2014.7</td>
<td>8060</td>
<td>0.513</td>
<td>0.203</td>
<td>0.181</td>
<td>0.563</td>
</tr>
<tr>
<td>003-4-03</td>
<td>2270.0</td>
<td>9081</td>
<td>0.491</td>
<td>0.166</td>
<td>0.152</td>
<td>0.456</td>
</tr>
<tr>
<td>003-4-04</td>
<td>1017.3</td>
<td>4070</td>
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<td>0.059</td>
<td>0.046</td>
<td>0.759</td>
</tr>
<tr>
<td>003-7-01</td>
<td>3119.3</td>
<td>12478</td>
<td>1.369</td>
<td>0.213</td>
<td>0.207</td>
<td>2.571</td>
</tr>
<tr>
<td>003-7-02</td>
<td>171.0</td>
<td>685</td>
<td>1.054</td>
<td>0.188</td>
<td>0.102</td>
<td>2.708</td>
</tr>
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<td>003-7-03</td>
<td>2906.5</td>
<td>11627</td>
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<td>1.185</td>
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</table>

3-3
### Table 3.2 SF₆ - CALPUFF model validation (continued)

#### TEST 4 - April 27, 1999 (13:00-16:50 MDT)

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Average Peak of Observ. (µg/m³)</th>
<th>1 Hour Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>004-4-01</td>
<td>1052.0</td>
<td>4209</td>
<td>0.434</td>
<td>0.123</td>
<td>0.069</td>
<td>0.096 0.121</td>
</tr>
<tr>
<td>004-4-02</td>
<td>1487.0</td>
<td>5949</td>
<td>0.323</td>
<td>0.065</td>
<td>0.036</td>
<td>0.140 0.273</td>
</tr>
<tr>
<td>004-4-03</td>
<td>299.8</td>
<td>1200</td>
<td>0.439</td>
<td>0.151</td>
<td>0.085</td>
<td>0.339 0.371</td>
</tr>
<tr>
<td>004-4-04</td>
<td>1360.7</td>
<td>5444</td>
<td>0.278</td>
<td>0.046</td>
<td>0.026</td>
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<tr>
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<td>294.8</td>
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<td>0.225</td>
<td>0.640 1.117</td>
</tr>
<tr>
<td>004-4-06</td>
<td>214.7</td>
<td>860</td>
<td>1.073</td>
<td>0.248</td>
<td>0.139</td>
<td>0.801 1.118</td>
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<td>004-7-01</td>
<td>1508.8</td>
<td>6036</td>
<td>1.485</td>
<td>0.216</td>
<td>0.120</td>
<td>3.227 5.443</td>
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<tr>
<td>004-7-02</td>
<td>1373.3</td>
<td>5494</td>
<td>3.684</td>
<td>0.313</td>
<td>0.175</td>
<td>2.326 4.817</td>
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<td>004-7-03</td>
<td>1519.3</td>
<td>6078</td>
<td>3.498</td>
<td>0.586</td>
<td>0.327</td>
<td>2.331 4.808</td>
</tr>
<tr>
<td>004-7-04</td>
<td>1704.5</td>
<td>6819</td>
<td>1.123</td>
<td>0.168</td>
<td>0.094</td>
<td>1.708 2.814</td>
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<td>004-7-05</td>
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<td>1587</td>
<td>1.397</td>
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<td>0.283</td>
<td>2.413 2.739</td>
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#### TEST 5 - May 02, 1999 (12:30-16:23 MDT)

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<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Average Peak of Observ. (µg/m³)</th>
<th>1 Hour Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>005-4-01</td>
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<td>0.048 0.265</td>
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<td>0.155</td>
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<td>0.000 0.000</td>
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<td>0.237 0.499</td>
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<td>005-7-08</td>
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<td>0.703 1.163</td>
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#### TEST 6 - May 07, 1999 (13:00-17:00 MDT)

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<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Average Peak of Observ. (µg/m³)</th>
<th>1 Hour Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>006-4-01</td>
<td>284.8</td>
<td>1240</td>
<td>0.087</td>
<td>0.090</td>
<td>0.054</td>
<td>0.457 0.593</td>
</tr>
<tr>
<td>006-4-02</td>
<td>400.2</td>
<td>1860</td>
<td>0.363</td>
<td>0.066</td>
<td>0.042</td>
<td>0.392 0.593</td>
</tr>
<tr>
<td>006-4-03</td>
<td>1511.8</td>
<td>1460</td>
<td>0.434</td>
<td>0.090</td>
<td>0.076</td>
<td>0.214 0.559</td>
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<tr>
<td>006-4-04</td>
<td>1169.8</td>
<td>1560</td>
<td>0.281</td>
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<td>0.029</td>
<td>0.158 0.426</td>
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<tr>
<td>006-7-01</td>
<td>284.8</td>
<td>1240</td>
<td>0.087</td>
<td>0.090</td>
<td>0.054</td>
<td>0.468 0.515</td>
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<tr>
<td>006-7-02</td>
<td>400.2</td>
<td>1860</td>
<td>0.363</td>
<td>0.066</td>
<td>0.042</td>
<td>0.343 0.593</td>
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<tr>
<td>006-7-03</td>
<td>1511.8</td>
<td>1460</td>
<td>0.434</td>
<td>0.090</td>
<td>0.076</td>
<td>0.395 0.749</td>
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<tr>
<td>006-7-04</td>
<td>1169.8</td>
<td>1560</td>
<td>0.281</td>
<td>0.036</td>
<td>0.029</td>
<td>0.674 0.888</td>
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<tr>
<td>006-7-05</td>
<td>1265.0</td>
<td>5061</td>
<td>3.917</td>
<td>1.144</td>
<td>0.928</td>
<td>0.672 1.699</td>
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<tr>
<td>006-7-06</td>
<td>1002.3</td>
<td>4010</td>
<td>0.394</td>
<td>0.071</td>
<td>0.055</td>
<td>0.563 0.802</td>
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<tr>
<td>006-7-07</td>
<td>1363.0</td>
<td>5453</td>
<td>0.301</td>
<td>0.078</td>
<td>0.064</td>
<td>0.314 0.633</td>
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<tr>
<td>006-7-08</td>
<td>389.8</td>
<td>1560</td>
<td>0.320</td>
<td>0.123</td>
<td>0.079</td>
<td>0.533 0.888</td>
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### Table 3.2  SF$_6$ - CALPUFF model validation (continued)

**TEST 7 - May 07/08, 1999 (22:15-02:15 MDT)**

<table>
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<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m$^3$)</th>
<th>Average Peak of Observ. (µg/m$^3$)</th>
<th>1 Hour Obs. (µg/m$^3$)</th>
<th>Model Prediction (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>007-4-01</td>
<td>244.7</td>
<td>980</td>
<td>0.220</td>
<td>0.059</td>
<td>0.037</td>
<td>0.186</td>
</tr>
<tr>
<td>007-4-04</td>
<td>1059.2</td>
<td>4238</td>
<td>3.265</td>
<td>1.473</td>
<td>1.201</td>
<td>0.370</td>
</tr>
<tr>
<td>007-4-08</td>
<td>2040.5</td>
<td>8163</td>
<td>19.723</td>
<td>6.339</td>
<td>5.766</td>
<td>3.433</td>
</tr>
<tr>
<td>005-4-12</td>
<td>299.8</td>
<td>1200</td>
<td>0.440</td>
<td>0.087</td>
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<td>2.739</td>
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<td>20.326</td>
<td>9.762</td>
<td>8.109</td>
<td>2.242</td>
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### Table 3.3  SF$_6$ - CALPUFF model validation > LOD, and >LOQ

**TEST 1 - April 19, 1999 (14:00-16:00 MDT)**

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m$^3$)</th>
<th>Avg&gt;LOD of Observ. (µg/m$^3$)</th>
<th>Avg&gt;LOQ Obs. (µg/m$^3$)</th>
<th>Model Prediction (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001-4-01</td>
<td>617.7</td>
<td>2472</td>
<td>0.616</td>
<td>0.286</td>
<td>0.579</td>
<td>0.342</td>
</tr>
<tr>
<td>001-4-02</td>
<td>152.0</td>
<td>609</td>
<td>0.437</td>
<td>0.268</td>
<td>N/A</td>
<td>0.997</td>
</tr>
<tr>
<td>001-7-01</td>
<td>309.7</td>
<td>1240</td>
<td>0.343</td>
<td>0.211</td>
<td>N/A</td>
<td>0.107</td>
</tr>
<tr>
<td>001-7-02</td>
<td>2759.5</td>
<td>11039</td>
<td>2.010</td>
<td>0.543</td>
<td>0.881</td>
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</table>

**TEST 2 - April 23, 1999 (13:00-17:00 MDT)**

<table>
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<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m$^3$)</th>
<th>Avg&gt;LOD of Observ. (µg/m$^3$)</th>
<th>Avg&gt;LOQ Obs. (µg/m$^3$)</th>
<th>Model Prediction (µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>002-4-01</td>
<td>250.3</td>
<td>1002</td>
<td>0.975</td>
<td>0.375</td>
<td>0.975</td>
<td>0.234</td>
</tr>
<tr>
<td>002-4-02</td>
<td>239.7</td>
<td>960</td>
<td>0.191</td>
<td>0.183</td>
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<td>0.036</td>
</tr>
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<td>002-4-03</td>
<td>129.8</td>
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<td>0.181</td>
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<td>001-7-01</td>
<td>1487.5</td>
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<td>0.587</td>
<td>0.151</td>
</tr>
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<td>001-7-02</td>
<td>1169.8</td>
<td>4680</td>
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<td>0.636</td>
<td>0.999</td>
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<td>0.764</td>
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<td>0.602</td>
<td>1.181</td>
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</table>
### Table 3.3  SF₆ - CALPUFF model validation > LOD, and >LOQ (continued)

#### TEST 3 - April 26, 1999 (12:45-16:45 MDT)

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<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Avg&gt;LOD of Observ. (µg/m³)</th>
<th>Avg&gt;LOQ Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>003-4-01</td>
<td>1004.7</td>
<td>4020</td>
<td>0.334</td>
<td>0.210</td>
<td>N/A</td>
<td>0.761 (0.854)</td>
</tr>
<tr>
<td>003-4-02</td>
<td>2014.7</td>
<td>8060</td>
<td>0.513</td>
<td>0.283</td>
<td>N/A</td>
<td>0.563 (0.852)</td>
</tr>
<tr>
<td>003-4-03</td>
<td>2270.0</td>
<td>9081</td>
<td>0.491</td>
<td>0.248</td>
<td>N/A</td>
<td>0.456 (0.851)</td>
</tr>
<tr>
<td>003-4-04</td>
<td>1017.3</td>
<td>4070</td>
<td>0.318</td>
<td>0.209</td>
<td>N/A</td>
<td>0.759 (0.804)</td>
</tr>
<tr>
<td>003-7-01</td>
<td>3119.3</td>
<td>12478</td>
<td>1.369</td>
<td>0.526</td>
<td>0.798</td>
<td>2.571 (2.571)</td>
</tr>
<tr>
<td>003-7-02</td>
<td>171.0</td>
<td>685</td>
<td>1.054</td>
<td>0.411</td>
<td>0.837</td>
<td>2.708 (2.755)</td>
</tr>
<tr>
<td>003-7-03</td>
<td>2906.5</td>
<td>11627</td>
<td>2.583</td>
<td>0.586</td>
<td>0.907</td>
<td>1.185 (2.956)</td>
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</table>

#### TEST 4 - April 27, 1999 (13:00-16:50 MDT)

<table>
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<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Avg&gt;LOD of Observ. (µg/m³)</th>
<th>Avg&gt;LOQ Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>004-4-01</td>
<td>1052.0</td>
<td>4209</td>
<td>0.434</td>
<td>0.267</td>
<td>N/A</td>
<td>0.096 (0.121)</td>
</tr>
<tr>
<td>004-4-02</td>
<td>1487.0</td>
<td>5949</td>
<td>0.323</td>
<td>0.201</td>
<td>N/A</td>
<td>0.140 (0.273)</td>
</tr>
<tr>
<td>004-4-03</td>
<td>299.8</td>
<td>1200</td>
<td>0.439</td>
<td>0.295</td>
<td>N/A</td>
<td>0.339 (0.371)</td>
</tr>
<tr>
<td>004-4-04</td>
<td>1360.7</td>
<td>5444</td>
<td>0.278</td>
<td>0.190</td>
<td>N/A</td>
<td>0.294 (0.703)</td>
</tr>
<tr>
<td>004-4-05</td>
<td>294.8</td>
<td>1180</td>
<td>1.448</td>
<td>0.684</td>
<td>1.046</td>
<td>0.640 (1.117)</td>
</tr>
<tr>
<td>004-4-06</td>
<td>214.7</td>
<td>860</td>
<td>1.073</td>
<td>0.444</td>
<td>0.807</td>
<td>0.801 (1.118)</td>
</tr>
<tr>
<td>004-7-01</td>
<td>1508.8</td>
<td>6036</td>
<td>1.485</td>
<td>0.359</td>
<td>0.703</td>
<td>3.227 (5.443)</td>
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<tr>
<td>004-7-02</td>
<td>1373.3</td>
<td>5494</td>
<td>3.684</td>
<td>0.572</td>
<td>1.137</td>
<td>2.326 (4.817)</td>
</tr>
<tr>
<td>004-7-03</td>
<td>1519.3</td>
<td>6078</td>
<td>3.498</td>
<td>0.813</td>
<td>1.185</td>
<td>2.331 (4.808)</td>
</tr>
<tr>
<td>004-7-04</td>
<td>1704.5</td>
<td>6819</td>
<td>1.123</td>
<td>0.375</td>
<td>0.732</td>
<td>1.708 (2.814)</td>
</tr>
<tr>
<td>004-7-05</td>
<td>396.5</td>
<td>1587</td>
<td>1.397</td>
<td>0.757</td>
<td>0.846</td>
<td>2.413 (2.739)</td>
</tr>
</tbody>
</table>

#### TEST 5 - May 02, 1999 (12:30-16:23 MDT)

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m³)</th>
<th>Avg&gt;LOD of Observ. (µg/m³)</th>
<th>Avg&gt;LOQ Obs. (µg/m³)</th>
<th>Model Prediction (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>005-4-01</td>
<td>1034.8</td>
<td>4140</td>
<td>0.504</td>
<td>0.236</td>
<td>N/A</td>
<td>0.048 (0.265)</td>
</tr>
<tr>
<td>005-4-04</td>
<td>324.7</td>
<td>1300</td>
<td>0.449</td>
<td>0.262</td>
<td>N/A</td>
<td>0.000 (0.000)</td>
</tr>
<tr>
<td>005-4-08</td>
<td>650.0</td>
<td>2601</td>
<td>0.536</td>
<td>0.266</td>
<td>N/A</td>
<td>0.237 (0.499)</td>
</tr>
<tr>
<td>005-7-04</td>
<td>744.8</td>
<td>2980</td>
<td>0.891</td>
<td>0.418</td>
<td>0.655</td>
<td>0.225 (0.644)</td>
</tr>
<tr>
<td>005-7-08</td>
<td>329.7</td>
<td>1320</td>
<td>0.930</td>
<td>0.442</td>
<td>0.643</td>
<td>0.979 (1.160)</td>
</tr>
<tr>
<td>005-7-12</td>
<td>869.7</td>
<td>3480</td>
<td>0.930</td>
<td>0.372</td>
<td>0.636</td>
<td>0.703 (1.163)</td>
</tr>
</tbody>
</table>
### Table 3.3 SF<sub>6</sub> - CALPUFF model validation > LOD, and >LOQ (continued)

#### TEST 6 – May 07, 1999 (13:00-17:00 MDT)

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Avg&gt;LOD of Observ. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Avg&gt;LOQ Obs. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Model Prediction (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>006-4-01</td>
<td>284.8</td>
<td>1240</td>
<td>0.264</td>
<td>0.189</td>
<td>N/A</td>
<td>0.457</td>
</tr>
<tr>
<td>006-4-02</td>
<td>400.2</td>
<td>1860</td>
<td>0.322</td>
<td>0.217</td>
<td>N/A</td>
<td>0.392</td>
</tr>
<tr>
<td>006-4-03</td>
<td>1511.8</td>
<td>1460</td>
<td>0.246</td>
<td>0.184</td>
<td>N/A</td>
<td>0.214</td>
</tr>
<tr>
<td>006-4-04</td>
<td>1169.8</td>
<td>1560</td>
<td>0.264</td>
<td>0.197</td>
<td>N/A</td>
<td>0.158</td>
</tr>
<tr>
<td>006-7-01</td>
<td>284.8</td>
<td>1240</td>
<td>0.382</td>
<td>0.210</td>
<td>N/A</td>
<td>0.468</td>
</tr>
<tr>
<td>006-7-02</td>
<td>400.2</td>
<td>1860</td>
<td>0.363</td>
<td>0.218</td>
<td>N/A</td>
<td>0.343</td>
</tr>
<tr>
<td>006-7-03</td>
<td>1511.8</td>
<td>1460</td>
<td>0.434</td>
<td>0.231</td>
<td>N/A</td>
<td>0.395</td>
</tr>
<tr>
<td>006-7-04</td>
<td>1169.8</td>
<td>1560</td>
<td>0.281</td>
<td>0.200</td>
<td>N/A</td>
<td>0.674</td>
</tr>
<tr>
<td>006-7-05</td>
<td>1265.0</td>
<td>5061</td>
<td>3.917</td>
<td>1.422</td>
<td>1.448</td>
<td>0.672</td>
</tr>
<tr>
<td>006-7-06</td>
<td>1002.3</td>
<td>4010</td>
<td>0.394</td>
<td>0.241</td>
<td>N/A</td>
<td>0.563</td>
</tr>
<tr>
<td>006-7-07</td>
<td>1363.0</td>
<td>5453</td>
<td>0.301</td>
<td>0.195</td>
<td>N/A</td>
<td>0.314</td>
</tr>
<tr>
<td>006-7-08</td>
<td>389.8</td>
<td>1560</td>
<td>0.320</td>
<td>0.212</td>
<td>N/A</td>
<td>0.533</td>
</tr>
</tbody>
</table>

#### TEST 7 - May 07/08, 1999 (22:15-02:15 MDT)

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Duration (s) of Sampling</th>
<th>Number of Sampling Points</th>
<th>Maximum Peak of Observ. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Avg&gt;LOD of Observ. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Avg&gt;LOQ Obs. (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Model Prediction (µg/m&lt;sup&gt;3&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>007-4-01</td>
<td>244.7</td>
<td>980</td>
<td>0.220</td>
<td>0.220</td>
<td>N/A</td>
<td>0.186</td>
</tr>
<tr>
<td>007-4-04</td>
<td>1059.2</td>
<td>4238</td>
<td>3.265</td>
<td>1.824</td>
<td>1.846</td>
<td>0.370</td>
</tr>
<tr>
<td>007-4-08</td>
<td>2040.5</td>
<td>8163</td>
<td>19.723</td>
<td>6.940</td>
<td>7.324</td>
<td>3.433</td>
</tr>
<tr>
<td>005-4-12</td>
<td>299.8</td>
<td>1200</td>
<td>0.440</td>
<td>0.281</td>
<td>N/A</td>
<td>0.370</td>
</tr>
<tr>
<td>007-7-03</td>
<td>2497.8</td>
<td>9992</td>
<td>16.373</td>
<td>4.742</td>
<td>5.038</td>
<td>2.739</td>
</tr>
<tr>
<td>007-7-07</td>
<td>1184.7</td>
<td>4740</td>
<td>20.326</td>
<td>11.036</td>
<td>11.292</td>
<td>2.242</td>
</tr>
</tbody>
</table>

Based on the maximum predicted and maximum observed numbers and following the EPA’s Protocol for the best performing model, the summary statistics for the model performance are as presented in Table 3.4. Figure 3.2 presents the scattergram of measured and predicted concentrations based on 54 sets of measurements with thousands of different locations and indicates a correlation between predicted and measured values.
Table 3.4   Maximum hourly model vs. observation results

<table>
<thead>
<tr>
<th>Statistics</th>
<th>All Tests 54 Sets of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of prediction</td>
<td>1.4</td>
</tr>
<tr>
<td>Mean of observations</td>
<td>1.1</td>
</tr>
<tr>
<td>Fractional bias of the average</td>
<td>0.17</td>
</tr>
<tr>
<td>Standard deviation of prediction</td>
<td>1.4</td>
</tr>
<tr>
<td>Standard deviation of observations</td>
<td>1.5</td>
</tr>
<tr>
<td>Fractional bias of standard deviation</td>
<td>-0.05</td>
</tr>
<tr>
<td>For paired data</td>
<td></td>
</tr>
<tr>
<td>Within a factor of two (%)</td>
<td>59.3</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Figure 3.2   Scattergram of model performance

Note: * For TEST 7, with stable atmospheric conditions, the predicted maximum concentrations were lower than those observed (overall average ratio of pred/obs of about 0.85). However, when the observed peaks were converted to hourly average values the comparison to maximum hourly predictions improved.
Figures 3.3, 3.4, and 3.5 represent the ratio of modeled results with the observation as a function of sampling time. These graphs demonstrate two things:

(a) As sampling time increases, there is a tendency for the ratio between model predictions and observations to converge (become less variable) as the averaging time for measurement approaches the averaging time for the predicted concentrations.

(b) When observed values are limited to those above the LOQ, the general agreement between the observations and model predictions improves.

Figure 3.3   Ratios of maximums as a function of sampling time
Figure 3.4  Ratios of averages > LOD as a function of sampling time

Figure 3.5  Ratios of averages > LOQ as a function of sampling time

Figure 3.6 presents CALPUFF results of 5-hour average concentrations for test 1 (April 19, 1999). This pattern compared quite well with the MDIFF output for the same time period shown in Figure 21 (Clawson, 1999).
Figure 3.6   CALPUFF results

5 Hour Average Ground Level Concentration in ug/m^3 of SF6  
Based on Emissions of 20.8 g/s
Apr, 19 1999 (13:00-17:00)
Figure 21 is an example “footprint” output of MDIFF showing trajectories (black lines) and total Integrated SF₆ concentration isopleths for Test 1 (19 April) from Clawson 1999.
Figure 3.7 shows one example of the sampling points and plume lines during the TEST 3 between 14:00 and 15:00 MDT. This figure demonstrates that sampling locations during this experiment were in the plume.

Figure 3.7  003701 max hour ground level concentration in ug/m³ of SF₆ based on emissions of 20.8 g/s
April 26, 1999 (14:00 – 15:00 MDT)
3.3 CALMET PERFORMANCE

Figure 2 (Clawson, 2000) and Figure 3.3 for TEST 4 (April 27, 1999 at 14:00 MST) are suggesting good agreement between the observations and CALMET predictions (Figure 3.8).

Figures D.1 through D.18 in Appendix D are the wind fields for selected hours during different tests. Note: the hours on the Figures are in MST time. Wind flow presented in Figure D.18 agrees with the description in the cited paper about the northwest cold air drainage from Birch Creek Canyon (a canyon located to the north-west of the INEL property). This is a good illustration of CALMET’s capabilities to capture the up-slope and down-slope winds.

Figure 2 (Clawson, 2000)

![Figure 2](image)

Figure 2 is an example INEL mesonet wind field over the test grid for Test 4 (27 April) at 1500 hours MDT.
Figure 3.8  Wind fields over Idaho National Engineering Laboratory property and CALPUFF modeling domain

SF6 - TEST4 - 14:00, April 27, 1999
3.4 CONCLUSIONS AND RECOMMENDATIONS

Based on this validation, it is evident that the CALMET/CALPUFF modeling system is quite applicable for the INEL site. The model validations demonstrate quite good agreement with the maximum measured values. Agreement with the average values is satisfactory but not as good, in our view, because of the LOD problem of the measurements.

Based on past experience, in view of this problem, validation through direct comparison of hourly predicted and observed values is likely to result in even further confidence concerning the reasonableness of the CALPUFF predicted concentrations, and subsequent dose calculations. Availability of hourly data for a year would allow model validation for longer averaging periods (1 hr, 24 hr and annual); time periods of greater importance for dose calculations.
4.0 CALPUFF PREDICTED IODINE-131 CONCENTRATIONS FOR DETERMINISTIC RUN

The concentrations of $^{131}$I predicted using the CALMET/CALPUFF options, as described previously, are summarized in this chapter. The deterministic modeling is based on daily emission factors and the CALMET meteorological predictions based on the three stations available in the 1957-1959 period. The annual $^{131}$I air concentrations predicted using daily emission factors for 1957, 1958 and 1959 are presented in Figures 4.1, 4.2 and 4.3 respectively. All presented concentrations are in Bq/m$^3$.

The variability in annual average concentrations, based on the deterministic runs, includes the effects of meteorological and emission variability. If the SE corner of the property is taken as a point of comparison it can be seen that in 1957 and 1958 predicted concentrations are approximately 0.01 Bq/m$^3$, while in 1959 the predicted concentration at the same location is 0.0015 Bq/m$^3$. A comparison of total emissions, given in Table 2.5, indicates that there is a 7 to 1 reduction in emissions between 1957-1958 and 1959. The temporal pattern in predicted concentrations follows this temporal pattern in emissions.

The patterns generally align along a southwest to northeast axis that is consistent with the predominant wind directions in the area. There is some variation in the pattern of annual average concentrations arising from, in part, differences in meteorology between the years. It is of note that the concentrations at Atomic City (location 3 on the figures) are greater that the concentrations measured at Mud Lake (location 20 on the figures). This arises because the uncertainty analyses include adjustments based on differences between dispersion with three stations and with 25 meteorological stations. These adjustments were not included in the deterministic modeling. The relative magnitude of air concentrations changes after the uncertainty analysis as described in Section 5.4.4.
Figure 4.1  Predicted annual iodine-131 CALPUFF concentrations for 1957
Figure 4.2  Predicted annual iodine-131 CALPUFF concentrations for 1958
Figure 4.3 Predicted annual Iodine-131 CALPUFF concentrations for 1959
From the summary of emission rates shown in Table 2.5, the three highest months from 1957 and 1958 are presented in Figures 4.4 through 4.9. Figures 4.4, 4.5 and 4.6 represent monthly concentrations for February, October and November in 1957 respectively. Figures 4.7, 4.8 and 4.9 show the three months (March, May and June) with the highest emissions in 1958. These figures represent the variability in monthly (daily) emissions as well as variability (seasonality) in meteorology.

On a monthly basis, the variability in concentrations at the SE corner of the property is in the range of 0.1 to 0.03 Bq/m³ (factor of 3) for these months with high emissions. It is important to note that the predicted monthly concentration levels can be higher than annual averages by about factor of 10 as a result of variability in both emissions and meteorology. Another characteristic of the monthly concentration prediction is the shape of contour lines, which represents, in part, the monthly (seasonal) meteorological variability. The month-to-month variations in shape are larger than the variation in shape of annual average concentrations shown in Figures 4.1 to 4.3.
Figure 4.4  Monthly iodine-131 CALPUFF concentrations – February 1957
Figure 4.5  Monthly iodine-131 CALPUFF concentrations – October 1957
Figure 4.6  Monthly iodine-131 CALPUFF concentrations – November 1957
Figure 4.7 Monthly iodine-131 CALPUFF concentrations – March 1958
Figure 4.8 Monthly iodine-131 CALPUFF concentrations – May 1958
Figure 4.9  Monthly iodine-131 CALPUFF concentrations – June 1958
5.0 PROBABILISTIC APPROACH

The objective of the probabilistic simulation was to estimate monthly average air concentrations and the uncertainty in these average concentrations. Three major sources of uncertainty in the air concentrations were considered: first, was the emission rate from the facility, second was the approach for air dispersion modeling and, third, was the uncertainty in air dispersion modeling introduced by uncertainty in the meteorological conditions.

Monte Carlo sampling techniques were used to formally quantify the uncertainty in the estimated air concentrations.

5.1 APPROACH

Variability in air concentrations and receptor locations will be present due to variations in release rates, air dispersion processes and meteorological conditions which can change substantially on time-scales of less than a month. Information is available on meteorological conditions on an hourly basis and for emissions on a daily basis. In order to account for variability in hourly meteorological conditions, air dispersion characteristics have been calculated on an hourly basis and summarized on a daily basis. These daily dispersion factors are combined with daily emission rates to estimate daily average concentrations. The daily average concentrations are then summarized on a monthly basis. In this way, the variability in meteorology, air dispersion and emission rates are addressed in the calculation of monthly average concentrations. The probabilistic approach addresses the uncertainty present in the daily emission rates and the hourly meteorological and air dispersion characteristics.

The overall approach was to use CALPUFF to calculate unit dispersion factors (concentration per unit emission) on an hourly basis for each receptor location in order to reflect the hourly variability in dispersion due to meteorology and location relative to the facility. Uncertainty is present in the air dispersion modeling even if meteorological conditions were known exactly due to the choice of algorithms within the mathematical model. Eight choices of algorithms within the CALPUFF dispersion model and the CALMET processor were identified and unit dispersion factors with these choices were stored in a database for access during the probabilistic assessment rather than re-running the CALPUFF model for each simulation.

Due to the complex local topography and meteorological characteristics present in the physical setting, there is uncertainty in the hourly meteorological characteristics using the three surface air stations available for the 1957-1959 period. An estimate of the uncertainty in meteorological conditions has been quantified using a recent and more intensive network of 25 surface air stations. This larger network is considered to provide “precise” characterization of meteorological conditions in the area. The uncertainty in air dispersion attributable to uncertainty in meteorological conditions can be quantified by comparing hourly unit dispersion factors calculated using the 25 surface air stations to the unit dispersion factors calculated using three surface air stations. This was completed for 1999 using each of the eight dispersion-modeling approaches. The uncertainty in unit air dispersion factors quantified for 1999 was considered applicable for 1957-1959. The uncertainty was applied to the 1957-1959 unit air dispersion
factors (estimated with three surface air stations) on an hourly basis and then summarized on a
daily basis. This step provided a probabilistic assessment of average daily dispersion factor.

The probabilistically generated daily dispersion factors were multiplied by the probabilistically
sampled emission rates to calculate the average concentration on a daily basis. For each
simulation, a monthly average was calculated.

For each radionuclide and receptor location, there were 500 simulations of average monthly air
concentrations for the 1957-1959 period.

5.2 SAMPLING DISTRIBUTIONS

5.2.1 Emission Rates

Five hundred (500) probabilistic simulations of daily emissions for each of the 13 radionuclides
were used (Wichner et al. 2005a,b). These values are summarized in a previous chapter.

5.2.2 Air Dispersion Modeling Scenarios

The options considered during air dispersion modeling include: i) the methods for calculation of
vertical wind profile by the CALMET processor; ii) the method for terrain adjustment within
CALPUFF; and, the method for estimating dispersion coefficients within CALPUFF. The
choice of a particular method was considered the major source of uncertainty in atmospheric
dispersion modeling given that meteorology and release characteristics are well known.

Overall, there are eight dispersion-modeling scenarios (i.e. two options for wind profile times
two options for terrain adjustment times two options for dispersion coefficients). Table 5.1
shows the probabilities for the dispersion modeling scenarios. The assigned subjective
probabilities were based on the experience of the authors. The scenario using similarity theory
for vertical wind profile in CALMET, partial plume for terrain adjustment in CALPUFF and PG
dispersion coefficients in CALPUFF was considered the most likely scenario for air dispersion
modeling.

During the probabilistic analyses, the same air dispersion modeling approach was used for all
receptors for the entire 1957-1959 period rather than changing the air dispersion modeling
approach from hour-to-hour or day-to-day.
Table 5.1  Probability for dispersion modeling scenarios

<table>
<thead>
<tr>
<th>Modeling Scenario</th>
<th>Scenario Code</th>
<th>Probability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity, partial plume, PG coefficients</td>
<td>s1</td>
<td>30</td>
</tr>
<tr>
<td>Similarity, partial plume, internal</td>
<td>s2</td>
<td>10</td>
</tr>
<tr>
<td>Similarity, simple CALPUFF, PG coefficients</td>
<td>s3</td>
<td>10</td>
</tr>
<tr>
<td>Similarity, simple CALPUFF, internal</td>
<td>s4</td>
<td>10</td>
</tr>
<tr>
<td>Power law, partial plume, PG coefficients</td>
<td>sa1</td>
<td>10</td>
</tr>
<tr>
<td>Power law, partial plume, internal</td>
<td>sa2</td>
<td>10</td>
</tr>
<tr>
<td>Power law, simple CALPUFF, PG coefficients</td>
<td>sa3</td>
<td>10</td>
</tr>
<tr>
<td>Power law, simple CALPUFF, internal</td>
<td>sa4</td>
<td>10</td>
</tr>
</tbody>
</table>

Notes:
Dispersion modeling scenario described by vertical wind profile method, terrain adjustment and dispersion coefficients.

5.2.3 Meteorological Uncertainty

Dispersion modeling was conducted for 1999 using each modeling scenario with either only the surface 3 stations also available in 1957-1959 or all 25 surface stations available in 1999. The 25 surface stations are assumed to provide “accurate” meteorological data for air dispersion modeling; therefore, the uncertainty in unit dispersion factors was defined as the difference between unit dispersion factors modeled with 25 surface stations and the unit dispersion factors modeled with 3 surface air stations.

Table 5.2 presents a matrix that shows how the approach to simulation of unit dispersion factors in 1957-1959 based on unit dispersion factors calculated using 3 stations related to the unit dispersion factors calculated for the same location using the meteorological data for 25 stations. This is potentially important, as there are situations where, for example, the concentrations predicted at a specific location using the meteorological data for 3 stations may be zero while the concentrations predicted using the meteorological data developed for 25 stations is non-zero and vice-versa. The modeled unit dispersion factor using three surface stations will either be zero or a value >0. When the modeled unit dispersion factor is zero, the sampled unit dispersion factor will be zero with probability P(0,0)*. For the remaining percentage, the uncertainty in the modeled unit dispersion factor will be sampled from the distribution of modeled unit dispersion factors observed in 1999 using 25 stations when the modeled unit dispersion factor using three stations was zero and the modeled unit dispersion factor using 25 stations was non-zero.

For the case when the unit dispersion factor for three stations is >0, the adjustment to the unit dispersion factor will be zero with probability P(0,>0). For the remaining percentage, a ratio between 25 and 3 station unit dispersion factors will be sampled from the distribution observed in 1999. The adjusted unit dispersion factor will be calculated by multiplying the unit dispersion factor, using three stations, by the sampled ratio.
Table 5.2  Approach to modeling effect of meteorological uncertainty for different categories

<table>
<thead>
<tr>
<th>Zero with 25 stations</th>
<th>Positive with 25 stations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zero with 3 stations</strong></td>
<td><strong>1 - P(0,0)</strong></td>
</tr>
<tr>
<td>$P(0,0)$ probability of zero for 25 stations when 3 stations also had a zero</td>
<td>Outcome: Sample a value of zero</td>
</tr>
<tr>
<td></td>
<td>Outcome: sample from distribution of unit dispersion factors with 25 stations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positive with 3 stations</th>
<th><strong>1-P(0,&gt;0)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P(0,&gt;0)$ probability of zero for 25 stations when 3 stations had a positive factor</td>
<td>Outcome: Sample a value of zero</td>
</tr>
<tr>
<td></td>
<td>Outcome: sample from distribution of ratio between unit dispersion factors with 25 stations and unit dispersion factor</td>
</tr>
</tbody>
</table>

* Where the concentrations predicted with both data set is zero [P (25 stations, 3 stations)]

The probability of zero with 25 stations and the uncertainty in unit dispersion factors are likely related to meteorological conditions. A more precise characterization of the uncertainty attributable to meteorological uncertainty has been pursued by subdividing the sampling probabilities by meteorological category relative to wind speed, direction and stability class, since these are important factors in air dispersion. The four categories for wind direction are N (315° – 45°), E (45° - 135°), S (135° - 225°), and W (225° - 315°). Three stability categories have been created by grouping AB, CD, and EF. Wind speeds were categorized by 0-2 m/s, 2-3 m/s, 3-5 m/s, 5-6 m/s and >6 m/s for CD stability class. Since higher wind speeds are infrequent for AB and EF stability classes, the wind speeds were categorized as 0-2 m/s, 2-3 m/s and >3 m/s for these stability categories. The meteorological categories are based on selected CALMET grid points.

Each hour in 1999 was categorized by the meteorological categories described above. The average unit dispersion factors for 3 and 25 surface air stations were calculated for each hour and the sampling distributions were developed for that meteorological category. The uncertainty estimated in 1999 was assumed to be the same that would be present in the 1957 to 1959 period between unit dispersion factors that were calculated with 3 surface stations and the unit dispersion factors that would have been calculated if 25 surface stations were available.
Adjustment to Reflect Uncertainty when the Unit Dispersion Factor with Three Stations is Zero

An example of P(0,0), the probability that the dispersion factor with 25 stations would be zero when the dispersion factor with 3 surface air stations is zero is provided in Table 5.3. There is some dependency between this probability and the meteorological characteristics developed with 3 surface air stations. The probability is highest for winds from the east and for higher wind speeds. This is consistent with the receptor location being located to the east of the facility and with less variable wind direction when wind speeds are generally high.

<table>
<thead>
<tr>
<th>Stability</th>
<th>Speed (m/s)</th>
<th>North</th>
<th>East</th>
<th>West</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>0-2</td>
<td>40</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>41</td>
<td>64</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>38</td>
<td>60</td>
<td>26</td>
<td>33</td>
</tr>
<tr>
<td>CD</td>
<td>0-2</td>
<td>22</td>
<td>33</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>41</td>
<td>48</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>51</td>
<td>94</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>5-6</td>
<td>70</td>
<td>100</td>
<td>50</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>6+</td>
<td>86</td>
<td>100</td>
<td>65</td>
<td>43</td>
</tr>
<tr>
<td>EF</td>
<td>0-2</td>
<td>50</td>
<td>54</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>65</td>
<td>65</td>
<td>34</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>67</td>
<td>65</td>
<td>54</td>
<td>48</td>
</tr>
</tbody>
</table>

Table 5.3 Probability (%) zero dispersion factor with 25 surface stations when zero dispersion factor with 3 surface stations

Note:
i) Table is for Mud Lake Receptor with Scenario S1

For some hours, the dispersion factor with 25 surface air stations is greater than zero when the air dispersion factor calculated with 3 surface air stations is zero. This occurs with the complementary probability of above. Table 5.4 shows the average dispersion factor during these hours by meteorological category. For the particular example, the average dispersion factors for west and south wind directions tend to be higher than for winds from the north or east. This would be consistent with the location being downwind from the facility for westerly and southerly winds.
### Table 5.4  
Average unit dispersion factor (s/m³) for 25 surface stations when zero dispersion factor with 3 surface stations

<table>
<thead>
<tr>
<th>Stability</th>
<th>Speed (m/s)</th>
<th>North</th>
<th>East</th>
<th>West</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>0-2</td>
<td>37E-10</td>
<td>67E-11</td>
<td>63E-10</td>
<td>62E-10</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>29E-10</td>
<td>62E-10</td>
<td>39E-10</td>
<td>11E-9</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>3E-9</td>
<td>6E-9</td>
<td>5E-9</td>
<td>38E-10</td>
</tr>
<tr>
<td>CD</td>
<td>0-2</td>
<td>26E-10</td>
<td>38E-10</td>
<td>62E-10</td>
<td>7E-9</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>87E-10</td>
<td>22E-10</td>
<td>85E-10</td>
<td>48E-10</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>33E-10</td>
<td>14E-10</td>
<td>95E-10</td>
<td>44E-10</td>
</tr>
<tr>
<td></td>
<td>5-6</td>
<td>25E-10</td>
<td>1E-8</td>
<td>18E-9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6+</td>
<td>8E-11</td>
<td>8E-9</td>
<td>11E-9</td>
<td></td>
</tr>
<tr>
<td>EF</td>
<td>0-2</td>
<td>18E-10</td>
<td>12E-10</td>
<td>4E-9</td>
<td>26E-10</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>18E-10</td>
<td>28E-11</td>
<td>11E-9</td>
<td>71E-10</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>58E-11</td>
<td>51E-11</td>
<td>58E-10</td>
<td>5E-9</td>
</tr>
</tbody>
</table>

**Note:**

i) Table is for Mud Lake Receptor with Scenario S1

---

**Adjustment to Unit Dispersion Factor when Unit Dispersion Factor with Three Stations is Greater than Zero**

An example of $P(0,>0)$, the probability that the dispersion factor with 25 stations would be zero when the dispersion factor with 3 surface air stations is greater than zero is provided in Table 5.5. There is some dependency between this probability and the meteorological characteristics developed with 3 surface air stations. The probability is higher with higher wind speeds.

The probability of adjusting with unit dispersion factor of zero is also related to the magnitude of the unit dispersion factor based on the 3 stations. Hence, the sampling distribution has been made conditional on the magnitude of the unit dispersion factor from 3 stations by assigning the probability based on 10 categories of the unit dispersion factor. Table 5.6 shows a specific example for CD stability and winds 2-3 m/s from the N. The probability of adjusting with a zero unit dispersion factor is higher when the unit dispersion factor from 3 stations is lower.
### Table 5.5  Probability (%) zero dispersion factor with 25 surface stations when dispersion factor with 3 surface stations greater than zero

<table>
<thead>
<tr>
<th>Stability</th>
<th>Speed (m/s)</th>
<th>North</th>
<th>East</th>
<th>West</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-2</td>
<td>12</td>
<td>11</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>23</td>
<td>34</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>33</td>
<td>25</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>CD</td>
<td>0-2</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>20</td>
<td>22</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>33</td>
<td>30</td>
<td>23</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>5-6</td>
<td>40</td>
<td>50</td>
<td>40</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>6+</td>
<td>30</td>
<td>100</td>
<td>61</td>
<td>47</td>
</tr>
<tr>
<td>EF</td>
<td>0-2</td>
<td>8</td>
<td>11</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>16</td>
<td>26</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>3+</td>
<td>7</td>
<td>29</td>
<td>11</td>
<td>30</td>
</tr>
</tbody>
</table>

Note:
1) At Mud Lake receptor location with scenario S1.

### Table 5.6  Specific example of dependency of adjusting with a zero unit dispersion factor when unit dispersion factor from three stations is greater than zero

<table>
<thead>
<tr>
<th>Range of unit dispersion factor (s/m³) with three stations</th>
<th>Probability of adjusting zero dispersion factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+ to 2E-12</td>
<td>55</td>
</tr>
<tr>
<td>2E-12 to 21E-12</td>
<td>45</td>
</tr>
<tr>
<td>21E-12 to 77E-12</td>
<td>27</td>
</tr>
<tr>
<td>77E-12 to 15E-11</td>
<td>45</td>
</tr>
<tr>
<td>15E-11 to 28E-11</td>
<td>9</td>
</tr>
<tr>
<td>28E-11 to 76E-11</td>
<td>17</td>
</tr>
<tr>
<td>76E-11 to 13E-10</td>
<td>0</td>
</tr>
<tr>
<td>13E-10 to 29E-10</td>
<td>0</td>
</tr>
<tr>
<td>29E-10 to 58E-10</td>
<td>0</td>
</tr>
<tr>
<td>58E-10 +</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:
1) At Mud Lake Receptor with Scenario S1
2) North winds CD stability Speed 2-3 m/s

The approach for adjusting with non-zero unit dispersion factors is more complex. Since the sampled unit dispersion factor will be positively correlated with the unit dispersion factor with 3 stations, the unit dispersion factors from 3 stations have been classified to categories based on their magnitude. For each of these categories, the unit dispersion factors were classified.
according to the unit dispersion factor calculated with 25 stations. A ratio was determined by dividing the average unit dispersion factor with 25 stations by the average unit dispersion factor with 3 stations. Table 5.7 shows the range of ratios and the probability for the case of CD stability, 2-3 m/s winds from the south and unit dispersion factors for 3 stations ranging from 1.9E-9 to 2.9E-9 s/m³. The table shows that the uncertainty in hourly unit dispersion factors using 3 stations can range by orders of magnitude.

Table 5.7 Specific example of sampled ratio of unit dispersion factors

<table>
<thead>
<tr>
<th>Probability (%</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.0072</td>
</tr>
<tr>
<td>12</td>
<td>0.0174</td>
</tr>
<tr>
<td>8</td>
<td>0.0553</td>
</tr>
<tr>
<td>12</td>
<td>0.2823</td>
</tr>
<tr>
<td>8</td>
<td>0.5453</td>
</tr>
<tr>
<td>12</td>
<td>0.6794</td>
</tr>
<tr>
<td>12</td>
<td>1.342</td>
</tr>
<tr>
<td>8</td>
<td>3.0878</td>
</tr>
<tr>
<td>12</td>
<td>9.6409</td>
</tr>
<tr>
<td>8</td>
<td>18.607</td>
</tr>
</tbody>
</table>

Notes:
At Mud Lake Receptor with Scenario S1
South Winds CD stability Speed 2-3 m/s
For Unit Dispersion Factors Ranging from 1.9E-9 to 2.9E-9 s/m³

5.3 IMPLEMENTATION

Figure 5.1 shows the probabilistic approach to estimating air concentrations.

For each simulation, one of the dispersion modeling approaches is randomly selected. This approach is used for all receptor locations the entire 1957-1959 period and for all radionuclides. The hourly unit dispersion factors for this modeling scenario are retrieved from a database of unit dispersion factors to remove the necessity of running the CALPUFF model for each simulation.
For each calendar day, the unit air dispersion factor using the three surface meteorological stations is averaged for the wind speed, direction and stability category. There are two general cases: first, the unit dispersion factor with 3 stations is zero. In this case, a probabilistic sampling is conducted to see if the adjusted unit dispersion factor is zero or a value greater than zero. If the sampling indicates that a value greater than zero is applicable, the value is probabilistically sampled from the range of unit dispersion factors in 1999 using the 25 surface stations. In the second case where the unit dispersion factor from three stations is non-zero, the probabilistic sampling selects whether the adjusted unit dispersion factor will be zero or a non-zero value. If this sampling indicates the adjusted unit dispersion factor is non-zero, an uncertainty factor is selected from the range of ratios (in 1999) when unit dispersion factors with both 3 and 25 stations are non-zero. A daily average unit dispersion factor is calculated, with weighting by the number of hours, from the adjusted unit dispersion factors for each meteorological condition.
The approach assumes independence from day-to-day in the uncertainty in unit dispersion factor for the same meteorological category. For example, the sampled uncertainty for speeds 2-3 m/s with AB stability class and directions from the north could be a factor of two higher on one day than on the following day. Within a day, the uncertainty is also uncorrelated between separate meteorological categories: the sampled dispersion factor may be higher than the modeled factor for one meteorological category and lower for another meteorological category. The sampling is also independent between locations. The uncertainty is however the same for all radionuclides considered in the simulation.

The daily unit dispersion factors are then multiplied by the probabilistically sampled emission rates for the day. Within a simulation, all receptor locations use the same emission rate when calculating air concentration.

For each simulation, the probabilistically generated air concentrations are summarized by calendar month.

### 5.4 RESULTS

#### 5.4.1 Predicted Air Concentrations

Air concentrations were predicted on a monthly basis and these results and the range of these concentrations are shown in Table 5.8. The central estimate in the table is the median, or 50th percentile, of the probabilistically sampled concentrations with the lower and upper bounds given by the 95th percentiles of the simulated concentrations. The table also shows the distribution for period average concentrations (February 1957 through December 1959). It is of note that February 1957 concentrations are about 10 times higher than average concentrations, due mostly to higher releases, and therefore this month accounts for about 30% of the period average.
### Table 5.8 Summary of iodine-131 air concentrations (Bq/m³)

<table>
<thead>
<tr>
<th>Off-site Location</th>
<th>Lower Bound</th>
<th>Central Estimate</th>
<th>Upper Bound</th>
<th>Lower Bound</th>
<th>Central Estimate</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Junction</td>
<td>2.0E-03</td>
<td>4.5E-03</td>
<td>8.5E-03</td>
<td>4.0E-04</td>
<td>6.2E-04</td>
<td>1.0E-03</td>
</tr>
<tr>
<td>Arco</td>
<td>4.2E-03</td>
<td>1.1E-02</td>
<td>4.2E-02</td>
<td>1.0E-03</td>
<td>1.8E-03</td>
<td>4.3E-03</td>
</tr>
<tr>
<td>Atomic City</td>
<td>8.7E-03</td>
<td>2.6E-02</td>
<td>3.4E-01</td>
<td>1.5E-03</td>
<td>3.8E-03</td>
<td>1.1E-02</td>
</tr>
<tr>
<td>Basalt</td>
<td>1.9E-03</td>
<td>3.6E-03</td>
<td>7.0E-03</td>
<td>3.1E-04</td>
<td>4.8E-04</td>
<td>8.0E-04</td>
</tr>
<tr>
<td>Blackfoot</td>
<td>1.4E-03</td>
<td>3.0E-03</td>
<td>6.2E-03</td>
<td>2.9E-04</td>
<td>4.4E-04</td>
<td>7.5E-04</td>
</tr>
<tr>
<td>Butte City</td>
<td>5.9E-03</td>
<td>1.5E-02</td>
<td>5.8E-02</td>
<td>1.5E-03</td>
<td>2.6E-03</td>
<td>6.3E-03</td>
</tr>
<tr>
<td>Dubois</td>
<td>1.5E-02</td>
<td>2.8E-02</td>
<td>4.9E-02</td>
<td>1.7E-03</td>
<td>2.5E-03</td>
<td>4.1E-03</td>
</tr>
<tr>
<td>Firth</td>
<td>1.8E-03</td>
<td>3.6E-03</td>
<td>9.6E-03</td>
<td>3.1E-04</td>
<td>4.7E-04</td>
<td>8.0E-04</td>
</tr>
<tr>
<td>Fort Hall</td>
<td>9.7E-04</td>
<td>2.9E-03</td>
<td>5.8E-03</td>
<td>2.4E-04</td>
<td>3.6E-04</td>
<td>6.4E-04</td>
</tr>
<tr>
<td>Grandview</td>
<td>1.4E-03</td>
<td>3.5E-03</td>
<td>1.8E-02</td>
<td>3.8E-04</td>
<td>6.5E-04</td>
<td>1.2E-03</td>
</tr>
<tr>
<td>Hamer</td>
<td>2.2E-02</td>
<td>3.3E-02</td>
<td>5.8E-02</td>
<td>2.3E-03</td>
<td>3.1E-03</td>
<td>5.1E-03</td>
</tr>
<tr>
<td>Howe</td>
<td>1.3E-02</td>
<td>3.1E-02</td>
<td>8.2E-02</td>
<td>2.6E-03</td>
<td>4.2E-03</td>
<td>9.6E-03</td>
</tr>
<tr>
<td>Idaho Falls</td>
<td>4.1E-03</td>
<td>7.6E-03</td>
<td>1.9E-02</td>
<td>4.1E-04</td>
<td>6.8E-04</td>
<td>1.2E-03</td>
</tr>
<tr>
<td>Lewisville</td>
<td>1.2E-02</td>
<td>1.8E-02</td>
<td>3.2E-02</td>
<td>9.4E-04</td>
<td>1.3E-03</td>
<td>2.2E-03</td>
</tr>
<tr>
<td>Lost River</td>
<td>2.5E-03</td>
<td>6.5E-03</td>
<td>2.0E-02</td>
<td>6.8E-04</td>
<td>1.1E-03</td>
<td>2.3E-03</td>
</tr>
<tr>
<td>Mackay</td>
<td>6.2E-04</td>
<td>1.9E-03</td>
<td>5.0E-03</td>
<td>2.0E-04</td>
<td>3.4E-04</td>
<td>6.3E-04</td>
</tr>
<tr>
<td>Menan</td>
<td>1.0E-02</td>
<td>1.6E-02</td>
<td>3.0E-02</td>
<td>8.8E-04</td>
<td>1.3E-03</td>
<td>2.1E-03</td>
</tr>
<tr>
<td>Moore</td>
<td>2.2E-03</td>
<td>6.0E-03</td>
<td>2.2E-02</td>
<td>5.8E-04</td>
<td>1.0E-03</td>
<td>2.3E-03</td>
</tr>
<tr>
<td>Montevideo</td>
<td>2.2E-02</td>
<td>4.1E-02</td>
<td>8.2E-02</td>
<td>2.8E-03</td>
<td>4.3E-03</td>
<td>7.4E-03</td>
</tr>
<tr>
<td>Mud Lake</td>
<td>2.8E-02</td>
<td>5.1E-02</td>
<td>8.9E-02</td>
<td>3.2E-03</td>
<td>5.0E-03</td>
<td>8.4E-03</td>
</tr>
<tr>
<td>Roberts</td>
<td>1.3E-02</td>
<td>2.1E-02</td>
<td>4.1E-02</td>
<td>1.2E-03</td>
<td>1.8E-03</td>
<td>2.9E-03</td>
</tr>
<tr>
<td>Shelley</td>
<td>2.5E-03</td>
<td>4.5E-03</td>
<td>9.6E-03</td>
<td>3.5E-04</td>
<td>5.3E-04</td>
<td>8.6E-04</td>
</tr>
<tr>
<td>Spencer</td>
<td>2.5E-03</td>
<td>4.7E-03</td>
<td>8.9E-03</td>
<td>3.7E-04</td>
<td>5.5E-04</td>
<td>9.2E-04</td>
</tr>
<tr>
<td>Terreton</td>
<td>2.6E-02</td>
<td>4.8E-02</td>
<td>8.4E-02</td>
<td>2.8E-03</td>
<td>4.7E-03</td>
<td>7.8E-03</td>
</tr>
<tr>
<td>Average milk prod area</td>
<td>4.8E-03</td>
<td>7.3E-03</td>
<td>1.2E-02</td>
<td>4.6E-04</td>
<td>6.7E-04</td>
<td>1.1E-03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>On Site Location</th>
<th>Lower Bound</th>
<th>Central Estimate</th>
<th>Upper Bound</th>
<th>Lower Bound</th>
<th>Central Estimate</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA @ 250ft Met Tower</td>
<td>4.8E-02</td>
<td>1.5E-01</td>
<td>4.7E-01</td>
<td>1.6E-02</td>
<td>2.6E-02</td>
<td>4.9E-02</td>
</tr>
<tr>
<td>BLR sink area</td>
<td>2.9E-02</td>
<td>5.9E-02</td>
<td>1.3E-01</td>
<td>4.3E-03</td>
<td>7.1E-03</td>
<td>1.5E-02</td>
</tr>
<tr>
<td>Average INEL area</td>
<td>2.9E-02</td>
<td>6.5E-02</td>
<td>1.2E-01</td>
<td>3.7E-03</td>
<td>7.5E-03</td>
<td>1.3E-02</td>
</tr>
</tbody>
</table>

Figure 5.2 shows the range of monthly average concentrations at the Atomic City receptor location. The figure shows an overall pattern of decreasing concentrations with time and, within this pattern, variation between months due to the pattern of releases over the period. Figure 5.3 summarizes the overall period average concentrations at the off-site discrete receptors. Mud Lake was the receptor with highest central estimate of air concentration; however, it is apparent the relative variation in air concentrations differs between receptor locations. Both Howe and Atomic City locations had upper bounds on the concentration that were higher than the upper bound at Mud Lake.
Figure 5.2  Estimated concentration of iodine-131 in air in Atomic City, Idaho, due to releases from the Idaho Chemical Processing Plant operations

Note:
The numbers represent each of the 37 RaLa runs, and the arrows indicate the approximate date of each run. The dotted lines represent the 95% confidence interval.
5.4.2 Contributions to Uncertainty

The contribution from the three sources of uncertainty has been assessed by calculating the sum of squared deviations explained by each source. Table 5.9 shows the relative contributions for February 1957, which is the month with the highest concentrations. Typically, the largest source of uncertainty (or variability in the estimated concentrations) is meteorological uncertainty with variation in release rates being the next largest source. The relative contribution to uncertainty from release rate tends to be higher for those receptor locations located northeast of the facility and this is consistent with being in a downwind direction from the facility. Meteorological uncertainty is lowest for the INEL area as would be expected since this is an average air concentration in several directions from the facility therefore the meteorological uncertainty has been “averaged out” spatially.
Table 5.9  Sources of uncertainty in iodine-131 air concentrations during February 1957

<table>
<thead>
<tr>
<th>Percent of Variation (%) Explained by Uncertainty Source</th>
<th>Off-site Locations</th>
<th>Release</th>
<th>Dispersion Approach</th>
<th>Meteorological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Junction</td>
<td>30</td>
<td>16</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Arco</td>
<td>8</td>
<td>41</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Atomic City</td>
<td>2</td>
<td>9</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Basalt</td>
<td>28</td>
<td>9</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Blackfoot</td>
<td>34</td>
<td>10</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Butte City</td>
<td>8</td>
<td>42</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Dubois</td>
<td>42</td>
<td>18</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Firth</td>
<td>21</td>
<td>16</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Fort Hall</td>
<td>31</td>
<td>48</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Grandview</td>
<td>5</td>
<td>9</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Hamer</td>
<td>62</td>
<td>7</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Howe</td>
<td>17</td>
<td>55</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Idaho Falls</td>
<td>29</td>
<td>24</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Lewisville</td>
<td>46</td>
<td>13</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Lost River</td>
<td>10</td>
<td>30</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Mackay</td>
<td>17</td>
<td>24</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Menan</td>
<td>49</td>
<td>17</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Moore</td>
<td>14</td>
<td>42</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Montevideo</td>
<td>35</td>
<td>42</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Mud Lake</td>
<td>44</td>
<td>28</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Roberts</td>
<td>48</td>
<td>19</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Shelley</td>
<td>40</td>
<td>11</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Spencer</td>
<td>40</td>
<td>13</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Terreton</td>
<td>43</td>
<td>30</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Average milk prod area</td>
<td>76</td>
<td>10</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.10 summarizes the contribution to the distribution of overall period average concentrations (i.e. the sum-of-squares) for the sources of uncertainty. Typically, uncertainty in average release rate is the largest source of variation in the estimate period average concentrations, followed by dispersion scenario and then by meteorological uncertainty. The short-term uncertainty in meteorological conditions has typically been “averaged out” when period averages are determined, compared to the uncertainty in release rates and dispersion approach that are correlated over longer time periods.

---

5-14
Regardless of this typical pattern, some locations have relatively large contributions from the meteorological uncertainty. For example, meteorological uncertainty contributes substantially to the overall uncertainty at Atomic City, the CFA and at Grandview. These receptors are located to the south of facility where winds from the direction of the facility are infrequent.

Table 5.10    Sources of uncertainty in period average iodine-131 air concentrations

<table>
<thead>
<tr>
<th>Off-site Locations</th>
<th>Release</th>
<th>Dispersion Approach</th>
<th>Meteorological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Junction</td>
<td>62</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Arco</td>
<td>24</td>
<td>64</td>
<td>12</td>
</tr>
<tr>
<td>Atomic City</td>
<td>10</td>
<td>30</td>
<td>61</td>
</tr>
<tr>
<td>Basalt</td>
<td>69</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Blackfoot</td>
<td>68</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>Butte City</td>
<td>27</td>
<td>62</td>
<td>11</td>
</tr>
<tr>
<td>Dubois</td>
<td>74</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>Firth</td>
<td>63</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Fort Hall</td>
<td>66</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td>Grandview</td>
<td>46</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Hamer</td>
<td>87</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Howe</td>
<td>28</td>
<td>66</td>
<td>6</td>
</tr>
<tr>
<td>Idaho Falls</td>
<td>55</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Lewisville</td>
<td>78</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Lost River</td>
<td>34</td>
<td>54</td>
<td>13</td>
</tr>
<tr>
<td>Mackay</td>
<td>49</td>
<td>39</td>
<td>12</td>
</tr>
<tr>
<td>Menan</td>
<td>79</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Moore</td>
<td>31</td>
<td>59</td>
<td>11</td>
</tr>
<tr>
<td>Montevue</td>
<td>57</td>
<td>37</td>
<td>7</td>
</tr>
<tr>
<td>Mud Lake</td>
<td>64</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Roberts</td>
<td>81</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Shelley</td>
<td>73</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Spencer</td>
<td>74</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Terretton</td>
<td>63</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>Average milk prod area</td>
<td>86</td>
<td>11</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Off-site Location</th>
<th>Release</th>
<th>Dispersion Approach</th>
<th>Meteorological</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA @ 250ft Met Tower</td>
<td>40</td>
<td>24</td>
<td>36</td>
</tr>
<tr>
<td>BLR sink area</td>
<td>32</td>
<td>62</td>
<td>6</td>
</tr>
<tr>
<td>Average INEL area</td>
<td>42</td>
<td>55</td>
<td>3</td>
</tr>
</tbody>
</table>
5.4.3 Differences by Air Dispersion Modeling Scenario

Some uncertainty arises due the differences in dispersion modeling approach. Table 5.11 shows the range of the central estimates of period average concentration. The table includes the central estimate for the S1 dispersion approach, which was considered the most likely scenario. The central estimates range by a factor of two or three between the lowest and highest values with the S1 scenario estimate typically between the highest and lowest estimates; however, the S1 dispersion modeling provides the lowest central estimate for the Moore receptor location.

Table 5.11 Comparison of central estimates of period average iodine-131 air concentrations by dispersion modeling scenario

<table>
<thead>
<tr>
<th>Off-site Receptor</th>
<th>Lowest Scenario</th>
<th>S1 Dispersion Scenario</th>
<th>Highest Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Junction</td>
<td>4.6E-04 (s2)</td>
<td>5.7E-04</td>
<td>7.7E-04 (sa4)</td>
</tr>
<tr>
<td>Arco</td>
<td>1.3E-03 (s3)</td>
<td>1.4E-03</td>
<td>3.6E-03 (sa4)</td>
</tr>
<tr>
<td>Atomic City</td>
<td>1.9E-03 (s2)</td>
<td>4.8E-03</td>
<td>5.9E-03 (s3)</td>
</tr>
<tr>
<td>Basalt</td>
<td>4.2E-04 (sa2)</td>
<td>4.4E-04</td>
<td>5.7E-04 (s4)</td>
</tr>
<tr>
<td>Blackfoot</td>
<td>3.7E-04 (s2)</td>
<td>4.1E-04</td>
<td>5.3E-04 (sa4)</td>
</tr>
<tr>
<td>Butte City</td>
<td>2.0E-03 (s3)</td>
<td>2.1E-03</td>
<td>4.9E-03 (sa4)</td>
</tr>
<tr>
<td>Dubois</td>
<td>2.3E-03 (s3)</td>
<td>2.3E-03</td>
<td>3.1E-03 (sa4)</td>
</tr>
<tr>
<td>Firth</td>
<td>4.2E-04 (sa2)</td>
<td>4.5E-04</td>
<td>6.1E-04 (s4)</td>
</tr>
<tr>
<td>Fort Hall</td>
<td>3.0E-04 (s2)</td>
<td>3.3E-04</td>
<td>4.8E-04 (sa4)</td>
</tr>
<tr>
<td>Grandview</td>
<td>5.2E-04 (s2)</td>
<td>6.0E-04</td>
<td>7.6E-04 (s3)</td>
</tr>
<tr>
<td>Hamer</td>
<td>2.7E-03 (sa2)</td>
<td>3.2E-03</td>
<td>3.3E-03 (s4)</td>
</tr>
<tr>
<td>Howe</td>
<td>3.4E-03 (s2)</td>
<td>3.5E-03</td>
<td>8.0E-03 (sa4)</td>
</tr>
<tr>
<td>Idaho Falls</td>
<td>5.2E-04 (sa1)</td>
<td>7.4E-04</td>
<td>8.8E-04 (s4)</td>
</tr>
<tr>
<td>Lewisville</td>
<td>1.2E-03 (sa2)</td>
<td>1.3E-03</td>
<td>1.5E-03 (sa4)</td>
</tr>
<tr>
<td>Lost River</td>
<td>8.8E-04 (s3)</td>
<td>9.1E-04</td>
<td>1.9E-03 (sa4)</td>
</tr>
<tr>
<td>Mackay</td>
<td>2.8E-04 (s3)</td>
<td>2.8E-04</td>
<td>4.7E-04 (sa4)</td>
</tr>
<tr>
<td>Menan</td>
<td>1.1E-03 (sa3)</td>
<td>1.3E-03</td>
<td>1.5E-03 (sa4)</td>
</tr>
<tr>
<td>Moore</td>
<td>7.9E-04 (s1)</td>
<td>7.9E-04</td>
<td>1.8E-03 (sa4)</td>
</tr>
<tr>
<td>Monteview</td>
<td>3.5E-03 (s2)</td>
<td>3.8E-03</td>
<td>6.0E-03 (sa4)</td>
</tr>
<tr>
<td>Mud Lake</td>
<td>3.5E-03 (s2)</td>
<td>4.9E-03</td>
<td>6.5E-03 (sa1)</td>
</tr>
<tr>
<td>Roberts</td>
<td>1.5E-03 (s2)</td>
<td>1.8E-03</td>
<td>2.1E-03 (sa4)</td>
</tr>
<tr>
<td>Shelley</td>
<td>4.5E-04 (sa1)</td>
<td>5.3E-04</td>
<td>6.4E-04 (s4)</td>
</tr>
<tr>
<td>Spencer</td>
<td>4.8E-04 (sa2)</td>
<td>5.5E-04</td>
<td>6.5E-04 (s4)</td>
</tr>
<tr>
<td>Terreton</td>
<td>3.2E-03 (s2)</td>
<td>4.7E-03</td>
<td>6.2E-03 (sa3)</td>
</tr>
<tr>
<td>Average milk prod area</td>
<td>5.8E-04 (sa2)</td>
<td>6.6E-04</td>
<td>7.8E-04 (s4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>On-site Receptor</th>
<th>Lowest Scenario</th>
<th>S1 Dispersion Scenario</th>
<th>Highest Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFA @ 250ft Met Tower</td>
<td>2.1E-02 (sa2)</td>
<td>2.5E-02</td>
<td>3.6E-02 (s3)</td>
</tr>
<tr>
<td>BLR sink area</td>
<td>5.0E-03 (s2)</td>
<td>6.6E-03</td>
<td>1.3E-02 (sa3)</td>
</tr>
<tr>
<td>Average INEL area</td>
<td>4.4E-03 (s2)</td>
<td>8.3E-03</td>
<td>1.0E-02 (sa3)</td>
</tr>
</tbody>
</table>
The lowest concentrations tend to be with s2 and s3 dispersion modeling approaches while the highest concentrations tend be to be with s3, s4 and sa4 modeling approaches. There is some direction dependency present: the s3 provides the highest concentrations at locations to the south of the facility.

5.4.4 Bias Introduced by Meteorology

The uncertainty introduced by meteorology includes not only variation about the estimated unit dispersion factors with 3 stations but also a shift, or bias, in the concentrations. The magnitude of this shift depends not only on the receptor location but also on the air dispersion modeling approach. Furthermore, the shift may lead to lower or higher unit dispersion factors than estimated with 3 surface stations. Table 5.12 compares an estimate of the monthly concentrations using the unit dispersion factor from 3 stations and the deterministic estimate of release rates with the 50th percentile of the simulated concentrations of the s1 scenario. Mud Lake is the receptor location with highest central estimate of air concentration and Atomic City is the receptor location with the highest upper bound of air concentrations.

<table>
<thead>
<tr>
<th>Month</th>
<th>With 3 Stations</th>
<th>Central Estimate</th>
<th>Change (%)</th>
<th>With 3 Stations</th>
<th>Central Estimate</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.8E-02</td>
<td>5.0E-02</td>
<td>79</td>
<td>3.7E-02</td>
<td>3.4E-02</td>
<td>-8</td>
</tr>
<tr>
<td>3</td>
<td>3.1E-03</td>
<td>4.4E-03</td>
<td>44</td>
<td>1.4E-02</td>
<td>6.0E-03</td>
<td>-56</td>
</tr>
<tr>
<td>4</td>
<td>1.6E-03</td>
<td>3.8E-03</td>
<td>147</td>
<td>4.7E-03</td>
<td>2.8E-03</td>
<td>-41</td>
</tr>
<tr>
<td>5</td>
<td>7.8E-04</td>
<td>2.4E-03</td>
<td>204</td>
<td>2.8E-03</td>
<td>1.7E-03</td>
<td>-63</td>
</tr>
<tr>
<td>6</td>
<td>7.2E-03</td>
<td>8.1E-03</td>
<td>13</td>
<td>1.5E-02</td>
<td>4.1E-03</td>
<td>-73</td>
</tr>
<tr>
<td>7</td>
<td>1.3E-03</td>
<td>1.3E-03</td>
<td>1</td>
<td>1.9E-03</td>
<td>6.9E-04</td>
<td>-64</td>
</tr>
<tr>
<td>8</td>
<td>6.5E-06</td>
<td>8.1E-06</td>
<td>23</td>
<td>1.1E-05</td>
<td>6.4E-06</td>
<td>-44</td>
</tr>
<tr>
<td>9</td>
<td>8.3E-04</td>
<td>1.6E-03</td>
<td>93</td>
<td>5.7E-03</td>
<td>2.5E-03</td>
<td>-56</td>
</tr>
<tr>
<td>10</td>
<td>1.1E-02</td>
<td>1.7E-02</td>
<td>56</td>
<td>2.2E-02</td>
<td>1.3E-02</td>
<td>-42</td>
</tr>
<tr>
<td>11</td>
<td>8.4E-03</td>
<td>1.4E-02</td>
<td>65</td>
<td>3.2E-02</td>
<td>1.8E-02</td>
<td>-46</td>
</tr>
<tr>
<td>12</td>
<td>7.9E-05</td>
<td>1.6E-04</td>
<td>103</td>
<td>1.8E-04</td>
<td>1.5E-04</td>
<td>-13</td>
</tr>
</tbody>
</table>

The monthly concentrations calculated with unit dispersion factors based on 3 stations are lower at Mud Lake compared to Atomic City. The shifts for this scenario and year act to increase concentrations at the Mud Lake and decrease concentrations at Atomic City relative to the calculation based on 3 stations. Mud Lake concentrations increase by up to a factor of 3 (i.e. 204%) while Atomic City concentrations decrease by up to a factor of about 3 (i.e. -73%). As a result, the probabilistically concentrations at Mud Lake tend to be lower than the probabilistically simulated concentrations at Atomic City.

This shift is consistent with differences in wind direction determined by the CALMET processor for 3 and 25 stations as shown on a monthly basis in Appendix D. There is a tendency for the wind directions with 25 stations to shift towards the north relative to the wind directions based on three stations. This would tend to increase the wind frequency, and concentrations, at the Mud Lake receptor location compared to the Atomic City location.
CALPUFF air dispersion modeling was used to estimate air concentrations. Comparisons with concentrations measured as part of SF₆ tracer studies showed good model agreement; however, additional validation data would have been useful.

Three sources of uncertainty were considered: i) emission rates; ii) dispersion modeling approach; and the effect of meteorological uncertainty due to only three surface air stations with data during the 1957-1959 period. An uncertainty analysis was conducted to estimate monthly average concentrations and confidence intervals on these estimates. Rather than run CALPUFF for each trial, a database of unit dispersion factors and empirical estimates of uncertainty were developed.

Uncertainty in release rates was typically the major source of uncertainty in period average concentrations while uncertainty in the dispersion modeling approach contributed a factor of two or three. The uncertainty in air concentrations arising from uncertainty in meteorological conditions included both shift, or bias, and variability. High variability was present on an hourly basis but this tended to “average out” over monthly and period average durations. There was however a shift in concentrations with some receptor locations tending to have higher concentrations than would be predicted with the uncertain wind field based on 3 stations with other locations having lower concentrations. This shift was on the order of a factor of 2 or 3 and is comparable, for period averages, to the uncertainty in air dispersion modeling approach.

The uncertainty was found to be complex and dependent on location, meteorology and air dispersion modeling approach. The use of empirical estimates removed the necessity of parameterization of the uncertainties but required extensive database manipulations.
REFERENCES


APPENDIX A: SAMPLE CALMET CONTROL FILE
APPENDIX A: SAMPLE CALMET CONTROL FILE

The CALMET dispersion model has optional algorithms and approaches for meteorological processing that are specified in the control file. Options, or algorithms, are specified as “switches” in the control file.

The switches in Input Groups 1 - 4 are set as required for the nature of the run, the grid sizes, and the outputs desired. Input Group 5 contains the wind field model options. Those switches that do not follow the default recommendations are as follows:

- INPUT Group 1 Defaults + Data Entry
- INPUT Group 2 Defaults + Data Entry
- INPUT Group 3 Defaults + Output Options
- INPUT Group 4 Defaults
- INPUT Group 5
  - IKINE = 0 which is the correct default (model output of default value in error) and kinematic effects are not computed.
  - RMIN2 set to -1 default value.
  - RMAX1 was set to 20 kilometers, RMAX2 was set to 20 km.
  - TERRAD was set at 20 kilometers, the terrain influence in this application.
  - R1 and R2 are set at 10 and 10.
  - NINTR2 was set at 5 to limit number of stations used in each layer of the interpolation to a grid point (not applicable here, only three surface stations).
- INPUT Group 6
  - ZIMIN and ZIMINW were set to 50 meters the default value.
  - SIGMAP was set to 50 kilometers although precipitation is not being used.
- INPUT Group 7 Station Variables
- INPUT Group 8 Upper Air Stations
- INPUT Group 9 Precipitation Stations
Examples of switches

INEL - 1957 CALMET Run
Using 3 Surface Stations + 2 Upper Air

---------------------------------- Run title (3 lines) ----------------------------------

CALMET MODEL CONTROL FILE

----------------------------------

INPUT GROUP: 0 -- Input and Output File Names

Subgroup (a)

------------

Default Name   Type       File Name
------------   ----       --------------
GEO.DAT       input      ! GEODAT=geo4km.DAT    !
SURF.DAT      input      ! SRFDAT=surf57.DAT    !
CLOUD.DAT     input      * CLDDAT=              *
PRECIP.DAT    input      ! PRCDAT=precip57.dat    !
MM4.DAT       input      * MM4DAT=              *
WT.DAT        input      * WTDAT=              *
CALMET.LST    output     ! METLST=jan57.LST    !
CALMET.DAT    output     ! METDAT=jan57.DAT    !
PACOUT.DAT    output     * PACDAT=              *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
    T = lower case       ! LCFILES = T !
    F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

    Number of upper air stations (NUSTA) No default ! NUSTA = 1 !
    Number of overwater met stations (NOWSTA) No default ! NOWSTA = 0 !

!END!

Subgroup (b)

----------------------------------

Upper air files (one per station)

Default Name   Type       File Name
------------   ----       --------------
UP1.DAT       input      1 ! UPDAT=2413157.DAT! !END!

Subgroup (c)

----------------------------------

Overwater station files (one per station)

Default Name   Type       File Name
------------   ----       --------------

Subgroup (d)

----------------------------------

Other file names

Default Name   Type       File Name
------------   ----       --------------
DIAG.DAT      input      * DIADAT=              *
PROG.DAT      input      * PRGDAT=              *

A-2
TEST.SLP output * TSTSLP= *

NOTES: (1) File/path names can be up to 70 characters in length
(2) Subgroups (a) and (d) must have ONE 'END' (surround by
    delimiters) at the end of the group
(3) Subgroups (b) and (c) must have an 'END' (surround by
delimiters) at the end of EACH LINE

!END!

INPUT GROUP: 1 -- General run control parameters

Starting date: Year (IBYR) -- No default ! IBYR= 1957 !
               Month (IBMO) -- No default ! IBMO= 1 !
               Day (IBDY) -- No default ! IBDY= 1 !
               Hour (IBHR) -- No default ! IBHR= 0 !

Base time zone (IBTZ) -- No default ! IBTZ= 7 !
   PST = 08, MST = 07
   CST = 06, EST = 05

Length of run (hours) (IRLG) -- No default ! IRLG= 744 !

Run type (IRTYPE) -- Default: 1 ! IRTYPE= 1 !
   0 = Computes wind fields only
   1 = Computes wind fields and micrometeorological variables
       (u*, w*, L, zi, etc.)
       (IRTYPE must be 1 to run CALPUFF or CALGRID)

Compute special data fields required
by CALGRID (i.e., 3-D fields of W wind
components and temperature)
in additional to regular Default: T ! LCALGRD = T !
fields ? (LCALGRD)
(LCALGRD must be T to run CALGRID)

Flag to stop run after
SETUP phase (ITEST) Default: 2 ! ITEST= 2 !
(Used to allow checking
of the model inputs, files, etc.)
ITEST = 1 = STOPS program after SETUP phase
ITEST = 2 = Continues with execution of
    COMPUTATIONAL phase after SETUP

!END!

INPUT GROUP: 2 -- Grid control parameters

HORIZONTAL GRID DEFINITION:

   No. X grid cells (NX) No default ! NX = 80 !
   No. Y grid cells (NY) No default ! NY = 80 !

GRID SPACING (DGRIDKM) No default ! DGRIDKM = 4. !
   Units: km

REFERENCE COORDINATES
of SOUTHWEST corner of grid cell (1,1)

   X coordinate (XORIGKM) No default ! XORIGKM = 0.000 !
   Y coordinate (YORIGKM) No default ! YORIGKM = 0.000 !
   Units: km
   Latitude (XLAT0) No default ! XLAT0 = 41.960 !
Longitude (XLON0) No default ! XLON0 = 113.890 !

UTM ZONE (IUTMZN) Default: 0 ! IUTMZN = 0 !

LAMBERT CONFORMAL PARAMETERS

Rotate input winds from true north to
map north using a Lambert conformal
projection? (LLCONF) Default: F ! LLCONF = T !

Latitude of 1st standard parallel Default: 30. ! XLAT1 = 30.000 !
Latitude of 2nd standard parallel Default: 60. ! XLAT2 = 60.000 !
(XLAT1 and XLAT2; + in NH, - in SH)

Longitude (RLON0) Default = 90. ! RLON0 = 113.89 !
(used only if LLCONF = T)
(Positive = W. Hemisphere;
Negative = E. Hemisphere)

Origin Latitude (RLAT0) Default = 40. ! RLAT0 = 41.960 !
(used only if IPROG > 2)
(Positive = N. Hemisphere;
Negative = S. Hemisphere)

Vertical grid definition:

No. of vertical layers (NZ) No default ! NZ = 11 !

Cell face heights in arbitrary
vertical grid (ZFACE(NZ+1)) No defaults
Units: m

!END!

INPUT GROUP: 3 -- Output Options

DISK OUTPUT OPTION

Save met. fields in an unformatted
output file ? (LSAVE) Default: T ! LSAVE = T !
(F = Do not save, T = Save)

Type of unformatted output file:
(IFORMO) Default: 1 ! IFORMO = 1 !
1 = CALPUFF/CALGRID type file (CALMET.DAT)
2 = MESOPUFF-II type file (PACOUT.DAT)

LINE PRINTER OUTPUT OPTIONS:

Print met. fields ? (LPRINT) Default: F ! LPRINT = T !
(F = Do not print, T = Print)

Print interval
(IPRINT) in hours Default: 1 ! IPRINT = 1 !
(Meteorological fields are printed
every 1 hours)

Specify which layers of U, V wind component
to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print)
(used only if LPRINT=T) Defaults: NZ*0
! IUVOUT = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 !
Specify which levels of the W wind component to print
(NOTE: W defined at TOP cell face -- 9 values)
(IWOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print)
(used only if LPRINT=T & LCALGRD=T)

Defaults: NZ*0

Specify which levels of the 3-D temperature field to print
(ITOUT(NZ)) -- NOTE: NZ values must be entered
(0=Do not print, 1=Print)
(used only if LPRINT=T & LCALGRD=T)

Defaults: NZ*0

Specify which meteorological fields to print
(used only if LPRINT=T)

Defaults: 0 (all variables)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Print ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = do not print, 1 = print</td>
<td></td>
</tr>
<tr>
<td>STABILITY</td>
<td></td>
</tr>
<tr>
<td>USTAR</td>
<td>0</td>
</tr>
<tr>
<td>MONIN</td>
<td>0</td>
</tr>
<tr>
<td>MIXHT</td>
<td>0</td>
</tr>
<tr>
<td>WSTAR</td>
<td>0</td>
</tr>
<tr>
<td>PRECIP</td>
<td>0</td>
</tr>
<tr>
<td>SENSHEAT</td>
<td>0</td>
</tr>
<tr>
<td>CONVZI</td>
<td>0</td>
</tr>
</tbody>
</table>

PGT stability class
Friction velocity
Monin-Obukhov length
Mixing height
Convective velocity scale
Precipitation rate
Sensible heat flux
Convective mixing ht.

Testing and debug print options for micrometeorological module

Print input meteorological data and internal variables (LDB)
Default: F
(F = Do not print, T = print)
(Note: this option produces large amounts of output)

First time step for which debug data are printed (NN1)
Default: 1

Last time step for which debug data are printed (NN2)
Default: 1

Testing and debug print options for wind field module
(all of the following print options control output to wind field module's output files: TEST.PRT, TEST.OUT, TEST.KIN, TEST.FRD, and TEST.SLP)

Control variable for writing the test/debug wind fields to disk files (IOUTD)
(0=Do not write, 1=write)
Default: 0

Number of levels, starting at the surface, to print (NZFRN2)
Default: 1

Print the INTERPOLATED wind components?
(IPRO) (0=no, 1=yes)
Default: 0

Print the TERRAIN ADJUSTED surface wind components?

IPRO = 0 !
(IPR1) (0=no, 1=yes) Default: 0 ! IPR1 = 0 !
Print the SMOOTHED wind components and the INITIAL DIVERGENCE fields ?
(IPR2) (0=no, 1=yes) Default: 0 ! IPR2 = 0 !
Print the FINAL wind speed and direction fields ?
(IPR3) (0=no, 1=yes) Default: 0 ! IPR3 = 0 !
Print the FINAL DIVERGENCE fields ?
(IPR4) (0=no, 1=yes) Default: 0 ! IPR4 = 0 !
Print the winds after KINEMATIC effects are added ?
(IPR5) (0=no, 1=yes) Default: 0 ! IPR5 = 0 !
Print the winds after the FROUDE NUMBER adjustment is made ?
(IPR6) (0=no, 1=yes) Default: 0 ! IPR6 = 0 !
Print the winds after SLOPE FLOWS are added ?
(IPR7) (0=no, 1=yes) Default: 0 ! IPR7 = 0 !
Print the FINAL wind field components ?
(IPR8) (0=no, 1=yes) Default: 0 ! IPR8 = 0 !

!END!

INPUT GROUP: 4 -- Meteorological data options

----------
NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS
Number of surface stations (NSSTA) No default ! NSSTA = 3 !
Number of precipitation stations (NPSTA) No default ! NPSTA = 3 !

CLOUD DATA OPTIONS
Gridded cloud fields:
(ICLOUD) Default: 0 ! ICLOUD = 0 !
ICLOUD = 0 - Gridded clouds not used
ICLOUD = 1 - Gridded CLOUD.DAT generated as OUTPUT
ICLOUD = 2 - Gridded CLOUD.DAT read as INPUT

FILE FORMATS
Surface meteorological data file format
(IFORMS) Default: 2 ! IFORMS = 2 !
(1 = unformatted (e.g., SMERGE output))
(2 = formatted (free-formatted user input))
Precipitation data file format
(IFORMP) Default: 2 ! IFORMP = 2 !
(1 = unformatted (e.g., PMERGE output))
(2 = formatted (free-formatted user input))
Cloud data file format
(IFORMC) Default: 2 ! IFORMC = 2 !
(1 = unformatted - CALMET unformatted output)
(2 = formatted - free-formatted CALMET output or user input)

!END!

----------
INPUT GROUP: 5 -- Wind Field Options and Parameters
----------
WIND FIELD MODEL OPTIONS

Model selection variable (IWFCOD) Default: 1 ! IWFCOD = 1 !
0 = Objective analysis only
1 = Diagnostic wind module

Compute Froude number adjustment effects? (IFRADJ)
Default: 1 ! IFRADJ = 1 !
(0 = NO, 1 = YES)

Compute kinematic effects? (IKINE)
Default: 0 ! IKINE = 0 !
(0 = NO, 1 = YES)

Use O'Brien procedure for adjustment of the vertical velocity? (IOBR)
Default: 0 ! IOBR = 0 !
(0 = NO, 1 = YES)

Compute slope flow effects? (ISLOPE)
Default: 1 ! ISLOPE = 1 !
(0 = NO, 1 = YES)

Extrapolate surface wind observations to upper layers? (IEXTRP)
Default: -4 ! IEXTRP = 4 !
(1 = no extrapolation is done,
2 = power law extrapolation used,
3 = user input multiplicative factors for layers 2 - NZ used (see FEXTRP array)
4 = similarity theory used
-1, -2, -3, -4 = same as above except layer 1 data at upper air stations are ignored

Extrapolate surface winds even if calm? (ICALM)
Default: 0 ! ICALM = 0 !
(0 = NO, 1 = YES)

Layer-dependent biases modifying the weights of surface and upper air stations (BIAS(NZ))
-1<BIAS<1
Negative BIAS reduces the weight of upper air stations
by 10%; BIAS=-1 reduces their weight by 100%
Positive BIAS reduces the weight of surface stations
by 20%; BIAS=1 reduces their weight by 100%
Zero BIAS leaves weights unchanged (1/R**2 interpolation)
Default: NZ*0

Minimum distance from nearest upper air station to surface station for which extrapolation
of surface winds at surface station will be allowed
(RMIN2: Set to -1 for IEXTRP = 4 or other situations
where all surface stations should be extrapolated)
Default: 4. ! RMIN2 = -1 !

Use gridded prognostic wind field model output fields as input to the diagnostic wind field model (IPROG)
Default: 0 ! IPROG = 0 !
(0 = No, [IWFCOD = 0 or 1]
1 = Yes, use CSUAMM prog. winds as Step 1 field, [IWFCOD = 0]
2 = Yes, use CSUAMM prog. winds as initial guess field [IWFCOD = 1]
3 = Yes, use winds from MM4.DAT file as Step 1 field [IWFCOD = 0]
4 = Yes, use winds from MM4.DAT file as initial guess field [IWFCOD = 1]
5 = Yes, use winds from MM4.DAT file as observations [IWFCOD = 1]
13 = Yes, use winds from MM5.DAT file as Step 1 field [IWFCOD = 0]
14 = Yes, use winds from MM5.DAT file as initial guess field [IWFCOD = 1]
15 = Yes, use winds from MM5.DAT file as observations [IWFCOD = 1]

RADIUS OF INFLUENCE PARAMETERS

Use varying radius of influence
Default: F ! LVARY = F!
(if no stations are found within RMAX1, RMAX2,
or RMAX3, then the closest station will be used)

Maximum radius of influence over land
in the surface layer (RMAX1)  No default ! RMAX1 = 20. !
Units: km

Maximum radius of influence over land
aloft (RMAX2)  No default ! RMAX2 = 20. !
Units: km

Maximum radius of influence over water
(RMAX3)  No default ! RMAX3 = 0. !
Units: km

OTHER WIND FIELD INPUT PARAMETERS

Minimum radius of influence used in
the wind field interpolation (RMIN)  Default: 0.1 ! RMIN = 0.1 !
Units: km

Radius of influence of terrain
features (TERRAD)  No default ! TERRAD = 20. !
Units: km

Relative weighting of the first
guess field and observations in the
SURFACE layer (R1)
(R1 is the distance from an
observational station at which the
observation and first guess field are
equally weighted)  No default ! R1 = 10. !
Units: km

Relative weighting of the first
guess field and observations in the
layers ALOFT (R2)
(R2 is applied in the upper layers
in the same manner as R1 is used in
the surface layer).  No default ! R2 = 10. !
Units: km

Relative weighting parameter of the
prognostic wind field data (RPROG)
(Used only if IPROG = 1)  No default ! RPROG = 0. !
Units: km

--------------------

Maximum acceptable divergence in the
divergence minimization procedure
(DIVLIM)  Default: 5.E-6 ! DIVLIM = 5.0E-06 !

Maximum number of iterations in the
divergence min. procedure (NITER)  Default: 50 ! NITER = 50 !

Number of passes in the smoothing
procedure (NSMTH(NZ))
NOTE: NZ values must be entered
Default: 2, (mznz-1)*4 ! NSMTH =
2, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4 !

Maximum number of stations used in
each layer for the interpolation of
data to a grid point (NINTR2(NZ))
NOTE: NZ values must be entered
Default: 99. ! NINTR2 =

Critical Froude number (CRITFN)  Default: 1.0 ! CRITFN = 1. !

Empirical factor controlling the
influence of kinematic effects
(ALPHA)  Default: 0.1 ! ALPHA = 0.1 !

Multiplicative scaling factor for
extrapolation of surface observations
to upper layers (FEXTR2(NZ))
Default: NZ*0.0
! FEXTR2 = 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0. !
(Used only if IEXTRP = 3 or -3)
BARRIER INFORMATION

Number of barriers to interpolation of the wind fields (NBAR) Default: 0 ! NBAR = 0 !

THE FOLLOWING 4 VARIABLES ARE INCLUDED ONLY IF NBAR > 0

NOTE: NBAR values must be entered for each variable No defaults

X coordinate of BEGINNING of each barrier (XBBAR(NBAR)) ! XBBAR = 0. !

Y coordinate of BEGINNING of each barrier (YBBAR(NBAR)) ! YBBAR = 0. !

X coordinate of ENDING of each barrier (XEBAR(NBAR)) ! XEBAR = 0. !

Y coordinate of ENDING of each barrier (YEBAR(NBAR)) ! YEBAR = 0. !

DIAGNOSTIC MODULE DATA INPUT OPTIONS

Surface temperature (IDIOPT1) Default: 0 ! IDIOPT1 = 0 !

0 = Compute internally from hourly surface observations
1 = Read preprocessed values from a data file (DIAG.DAT)

Surface met. station to use for the surface temperature (ISURFT) No default ! ISURFT = 1 !
(Must be a value from 1 to NSSTA)
(Used only if IDIOPT1 = 0)

Domain-averaged temperature lapse rate (IDIOPT2) Default: 0 ! IDIOPT2 = 0 !

0 = Compute internally from twice-daily upper air observations
1 = Read hourly preprocessed values from a data file (DIAG.DAT)

Upper air station to use for the domain-scale lapse rate (IUPT) No default ! IUPT = 1 !
(Must be a value from 1 to NUSTA)
(Used only if IDIOPT2 = 0)

Depth through which the domain-scale lapse rate is computed (ZUPT) Default: 200. ! ZUPT = 200. !
(Used only if IDIOPT2 = 0) Units: meters

Domain-averaged wind components (IDIOPT3) Default: 0 ! IDIOPT3 = 0 !

0 = Compute internally from twice-daily upper air observations
1 = Read hourly preprocessed values from a data file (DIAG.DAT)

Upper air station to use for the domain-scale winds (IUPWND) Default: -1 ! IUPWND = -1 !
(Must be a value from -1 to NUSTA)
(Used only if IDIOPT3 = 0)

Bottom and top of layer through which the domain-scale winds are computed (ZUPWND(1), ZUPWND(2)) Defaults: 1., 1000. ! ZUPWND= 1., 1000. !
(Used only if IDIOPT3 = 0) Units: meters
--------------------------
Observed surface wind components
for wind field module (IDIOPT4) Default: 0 ! IDIOPT4 = 0 !
0 = Read WS, WD from a surface
data file (SURF.DAT)
1 = Read hourly preprocessed U, V from
a data file (DIAG.DAT)

Observed upper air wind components
for wind field module (IDIOPT5) Default: 0 ! IDIOPT5 = 0 !
0 = Read WS, WD from an upper
air data file (UP1.DAT, UP2.DAT, etc.)
1 = Read hourly preprocessed U, V from
a data file (DIAG.DAT)

LAKE BREEZE INFORMATION

Use Lake Breeze Module (LLBREZE)
 Default: F ! LLBREZE = F !

Number of lake breeze regions (NBOX)
 Default: 0 ! NBOX = 0 !

X Grid line 1 defining the region of interest
 XG1 = 0. !

X Grid line 2 defining the region of interest
 XG2 = 0. !

Y Grid line 1 defining the region of interest
 YG1 = 0. !

Y Grid line 2 defining the region of interest
 YG2 = 0. !

X Point defining the coastline (Straight line)
 (XBCST) (KM) Default: none ! XBCST = 0. !

Y Point defining the coastline (Straight line)
 (YBCST) (KM) Default: none ! YBCST = 0. !

X Point defining the coastline (Straight line)
 (XECST) (KM) Default: none ! XECST = 0. !

Y Point defining the coastline (Straight line)
 (YECST) (KM) Default: none ! YECST = 0. !

Number of stations in the region
 Default: none ! NLB = *1 !*
(Surface stations + upper air stations)

Station ID's in the region (METBXID(NLB))
(Surface stations first, then upper air stations)
 ! METBXID = *0 !*

!END!

----------------------------------------------------------------------
INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
------------

EMPIRICAL MIXING HEIGHT CONSTANTS

Neutral, mechanical equation
(CONSTB)
 Default: 1.41 ! CONSTB = 1.41 !

Convective mixing ht. equation
(CONSTE)
 Default: 0.15 ! CONSTE = 0.15 !

Stable mixing ht. equation
(CONSTN)
 Default: 2400. ! CONSTN = 2400. !

Overwater mixing ht. equation
(CONSTW)
 Default: 0.16 ! CONSTW = 0.16 !

Absolute value of Coriolis
parameter (FCORIOL)  Default: 1.E-4  ! FCORIOL = 1.0E-04!
Units: (1/s)

SPATIAL AVERAGING OF MIXING HEIGHTS

Conduct spatial averaging
 Cơ số (IAVEZI)  (0-no, 1-yes) Default: 1  ! IAVEZI = 1

Max. search radius in averaging process (MNMDAV) Default: 1  ! MNMDAV = 1
Units: Grid cells

Units: deg.

Layer of winds used in upwind averaging (ILEVZI) Default: 1  ! ILEVZI = 1
(must be between 1 and NZ)

OTHER MIXING HEIGHT VARIABLES

Minimum potential temperature lapse rate in the stable layer above the current convective mixing ht. (DPTMIN) Default: 0.001  ! DPTMIN = 0.001
Units: deg. K/m

Depth of layer above current conv. mixing height through which lapse rate is computed (DZZI) Default: 200.  ! DZZI = 200.
Units: meters

Minimum overland mixing height (ZMIN) Default: 50.  ! ZMIN = 50.
Units: meters

Units: meters

Minimum overwater mixing height (ZMINW) -- (Not used if observed overwater mixing hts. are used) Default: 50.  ! ZMINW = 50.
Units: meters

Maximum overwater mixing height (ZMAXW) -- (Not used if observed overwater mixing hts. are used) Default: 3000.  ! ZMAXW = 3000.

TEMPERATURE PARAMETERS

Interpolation type (1 = 1/R; 2 = 1/R**2) Default:1  ! IRAD = 1

Units: km

Maximum Number of stations to include in temperature interpolation (NUMTS) Default: 5  ! NUMTS = 5

Conduct spatial averaging of temperatures (IAVET) (0-no, 1-yes) (will use mixing ht MNMDAV,HAFANG so make sure they are correct) Default: 1  ! IAVET = 1

Default temperature gradient below the mixing height over water (K/m) (TGDEFB) Default: -.0098  ! TGDEFB = -0.0098

Default temperature gradient above the mixing height over water (K/m) (TGDEFA) Default: -.0045  ! TGDEFA = -0.0045

Beginning (JWAT1) and ending (JWAT2) land use categories for temperature interpolation over water -- Make bigger than largest land use to disable PRECIP INTERPOLATION PARAMETERS
Method of interpolation (NFLAGP)  Default = 2 ! NFLAGP = 2 !
(1=1/R,2=1/R**2,3=EXP/R**2)
Radius of Influence (km) (SIGMAP)  Default = 100.0 ! SIGMAP = 100. !
(0.0 -> use half dist. btwn nearest stns w & w/out precip when NFLAGP = 3)
Minimum Precip. Rate Cutoff (mm/hr)  Default = 0.01 ! CUTP = 0.01 !
(values < CUTP = 0.0 mm/hr)

-----------------------------------

INPUT GROUP: 7 -- Surface meteorological station parameters

SURFACE STATION VARIABLES
(One record per station -- 4 records in all)

<table>
<thead>
<tr>
<th>Name</th>
<th>ID</th>
<th>X coord. (km)</th>
<th>Y coord. (km)</th>
<th>Time zone</th>
<th>Anem. Ht. (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS1</td>
<td>'POCA'</td>
<td>24156</td>
<td>101.536</td>
<td>103.724</td>
<td>7</td>
</tr>
<tr>
<td>SS2</td>
<td>'NORT'</td>
<td>10000</td>
<td>89.818</td>
<td>204.848</td>
<td>7</td>
</tr>
<tr>
<td>SS3</td>
<td>'SOUT'</td>
<td>10055</td>
<td>73.394</td>
<td>169.497</td>
<td>7</td>
</tr>
</tbody>
</table>

1
Four character string for station name
(MUST START IN COLUMN 9)

2
Five digit integer for station ID

-----------------------------------

INPUT GROUP: 8 -- Upper air meteorological station parameters

UPPER AIR STATION VARIABLES
(One record per station -- 2 records in all)

<table>
<thead>
<tr>
<th>Name</th>
<th>ID</th>
<th>X coord. (km)</th>
<th>Y coord. (km)</th>
<th>Time zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>US1</td>
<td>'BOIS'</td>
<td>24131</td>
<td>-181.335</td>
<td>175.713</td>
</tr>
</tbody>
</table>

1
Four character string for station name
(MUST START IN COLUMN 9)

2
Five digit integer for station ID

-----------------------------------

INPUT GROUP: 9 -- Precipitation station parameters

PRECIPITATION STATION VARIABLES
(One record per station -- 0 records in all)
(NOT INCLUDED IF NPSTA = 0)

1 2
Name       Station Code   X coord. (km)  Y coord. (km)

<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
<th>X coord.</th>
<th>Y coord.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td>'2ESE'</td>
<td>14455</td>
<td>145.994</td>
</tr>
<tr>
<td>PS2</td>
<td>'49WI'</td>
<td>14460</td>
<td>73.212</td>
</tr>
<tr>
<td>PS3</td>
<td>'POCA'</td>
<td>17211</td>
<td>101.536</td>
</tr>
</tbody>
</table>

1. Four character string for station name (MUST START IN COLUMN 9)

2. Six digit station code composed of state code (first 2 digits) and station ID (last 4 digits)

!END!
APPENDIX B: CALMET RESULTS BASED ON 3 AND 25 SURFACE STATIONS
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Description</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.1</td>
<td>CALMET Simulation – Average for January 1999</td>
<td>B-1</td>
</tr>
<tr>
<td>B.2</td>
<td>CALMET Simulation – Average for February 1999</td>
<td>B-2</td>
</tr>
<tr>
<td>B.3</td>
<td>CALMET Simulation – Average for March 1999</td>
<td>B-3</td>
</tr>
<tr>
<td>B.4</td>
<td>CALMET Simulation – Average for April 1999</td>
<td>B-4</td>
</tr>
<tr>
<td>B.5</td>
<td>CALMET Simulation – Average for May 1999</td>
<td>B-5</td>
</tr>
<tr>
<td>B.6</td>
<td>CALMET Simulation – Average for June 1999</td>
<td>B-6</td>
</tr>
<tr>
<td>B.7</td>
<td>CALMET Simulation – Average for July 1999</td>
<td>B-7</td>
</tr>
<tr>
<td>B.8</td>
<td>CALMET Simulation – Average for August 1999</td>
<td>B-8</td>
</tr>
<tr>
<td>B.9</td>
<td>CALMET Simulation – Average for September 1999</td>
<td>B-9</td>
</tr>
<tr>
<td>B.10</td>
<td>CALMET Simulation – Average for October 1999</td>
<td>B-10</td>
</tr>
<tr>
<td>B.11</td>
<td>CALMET Simulation – Average for November 1999</td>
<td>B-11</td>
</tr>
<tr>
<td>B.12</td>
<td>CALMET Simulation – Average for December 1999</td>
<td>B-12</td>
</tr>
</tbody>
</table>
APPENDIX B: CALMET RESULTS BASED ON 3 AND 25 SURFACE STATIONS

Figure B.1  CALMET simulation – average for January 1999
3 STATIONS - BLUE
25 STATIONS – RED
Figure B.2  CALMET simulation – average for February 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.3  CALMET simulation – average for March 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.4  CALMET simulation – average for April 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.5  CALMET simulation – average for May 1999
3 STATIONS - GREEN
25 STATIONS – RED

Reference Vectors
0.12  4.24
0.36  3.72
Figure B.6  CALMET simulation – average for June 1999
3 STATIONS - GREEN
25 STATIONS – RED

Reference Vectors

0.37  2.91

Reference Vectors

0.42  2.92
Figure B.7  CALMET simulation – average for July 1999
3 STATIONS - GREEN
25 STATIONS – RED

<table>
<thead>
<tr>
<th>Reference Vectors</th>
<th>0.091</th>
<th>2.99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Vectors</td>
<td>0.25</td>
<td>2.74</td>
</tr>
</tbody>
</table>
Figure B.8 CALMET simulation – average for August 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.9  CALMET simulation – average for September 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.10  CALMET simulation – average for October 1999
3 STATIONS - GREEN
25 STATIONS – RED

Reference Vectors
0.08 2.73

Reference Vectors
0.13 2.93
Figure B.11  CALMET simulation – average for November 1999
3 STATIONS - GREEN
25 STATIONS – RED
Figure B.12  CALMET simulation – average for December 1999
3 STATIONS - GREEN
25 STATIONS – RED
APPENDIX C: SAMPLE CALPUFF CONTROL FILE
APPENDIX C: SAMPLE CALPUFF CONTROL FILE

Modeling test source 20m Stack
One Pollutant

------------------- Run title (3 lines) -------------------------------

CALPUFF MODEL CONTROL FILE

-------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

------------------ Default Name Type File Name ------------------
CALMET.DAT input * METDAT = *
or
ISCMET.DAT input * ISCDAT = *
or
PLMET.DAT input * PLMDAT = *
or
PROFILE.DAT input * PRFDAT = *
SURFACE.DAT input * SFCDAT = *
RESTARTA.DAT input * RSTAR= *

--------------------------
CALPUFF.LST output ! PULST =cpu57.LST !
CONC.DAT output ! CONDAT =cpu57.con !
DFLX.DAT output ! DFDAT =cpu57.dry !
WFLX.DAT output ! WFDAT =cpu57.wet !

VISO.DAT output * VISDAT =VISO.DAT *
RESTARTA.DAT output * RSTAR= *

-------------------------

Emission Files

------------------ PTEMARB.DAT input * PTDAT = PTEMARB.DAT !
VOLEMARB.DAT input * VOLDAT = *
BAEMARB.DAT input * ARDAT = *
LNEMAR.DAT input * LNADAT = *

-------------------------

Other Files

------------------ OZONE.DAT input * OZDAT = *
VD.DAT input * VDDAT = *
CHEM.DAT input * CHEMDAT= *
H2O2.DAT input * H2O2DAT= *
HILL.DAT input * HILDAT= *
HILL.RCT.DAT input * RCTDAT= *
COASTL.DAT input * CSTDAT= *
FLUXBDY.DAT input * BDYDAT= *
BCON.DAT input * BCNDAT= *
DEBUG.DAT output ! DEBUG =DEBUG.DAT !
MASSFLX.DAT output * FLXDAT= *
MASSBAL.DAT output * BALDAT= *
FOG.DAT output * FOGDAT= *

-------------------

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
T = lower case　　! LCFILES = T !
F = UPPER CASE

NOTE: (1) file/path names can be up to 70 characters in length

 Provision for multiple input files

------------------
Number of CALMET.DAT files for run (NMETDAT)
Default: 1　　! NMETDAT = 12　　!

Number of PTEMARB.DAT files for run (NPTDAT)
Atmospheric Dispersion of Radionuclides

Number of BAEMARB.DAT files for run (NARDAT)
Default: 0 ! NARDAT = 0 !

Number of VOLEMARB.DAT files for run (NVOLDAT)
Default: 0 ! NVOLDAT = 0 !

!END!

Subgroup (0a)

The following CALMET.DAT filenames are processed in sequence if NMETDAT>1

<table>
<thead>
<tr>
<th>Default Name</th>
<th>Type</th>
<th>File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\JAN58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\FEB58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\MAR58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\APR58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\MAY58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\JUN58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\JUL58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\AUG58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\SEP58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\OCT58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\NOV58.DAT ! END!</td>
</tr>
<tr>
<td>none</td>
<td>input</td>
<td>METDAT=c:\P33294\calmet\DEC58.DAT ! END!</td>
</tr>
</tbody>
</table>

INPUT GROUP: 1 -- General run control parameters

Option to run all periods found in the met. file (METRUN)
Default: 0 ! METRUN = 0 !

METRUN = 0 - Run period explicitly defined below
METRUN = 1 - Run all periods in met. file

Starting date: Year (IBYR) -- No default ! IBYR = 1957 !
(used only if Month (IBMO) -- No default ! IBMO = 1 !
METRUN = 0) Day (IBDY) -- No default ! IBDY = 1 !
Hour (IBHR) -- No default ! IBHR = 0 !

Base time zone (XBTZ) -- No default ! XBTZ = 7.0 !
PST = 8., MST = 7.
CST = 6., EST = 5.

Length of run (hours) (IRLG) -- No default ! IRLG = 8736 !

Number of chemical species (NSPEC)
Default: 5 ! NSPEC = 1 !

Number of chemical species to be emitted (NSE)
Default: 3 ! NSE = 1 !

Flag to stop run after SETUP phase (ITEST)
Default: 2 ! ITEST = 2 !
(Used to allow checking of the model inputs, files, etc.)
ITEST = 1 - STOPS program after SETUP phase
ITEST = 2 - Continues with execution of program after SETUP

Restart Configuration:

Control flag (MRESTART)
Default: 0 ! MRESTART = 0 !
0 = Do not read or write a restart file
1 = Read a restart file at the beginning of the run
2 = Write a restart file during run
3 = Read a restart file at beginning of run and write a restart file during run

Number of periods in Restart output cycle (NRESPD) Default: 0 ! NRESPD = 0 |
0 = File written only at last period
>0 = File updated every NRESPD periods

Meteorological Data Format (METFM) Default: 1 ! METFM = 1 |
METFM = 1 - CALMET binary file (CALMET.MET)
METFM = 2 - ISC ASCII file (ISCMET.MET)
METFM = 3 - AUSPLUME ASCII file (PLMNET.MET)
METFM = 4 - CTDM plus tower file (PROFILE.DAT) and surface parameters file (SURFACE.DAT)

PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
Averaging Time (minutes) (AVET) Default: 60.0 ! AVET = 60. !
PG Averaging Time (minutes) (PGTIME) Default: 60.0 ! PGTIME = 60. !

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
-------------

Vertical distribution used in the near field (MGAUSS) Default: 1 ! MGAUSS = 1 |
0 = uniform
1 = Gaussian

Terrain adjustment method (MCTADJ) Default: 3 ! MCTADJ = 3 |
0 = no adjustment
1 = ISC-type of terrain adjustment
2 = simple, CALPUFF-type of terrain adjustment
3 = partial plume path adjustment

Subgrid-scale complex terrain flag (MCTSG) Default: 0 ! MCTSG = 0 |
0 = not modeled
1 = modeled

Near-field puffs modeled as elongated 0 (MSLUG) Default: 0 ! MSLUG = 0 |
0 = no
1 = yes (slug model used)

Transitional plume rise modeled ? (MTRANS) Default: 1 ! MTRANS = 1 |
0 = no (i.e., final rise only)
1 = yes (i.e., transitional rise computed)

Stack tip downwash? (MTIP) Default: 1 ! MTIP = 1 |
0 = no (i.e., no stack tip downwash)
1 = yes (i.e., use stack tip downwash)

Vertical wind shear modeled above

C-3
stack top? (MSHEAR) Default: 0  ! MSHEAR = 0  !
  0 = no (i.e., vertical wind shear not modeled)
  1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT) Default: 0  ! MSPLIT = 0  !
  0 = no (i.e., puffs not split)
  1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM) Default: 1  ! MCHEM = 0  !
  0 = chemical transformation not modeled
  1 = transformation rates computed internally (MESOPUFF II scheme)
  2 = user-specified transformation rates used
  3 = transformation rates computed internally (RIVAD/ARM3 scheme)
  4 = secondary organic aerosol formation computed (MESOPUFF II scheme for OH)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 1, or 3) Default: 0  ! MAQCHEM = 0  !
  0 = aqueous phase transformation not modeled
  1 = transformation rates adjusted for aqueous phase reactions

Wet removal modeled? (MWET) Default: 1  ! MWET = 1  !
  0 = no
  1 = yes

Dry deposition modeled? (MDRY) Default: 1  ! MDRY = 1  !
  0 = no
  1 = yes
(dry deposition method specified for each species in Input Group 3)

Method used to compute dispersion coefficients (MDISP) Default: 3  ! MDISP = 3  !
  1 = dispersion coefficients computed from measured values of turbulence, sigma v, sigma w
  2 = dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (\(u^*, w^*, L\), etc.)
  3 = PG dispersion coefficients for RURAL areas (computed using the ISCST multi-segment approximation) and MP coefficients in urban areas
  4 = same as 3 except PG coefficients computed using the MESOPUFF II eqns.
  5 = CTDM sigmas used for stable and neutral conditions. For unstable conditions, sigmas are computed as in MDISP = 3, described above. MDISP = 5 assumes that measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5) Default: 3  ! MTURBVW = 0  !
  1 = use sigma-v or sigma-theta measurements from PROFILE.DAT to compute sigma-y
    (valid for METFM = 1, 2, 3, 4)
  2 = use sigma-w measurements from PROFILE.DAT to compute sigma-z
    (valid for METFM = 1, 2, 3, 4)
  3 = use both sigma-\((v/\theta)\) and sigma-w from PROFILE.DAT to compute sigma-y and sigma-z
    (valid for METFM = 1, 2, 3, 4)
  4 = use sigma-theta measurements from PLMNET.DAT to compute sigma-y
    (valid only if METFM = 3)

Back-up method used to compute dispersion when measured turbulence data are
missing (MDISP2) Default: 3  ! MDISP2 = 4 
(used only if MDISP = 1 or 5) 
2 = dispersion coefficients from internally calculated
sigma v, sigma w using micrometeorological variables 
(u*, w*, L, etc.)
3 = PG dispersion coefficients for RURAL areas (computed using 
the ISCBST multi-segment approximation) and MP coefficients in 
urban areas
4 = same as 3 except PG coefficients computed using 
the MESOPUFF II eqns.

PG sigma-y,z adj. for roughness? Default: 0  ! MROUGH = 0 
(MROUGH)
0 = no
1 = yes

Partial plume penetration of 
elevated inversion? Default: 1  ! MPARTL = 1 
(MPARTL)
0 = no
1 = yes

Strength of temperature inversion Default: 0  ! MTINV = 0 
provided in PROFILE.DAT extended records?
(MTINV)
0 = no (computed from measured/default gradients)
1 = yes

PDF used for dispersion under convective conditions? Default: 0  ! MPDF = 0 
(MPDF)
0 = no
1 = yes

Sub-Grid TIBL module used for shore line? Default: 0  ! MSGTIBL = 0 
(MSGTIBL)
0 = no
1 = yes

Boundary conditions (concentration) modeled? Default: 0  ! MBCON = 0 
(MBCON)
0 = no
1 = yes

Analyses of fogging and icing impacts due to emissions from 
arrays of mechanically-forced cooling towers can be performed 
using CALPUFF in conjunction with a cooling tower emissions 
processor (CTEMISS) and its associated postprocessors. Hourly 
emissions of water vapor and temperature from each cooling tower 
cell are computed for the current cell configuration and ambient 
conditions by CTEMISS. CALPUFF models the dispersion of these 
emissions and provides cloud information in a specialized format 
for further analysis. Output to FOG.DAT is provided in either 
'plume mode' or 'receptor mode' format.

Configure for FOG Model output? Default: 0  ! MFOG = 0 
(MFOG)
0 = no
1 = yes  - report results in PLUME Mode format
2 = yes  - report results in RECEPTOR Mode format

Test options specified to see if 
they conform to regulatory 
values? (MREG) Default: 1  ! MREG = 0 

0 = NO checks are made
1 = Technical options must conform to USEPA values
Metastable 1
AVET 60. (min)
MGAUSS 1
MCTADJ 3
MTRANS 1
MTIP 1
MCHEM 1 (if modeling SOx, NOx)
MWET 1
MDRY 1
MDISP 3
MROUGH 0
MPARTL 1
SYTDEP 550. (m)
MHFTSZ 0

!END!

INPUT GROUP: 3a, 3b -- Species list

Subgroup (3a)

The following species are modeled:

! CSPEC = I131 ! !END!

Subgroup (3b)

The following names are used for Species-Groups in which results for certain species are combined (added) prior to output. The CGRP name will be used as the species name in output files. Use this feature to model specific particle-size distributions by treating each size-range as a separate species. Order must be consistent with 3(a) above.

INPUT GROUP: 4 -- Grid control parameters

METEOROLOGICAL grid:

No. X grid cells (NX) No default ! NX = 80 !
No. Y grid cells (NY) No default ! NY = 80 !
No. vertical layers (NZ) No default ! NZ = 11 !
Grid spacing (DGRIDKM) No default ! DGRIDKM = 4. !
Units: km

Cell face heights
 Computational grid:

The computational grid is identical to or a subset of the MET. grid. The lower left (LL) corner of the computational grid is at grid point (IBCOMP, JBCOMP) of the MET. grid. The upper right (UR) corner of the computational grid is at grid point (IECOMP, JECOMP) of the MET. grid. The grid spacing of the computational grid is the same as the MET. grid.

X index of LL corner (IBCOMP) No default ! IBCOMP = 1 ! (1 <= IBCOMP <= NX)

Y index of LL corner (JBCOMP) No default ! JBCOMP = 1 ! (1 <= JBCOMP <= NY)

X index of UR corner (IECOMP) No default ! IECOMP = 80 ! (1 <= IECOMP <= NX)

Y index of UR corner (JECOMP) No default ! JECOMP = 80 ! (1 <= JECOMP <= NY)

SAMPLING GRID (GRIDDED RECEPTORS):

The lower left (LL) corner of the sampling grid is at grid point (IBSAMP, JBSAMP) of the MET. grid. The upper right (UR) corner of the sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid. The sampling grid must be identical to or a subset of the computational grid. It may be a nested grid inside the computational grid. The grid spacing of the sampling grid is DGRIDXM/MESHDN.

Logical flag indicating if gridded receptors are used (LSAMP) Default: T ! LSAMP = T ! (T=yea, F=no)

X index of LL corner (IBSAMP) No default ! IBSAMP = 1 ! (IBCOMP <= IBSAMP <= IECOMP)

Y index of LL corner (JBSAMP) No default ! JBSAMP = 1 ! (JBCOMP <= JBSAMP <= JECOMP)

X index of UR corner (IESAMP) No default ! IESAMP = 80 ! (IBCOMP <= IESAMP <= IECOMP)

Y index of UR corner (JESAMP) No default ! JESAMP = 80 ! (JBCOMP <= JESAMP <= JECOMP)
**INPUT GROUP: 5 -- Output Options**

<table>
<thead>
<tr>
<th>FILE</th>
<th>DEFAULT VALUE</th>
<th>VALUE THIS RUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrations (ICON)</td>
<td>1</td>
<td>ICON = 1 !</td>
</tr>
<tr>
<td>Dry Fluxes (IDRY)</td>
<td>1</td>
<td>IDRY = 1 !</td>
</tr>
<tr>
<td>Wet Fluxes (IWET)</td>
<td>1</td>
<td>IWET = 1 !</td>
</tr>
<tr>
<td>Relative Humidity (IVIS)</td>
<td>1</td>
<td>IVIS = 0 !</td>
</tr>
<tr>
<td>(relative humidity file is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>required for visibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>analysis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use data compression option in output file? (LCOMPRS)</td>
<td>Default: T</td>
<td>LCOMPRS = T !</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass flux across specified boundaries for selected species reported hourly? (IMFLX)</td>
<td>Default: 0</td>
<td>IMFLX = 0 !</td>
</tr>
<tr>
<td>0 = no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames are specified in Input Group 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass balance for each species reported hourly? (IMBAL)</td>
<td>Default: 0</td>
<td>IMBAL = 0 !</td>
</tr>
<tr>
<td>0 = no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = yes (MASSBAL.DAT filename is specified in Input Group 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LINE PRINTER OUTPUT OPTIONS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print concentrations (ICPRT)</td>
<td>Default: 0</td>
<td>ICPRT = 0 !</td>
</tr>
<tr>
<td>Print dry fluxes (IDPRT)</td>
<td>Default: 0</td>
<td>IDPRT = 0 !</td>
</tr>
<tr>
<td>Print wet fluxes (IWPRT)</td>
<td>Default: 0</td>
<td>IWPRT = 0 !</td>
</tr>
<tr>
<td>(0 = Do not print, 1 = Print)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentration print interval (ICFRQ) in hours</td>
<td>Default: 1</td>
<td>ICFRQ = 1 !</td>
</tr>
<tr>
<td>Dry flux print interval (IDFRQ) in hours</td>
<td>Default: 1</td>
<td>IDFRQ = 1 !</td>
</tr>
<tr>
<td>Wet flux print interval (IWFRQ) in hours</td>
<td>Default: 1</td>
<td>IWFRQ = 1 !</td>
</tr>
<tr>
<td>Units for Line Printer Output (IPRTU)</td>
<td>Default: 1</td>
<td>IPRTU = 3 !</td>
</tr>
<tr>
<td>for Concentration</td>
<td>g/m**3</td>
<td></td>
</tr>
<tr>
<td>for Deposition</td>
<td>g/m**2/s</td>
<td></td>
</tr>
<tr>
<td>1 =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 =</td>
<td>mg/m**3</td>
<td>mg/m**2/s</td>
</tr>
<tr>
<td>3 =</td>
<td>ug/m**3</td>
<td>ug/m**2/s</td>
</tr>
<tr>
<td>4 =</td>
<td>ng/m**3</td>
<td>ng/m**2/s</td>
</tr>
<tr>
<td>5 = Odour Units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Messages tracking progress of run written to the screen ?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Atmospheric Dispersion of Radionuclides

July 2005

(IMESG) 
0 = no
1 = yes (advection step, puff ID)
2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)

SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

-- MASS FLUX --

SPECIES

/GROUP

SAVED ON DISK?

PRINTED? SAVED ON DISK? PRINTED? SAVED ON DISK? PRINTED? SAVED ON DISK?

------------- ---- CONCENTRATIONS ------ DRY FLUXES ------ WET FLUXES -------

! 1131 = 0, 1, 0, 1, 0, 1, 0 !

OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

Logical for debug output
(LDEBUG) 
Default: F ! LDEBUG = F !

First puff to track
(IPFDEB) 
Default: 1 ! IPFDEB = 1 !

Number of puffs to track
(NPFDEB) 
Default: 1 ! NPFDEB = 1 !

Met. period to start output
(NN1) 
Default: 1 ! NN1 = 1 !

Met. period to end output
(NN2) 
Default: 10 ! NN2 = 10 !

!END!

INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs

------------------------

Subgroup (6a)

------------------------

Number of terrain features (NHILL) 
Default: 0 ! NHILL = 0 !

Number of special complex terrain
receptors (NCTREC) 
Default: 0 ! NCTREC = 0 !

Terrain and CTSG Receptor data for
CTSG hills input in CTDM format?

(MHILL) 
No Default ! MHILL = 0 !

1 = Hill and Receptor data created
by CTDM processors & read from
HILL.DAT and HILLRCT.DAT files
2 = Hill data created by OPTHILL &
input below in Subgroup (6b);
Receptor data in Subgroup (6c)

Factor to convert horizontal dimensions
to meters (MHILL=1) 
Default: 1.0 ! XHILL2M = 1. !

Factor to convert vertical dimensions
to meters (MHILL=1) 
Default: 1.0 ! ZHILL2M = 1. !

X-origin of CTDM system relative to
CALPUFF coordinate system, in Kilometers
(MHILL=1) 
No Default ! XCTDMKM = 0.0E00 !

Y-origin of CTDM system relative to
No Default ! YCTDMKM = 0.0E00 !
CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

-------------------
Subgroup (6b)
-------------------
1 **

HILL information

<table>
<thead>
<tr>
<th>HILL NO.</th>
<th>XC (km)</th>
<th>YC (km)</th>
<th>THETAH (deg.)</th>
<th>ZGRID (m)</th>
<th>RELIEF (m)</th>
<th>EXPO 1 (m)</th>
<th>EXPO 2 (m)</th>
<th>SCALE 1 (m)</th>
<th>SCALE 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>----</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

-------------------
Subgroup (6c)
-------------------

COMPLEX TERRAIN RECEPTOR INFORMATION

<table>
<thead>
<tr>
<th>XRCT (km)</th>
<th>YRCT (km)</th>
<th>ZRCT (m)</th>
<th>XHH</th>
</tr>
</thead>
<tbody>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Description of Complex Terrain Variables:

XC, YC = Coordinates of center of hill
THETAH = Orientation of major axis of hill (clockwise from North)
ZGRID = Height of the 0 of the grid above mean sea level
RELIEF = Height of the crest of the hill above the grid elevation
EXPO 1 = Hill-shape exponent for the major axis
EXPO 2 = Hill-shape exponent for the major axis
SCALE 1 = Horizontal length scale along the major axis
SCALE 2 = Horizontal length scale along the minor axis
AMAX = Maximum allowed axis length for the major axis
BMAX = Maximum allowed axis length for the major axis
XRCT, YRCT = Coordinates of the complex terrain receptors
ZRCT = Height of the ground (MSL) at the complex terrain receptor
XHH = Hill number associated with each complex terrain receptor (NOTE: MUST BE ENTERED AS A REAL NUMBER)

**

NOTE: DATA for each hill and CTSG receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

-------------------
INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
-------------------

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>DIFFUSIVITY (cm**2/s)</th>
<th>ALPHA STAR</th>
<th>REACTIVITY</th>
<th>MESOPHYLL RESISTANCE (s/cm)</th>
<th>HENRY'S</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>!</td>
<td>I131 = 0.1345</td>
<td>1.0</td>
<td>2.0</td>
<td>25.0</td>
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<tr>
<td>18. !</td>
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</tbody>
</table>

!END!

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INPUT GROUP: 8 -- Size parameters for dry deposition of particles
-------------------
For SINGLE SPECIES, the mean and standard deviation are used to compute a deposition velocity for NINT (see group 9) size-ranges, and these are then averaged to obtain a mean deposition velocity.

For GROUPED SPECIES, the size distribution should be explicitly specified (by the 'species' in the group), and the standard deviation for each should be entered as 0. The model will then use the deposition velocity for the stated mean diameter.

<table>
<thead>
<tr>
<th>SPECIES NAME</th>
<th>GEOMETRIC MASS MEAN DIAMETER (microns)</th>
<th>GEOMETRIC STANDARD DEVIATION (microns)</th>
</tr>
</thead>
</table>

!END!

INPUT GROUP: 9 -- Miscellaneous dry deposition parameters

Reference cuticle resistance (s/cm)
(RCUTR) Default: 30 ! RCUTR = 30.0 !
Reference ground resistance (s/cm)
(RGR) Default: 10 ! RGR = 5.0 !
Reference pollutant reactivity
(REACTR) Default: 8 ! REACTR = 8.0 !

Number of particle-size intervals used to evaluate effective particle deposition velocity
(NINT) Default: 9 ! NINT = 9 !

Vegetation state in unirrigated areas
(IVEG) Default: 1 ! IVEG = 1 !
IVEG=1 for active and unstressed vegetation
IVEG=2 for active and stressed vegetation
IVEG=3 for inactive vegetation

!END!

INPUT GROUP: 10 -- Wet Deposition Parameters

Scavenging Coefficient -- Units: (sec)**(-1)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Liquid Precip.</th>
<th>Frozen Precip.</th>
</tr>
</thead>
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<tr>
<td>I131</td>
<td>1.0E-04</td>
<td>3.0E-05</td>
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</tbody>
</table>

!END!

INPUT GROUP: 11 -- Chemistry Parameters

Ozone data input option (MOZ) Default: 1 ! MOZ = 0 !
(Used only if MCHEM = 1, 3, or 4)
0 = use a monthly background ozone value
1 = read hourly ozone concentrations from the OZONE.DAT data file
Monthly ozone concentrations
(Used only if MCHEM = 1, 3, or 4 and
MOZ = 0 or MOZ = 1 and all hourly O3 data missing)
(BCKO3) in ppb Default: 12*80.

! BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00

Monthly ammonia concentrations
(Used only if MCHEM = 1, or 3)
(BCKNH3) in ppb Default: 12*10.

! BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00

Nighttime SO2 loss rate (RNITE1)
in percent/hour Default: 0.2 ! RNITE1 = .2 !

Nighttime NOx loss rate (RNITE2)
in percent/hour Default: 2.0 ! RNITE2 = 2.0 !

Nighttime HNO3 formation rate (RNITE3)
in percent/hour Default: 2.0 ! RNITE3 = 2.0 !

H2O2 data input option (MH2O2) Default: 1 ! MH2O2 = 1 !
(Used only if MQCHEM = 1)
0 = use a monthly background H2O2 value
1 = read hourly H2O2 concentrations from the H2O2.DAT data file

Monthly H2O2 concentrations
(Used only if MQCHEM = 1 and
MH2O2 = 0 or MH2O2 = 1 and all hourly H2O2 data missing)
(BCKH2O2) in ppb Default: 12*1.1

! BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00

--- Data for SECONDARY ORGANIC AEROSOL (SOA) Option
(used only if MCHEM = 4)

The SOA module uses monthly values of:
Fine particulate concentration in ug/m^3 (BCKPMF)
Organic fraction of fine particulate (OFRAC)
VOC / NOx ratio (after reaction) (VCNX)
to characterize the air mass when computing the formation of SOA from VOC emissions.
Typical values for several distinct air mass types are:

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<thead>
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<th>Month</th>
<th>1</th>
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<td>BCKPMF</td>
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</table>
OFRAC .20 .20 .25 .35 .25 .40 .40 .40 .30 .30 .30 .20
VCNX  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

Urban - no controls present
BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
OFRAC .30 .30 .35 .35 .35 .55 .55 .55 .35 .35 .35 .30
VCNX  2.  2.  2.  2.  2.  2.  2.  2.  2.  2.  2.  2.

Default: Clean Continental
! BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
! OFRAC = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
! VCNX = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00 !

!END!

-------------------------------------------------------------------------------------------------

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters

Horizontal size of puff (m) beyond which
time-dependent dispersion equations (Heefter)
are used to determine sigma-y and
sigma-z (SYTDEP)
  Default: 550.  ! SYTDEP = 5.5E02 !

Switch for using Heefter equation for sigma z
as above (0 = Not use Heefter; 1 = use Heefter)
(MHFTSZ)
  Default: 0  ! MHFTSZ = 0  !

Stability class used to determine plume
growth rates for puffs above the boundary
layer (JSUP)
  Default: 5  ! JSUP = 5  !

Vertical dispersion constant for stable
conditions (k1 in Eqn. 2.7-3)  (CONK1)
  Default: 0.01  ! CONK1 = .01  !

Vertical dispersion constant for neutral/
unstable conditions (k2 in Eqn. 2.7-4)
(CONK2)
  Default: 0.1  ! CONK2 = .1  !

Factor for determining Transition-point from
Schulman-Scire to Huber-Snyder Building Downwash
scheme (SS used for Hs < Hb + TBD * HL)
(TBD)
  Default: 0.5  ! TBD = .5  !
  TBD < 0  ==> always use Huber-Snyder
  TBD = 1.5  ==> always use Schulman-Scire
  TBD = 0.5  ==> ISC Transition-point

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)
  Default: 10  ! IURB1 = 10  !
  19  ! IURB2 = 19  !

Site characterization parameters for single-point Met data files --------
(needed for METFM = 2,3,4)

Land use category for modeling domain
(ILANDUIN)
  Default: 20  ! ILANDUIN = 20  !

Roughness length (m) for modeling domain
(ZOIN)
  Default: 0.25  ! ZOIN = .25  !

Leaf area index for modeling domain
(XLAIN)
  Default: 3.0  ! XLAIN = 3.0  !

Elevation above sea level (m)
(ELEVIN)
  Default: 0.0  ! ELEVIN = .0  !

Latitude (degrees) for met location
Atmospheric Dispersion of Radionuclides

July 2005

(XLATIN) Default: -999. ! XLATIN = -999.0 !

Longitude (degrees) for met location (XLONIN) Default: -999. ! XLONIN = -999.0 !

Specialized information for interpreting single-point Met data files -----

Anemometer height (m) (Used only if METFM = 2,3)
(ANEMHT) Default: 10. ! ANEMHT = 10.0 !

Form of lateral turbulence data in PROFILE.DAT file
(Used only if METFM = 4 or MTURBVW = 1 or 3)
(ISIGMAV) Default: 1 ! ISIGMAV = 2 !

0 = read sigma-theta
1 = read sigma-v

Choice of mixing heights (Used only if METFM = 4)
(IMXCTDM) Default: 0 ! IMXCTDM = 0 !

0 = read PREDICTED mixing heights
1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN) Default: 1.0 ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN) Default: 1.0 ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW) Default: 99 ! MXNEW = 99 !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM) Default: 99 ! MXSAM = 99 !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT) Default: 2 ! NCOUNT = 2 !

Minimum sigma y for a new puff/slug (m)
(SYMIN) Default: 1.0 ! SYMIN = 1.0 !

Minimum sigma z for a new puff/slug (m)
(SZMIN) Default: 1.0 ! SZMIN = 1.0 !

Default minimum turbulence velocities
sigma-v and sigma-w for each
stability class (m/s)
(SVMIN(6) and SWMIN(6)) Default SVMIN : .50, .50, .50, .50, .50, .50
Default SWMIN : .20, .12, .08, .06, .03, .016

Stability Class : A B C D E F
--- --- --- --- --- ---
! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500!
! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!

Divergence criterion for dw/dz across puff
used to initiate adjustment for horizontal
convergence (1/s)
Partial adjustment starts at CDIV(1), and
full adjustment is reached at CDIV(2)
(CDIV(2)) Default: 0.0,0.0 ! CDIV = .0, .0 !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(WSCALM) Default: 0.5 ! WSCALM = .3 !
Maximum mixing height (m)  
(XMAXZI) Default: 3000.  ! XMAXZI = 3000.0 !

Minimum mixing height (m)  
(XMINZI) Default: 50.  ! XMINZI = 50.0 !

Default wind speed classes -- 
5 upper bounds (m/s) are entered; 
the 6th class has no upper limit  
(WSCAT(5)) Default:  
ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8 (10.8+)
ISC URBAN : .15, .15, .20, .25, .30

Wind Speed Class : 1 2 3 4 5
--- --- --- --- ---
! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

Default wind speed profile power-law 
exponents for stabilities 1-6  
(PLX0(6)) Default: ISC RURAL values
ISC RURAL : .07, .07, .10, .15, .35, .55
ISC URBAN : .15, .15, .20, .25, .30, .30

Stability Class : A B C D E F
--- --- --- --- --- ---
! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient 
for stable classes E, F (degK/m)  
(PTG0(2)) Default: 0.020, 0.035
! PTG0 = 0.020, 0.035 !

Default plume path coefficients for 
each stability class (used when option 
for partial plume height terrain adjustment 
is selected -- MCTADJ=3)  
(PPC(6)) Stability Class : A B C D E F
Default PPC : .50, .50, .50, .50, .35, .35
--- --- --- --- --- ---
! PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor 
equal to sigma-y/length of slug  
(SL2PF) Default: 10.  ! SL2PF = 10.0 !

Puff-splitting control variables  -----------------------------

VERTICAL SPLIT
-----------------

Number of puffs that result every time a puff is split - nsplit=2 means that 1 puff splits into 2  
(NSPLIT) Default: 3  ! NSPLIT = 3 !

Time(s) of a day when split puffs are eligible to be split once again; this is typically set once per day, around sunset before nocturnal shear develops. 24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
0=do not re-split  1=eligible for re-split  
(IRESPLIT(24)) Default: Hour 17 = 1
! IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 !

Split is allowed only if last hour's mixing height (m) exceeds a minimum value  
(ZISPLIT) Default: 100.  ! ZISPLIT = 100.0 !

Split is allowed only if ratio of last hour's mixing ht to the maximum mixing ht experienced by the puff is less than a maximum value (this postpones a split until a nocturnal layer develops)  
(ROLDMAX) Default: 0.25  ! ROLDMAX = 0.25 !
HORIZONTAL SPLIT

Number of puffs that result every time a puff is split - nsplith=5 means that 1 puff splits into 5
Default: 5 ! NSPLITH = 5 !

Minimum sigma-y (Grid Cells Units) of puff before it may be split
Default: 1.0 ! SYSPLITH = 1.0 !

Minimum puff elongation rate (SYSPLITH/hr) due to wind shear, before it may be split
Default: 2. ! SHSPLITH = 2.0 !

Minimum concentration (g/m^3) of each species in puff before it may be split
Default: 1.0E-07 ! CNSPLITH = 1.0E-07 !

Integration control variables

Fractional convergence criterion for numerical SLUG sampling integration
Default: 1.0e-04 ! EPSSLUG = 1.0E-04 !

Fractional convergence criterion for numerical AREA source integration
Default: 1.0e-06 ! EPSAREA = 1.0E-06 !

Trajectory step-length (m) used for numerical rise integration
Default: 1.0 ! DSRISE = 1.0 !

END!

INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters

Subgroup (13a)

Number of point sources with parameters provided below
(NPT1) No default ! NPT1 = 0 !
Units used for point source emissions below
(IPTU) Default: 1 ! IPTU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr

Number of source-species combinations with variable emissions scaling factors provided below in (13d)
(NSPT1) Default: 0 ! NSPT1 = 0 !

Number of point sources with variable emission parameters provided in external file
(NPT2) No default ! NPT2 = 1 !
(If NPT2 > 0, these point
source emissions are read from
the file: PTEMARB.DAT)

!END!

Subgroup (13b)

POINT SOURCE: CONSTANT DATA
---------------------------------------------

<table>
<thead>
<tr>
<th>Source No.</th>
<th>X UTM (km)</th>
<th>Y UTM (km)</th>
<th>Stack Height (m)</th>
<th>Base Elevation (m)</th>
<th>Exit Diameter (m)</th>
<th>Exit Vel. (m/s)</th>
<th>Exit Temp. (deg. K)</th>
<th>Bldg. Dwash Rates</th>
</tr>
</thead>
</table>

\[ a \]

Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

\[ \text{SRCNAM} \text{ is a 12-character name for a source (No default)} \]

\[ \text{X} \text{ is an array holding the source data listed by the column headings (No default)} \]

\[ \text{SIGYZI} \text{ is an array holding the initial sigma-y and sigma-z (m) (Default: 0.0.)} \]

\[ \text{FMFAC} \text{ is a vertical momentum flux factor (0. or 1.0) used to represent the effect of rain-caps or other physical configurations that reduce momentum rise associated with the actual exit velocity. (Default: 1.0 -- full momentum used)} \]

\[ \text{b} \]

0. = No building downwash modeled, 1. = downwash modeled

\[ \text{NOTE: must be entered as a REAL number (i.e., with decimal point)} \]

\[ \text{c} \]

An emission rate must be entered for every pollutant modeled.

\[ \text{Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by IPTU (e.g. 1 for g/s).} \]

Subgroup (13c)

BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
----------------------------------------------------------

<table>
<thead>
<tr>
<th>Source No.</th>
<th>Effective building width and height (in meters) every 10 degrees</th>
</tr>
</thead>
</table>

\[ a \]

Each pair of width and height values is treated as a separate input subgroup and therefore must end with an input group terminator.

Subgroup (13d)

POINT SOURCE: VARIABLE EMISSIONS DATA
----------------------------------------

Use this subgroup to describe temporal variations in the emission rates given in 13b. Factors entered multiply the rates in 13b.

Skip sources here that have constant emissions. For more elaborate variation in source parameters, use PTEMARB.DAT and NPT2 > 0.
IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0
0 - Constant
1 - Diurnal cycle (24 scaling factors: hours 1-24)
2 - Monthly cycle (12 scaling factors: months 1-12)
3 - Hour & Season (4 groups of 24 hourly scaling factors,
where first group is DEC-JAN-FEB)
4 - Speed & Stab. (6 groups of 6 scaling factors, where
first group is Stability Class A,
and the speed classes have upper
bounds (m/s) defined in Group 12
5 - Temperature (12 scaling factors, where temperature
classes have upper bounds (°C) of:
0, 5, 10, 15, 20, 25, 30, 35, 40,
45, 50, 50+)

--------

Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

--------------------------------

INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters

Subgroup (14a)

Number of polygon area sources with
parameters specified below (NAR1) No default ! NAR1 = 0 !

Units used for area source
emissions below (IARU) Default: 1 ! IARU = 1 !
1 - g/m**2/s
2 - kg/m**2/hr
3 - lb/m**2/hr
4 - tons/m**2/yr
5 - Odour Unit * m/s (vol. flux/m**2 of odour compound)
6 - Odour Unit * m/min
7 - metric tons/m**2/yr

Number of source-species
combinations with variable
emissions scaling factors
provided below in (14d) (NSAR1) Default: 0 ! NSAR1 = 0 !

Number of buoyant polygon area sources
with variable location and emission
parameters (NAR2) No default ! NAR2 = 0 !
(If NAR2 > 0, ALL parameter data for
these sources are read from the file: BAEMAR.BDAT)

END!

Subgroup (14b)

AREA SOURCE: CONSTANT DATA

<table>
<thead>
<tr>
<th>Source No.</th>
<th>Effect. Height (m)</th>
<th>Base Elevation (m)</th>
<th>Initial Sigma z (m)</th>
<th>Emission Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
a Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

b An emission rate must be entered for every pollutant modeled. Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by IARU (e.g. 1 for g/m**2/s).

Subgroup (14c)

COORDINATES (UTM-km) FOR EACH VERTEX(4) OF EACH POLYGON

Source No.  Ordered list of X followed by list of Y, grouped by source

---

---

a Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

Subgroup (14d)

AREA SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission rates given in 14b. Factors entered multiply the rates in 14b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

IVARY determines the type of variation, and is source-specific:

(IVARY)

Default: 0

0 = Constant
1 = Diurnal cycle (24 scaling factors: hours 1-24)
2 = Monthly cycle (12 scaling factors: months 1-12)
3 = Hour & Season (4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
4 = Speed & Stab. (6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
5 = Temperature (12 scaling factors, where temperature classes have upper bounds (C) of:
  0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

a Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

---

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters

Subgroup (15a)

Number of buoyant line sources
with variable location and emission parameters (NLN2) No default ! NLN2 = 0 !

(If NLN2 > 0, ALL parameter data for these sources are read from the file: LNEMARB.DAT)

Number of buoyant line sources (NLINES) No default ! NLINES = 0 !

Units used for line source emissions below (ILNU) Default: 1 ! ILNU = 1 !
1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr

Number of source-species combinations with variable emissions scaling factors provided below in (NSLN1) Default: 0 ! NSLN1 = 0 !

Maximum number of segments used to model each line (MXNSEG) Default: 7 ! MXNSEG = 7 !

The following variables are required only if NLINES > 0. They are used in the buoyant line source plume rise calculations.

Number of distances at which transitional rise is computed Default: 6 ! NLRSE = 6 !

Average building length (XL) No default ! XL = .0 ! (in meters)

Average building height (HBL) No default ! HBL = .0 ! (in meters)

Average building width (WBL) No default ! WBL = .0 ! (in meters)

Average line source width (WML) No default ! WML = .0 ! (in meters)

Average separation between buildings (DXL) No default ! DXL = .0 ! (in meters)

Average buoyancy parameter (FPRIMEL) No default ! FPRIMEL = .0 ! (in m**4/a**3)

!END!

---------------
Subgroup (15b)
---------------

BUOYANT LINE SOURCE: CONSTANT DATA
--------------------------------------

<table>
<thead>
<tr>
<th>Source No.</th>
<th>Beg. X Coordinate (km)</th>
<th>Beg. Y Coordinate (km)</th>
<th>End. X Coordinate (km)</th>
<th>End. Y Coordinate (km)</th>
<th>Release Height (m)</th>
<th>Base Elevation (m)</th>
<th>Emission Rates</th>
</tr>
</thead>
</table>

\( ^a \) Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

\( ^b \) An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by ILNTU (e.g. 1 for g/s).

-----------
Subgroup (15c)
-----------

`a`

**BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA**

Use this subgroup to describe temporal variations in the emission rates given in 15b. Factors entered multiply the rates in 15b. Skip sources here that have constant emissions.

IVARY determines the type of variation, and is source-specific:

```
<table>
<thead>
<tr>
<th>IVARY</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Constant</td>
</tr>
<tr>
<td>1</td>
<td>Diurnal cycle (24 scaling factors: hours 1-24)</td>
</tr>
<tr>
<td>2</td>
<td>Monthly cycle (12 scaling factors: months 1-12)</td>
</tr>
<tr>
<td>3</td>
<td>Hour &amp; Season (4 groups of 24 hourly scaling factors,</td>
</tr>
<tr>
<td></td>
<td>where first group is DEC-JAN-FEB)</td>
</tr>
<tr>
<td>4</td>
<td>Speed &amp; Stab. (6 groups of 6 scaling factors, where</td>
</tr>
<tr>
<td></td>
<td>first group is Stability Class A, and the speed</td>
</tr>
<tr>
<td></td>
<td>classes have upper bounds (m/s) defined in Group 12</td>
</tr>
<tr>
<td>5</td>
<td>Temperature (12 scaling factors, where temperature</td>
</tr>
<tr>
<td></td>
<td>classes have upper bounds (C) of:</td>
</tr>
<tr>
<td></td>
<td>0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+</td>
</tr>
</tbody>
</table>
```

---

Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

-----------
INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
-----------

Subgroup (16a)

Number of volume sources with parameters provided in 16b,c (NVL1) No default! NVL1 = 0 !

Units used for volume source emissions below in 16b (IVLU) Default: 1 ! IVLU = 1 !

<table>
<thead>
<tr>
<th>IVLU</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>g/s</td>
</tr>
<tr>
<td>2</td>
<td>kg/hr</td>
</tr>
<tr>
<td>3</td>
<td>lb/hr</td>
</tr>
<tr>
<td>4</td>
<td>tons/yr</td>
</tr>
<tr>
<td>5</td>
<td>Odour Unit * m**3/s (vol. flux of odour compound)</td>
</tr>
<tr>
<td>6</td>
<td>Odour Unit * m**3/min</td>
</tr>
<tr>
<td>7</td>
<td>metric tons/yr</td>
</tr>
</tbody>
</table>

Number of source-species combinations with variable emissions scaling factors provided below in (16c) (NSVL1) Default: 0 ! NSVL1 = 0 !

Number of volume sources with variable location and emission parameters (NVL2) No default! NVL2 = 0 !

(If NVL2 > 0, ALL parameter data for...
Atmospheric Dispersion of Radionuclides

these sources are read from the VOLEMARB.DAT file(s)

!END!

Subgroup (16b)

\[ a \]

**VOLUME SOURCE: CONSTANT DATA**

<table>
<thead>
<tr>
<th>X UTM Coordinate (km)</th>
<th>Y UTM Coordinate (km)</th>
<th>Effect. Height (m)</th>
<th>Base Elevation (m)</th>
<th>Initial Sigma y (m)</th>
<th>Initial Sigma z (m)</th>
<th>Emission Rates</th>
</tr>
</thead>
</table>

\[ b \]

Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

An emission rate must be entered for every pollutant modeled. Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by IVLU (e.g. 1 for g/s).

Subgroup (16c)

\[ a \]

**VOLUME SOURCE: VARIABLE EMISSIONS DATA**

Use this subgroup to describe temporal variations in the emission rates given in 16b. Factors entered multiply the rates in 16b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

**IVARY** determines the type of variation, and is source-specific:

<table>
<thead>
<tr>
<th>IVARY</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Constant</td>
</tr>
<tr>
<td>1</td>
<td>Diurnal cycle (24 scaling factors: hours 1-24)</td>
</tr>
<tr>
<td>2</td>
<td>Monthly cycle (12 scaling factors: months 1-12)</td>
</tr>
<tr>
<td>3</td>
<td>Hour &amp; Season (4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)</td>
</tr>
<tr>
<td>4</td>
<td>Speed &amp; Stab. (6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12</td>
</tr>
<tr>
<td>5</td>
<td>Temperature (12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)</td>
</tr>
</tbody>
</table>

\[ a \]

Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information

Subgroup (17a)

Number of non-gridded receptors (NREC) No default ! NREC = 0 !
### Subgroup (17b) 

#### NON-GRIDDED (DISCRETE) RECEPTOR DATA

<table>
<thead>
<tr>
<th>Receptor No.</th>
<th>X UTM Coordinate (km)</th>
<th>Y UTM Coordinate (km)</th>
<th>Ground Elevation (m)</th>
<th>Height Above Ground (m)</th>
</tr>
</thead>
</table>

\[ a \]

Data for each receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

\[ b \]

Receptor height above ground is optional. If no value is entered, the receptor is placed on the ground.
APPENDIX D: CALMET WIND FIELDS DURING SELECTED HOURS OF SF₆ EXPERIMENT
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Description</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.1</td>
<td>SF₆ – Test 1 – 13:00, April 19, 1999</td>
<td>D-1</td>
</tr>
<tr>
<td>D.2</td>
<td>SF₆ – Test 1 – 14:00, April 19, 1999</td>
<td>D-2</td>
</tr>
<tr>
<td>D.3</td>
<td>SF₆ – Test 1 – 15:00, April 19, 1999</td>
<td>D-3</td>
</tr>
<tr>
<td>D.4</td>
<td>SF₆ – Test 2 – 13:00, April 23, 1999</td>
<td>D-4</td>
</tr>
<tr>
<td>D.5</td>
<td>SF₆ – Test 2 – 14:00, April 23, 1999</td>
<td>D-5</td>
</tr>
<tr>
<td>D.6</td>
<td>SF₆ – Test 2 – 15:00, April 23, 1999</td>
<td>D-6</td>
</tr>
<tr>
<td>D.7</td>
<td>SF₆ – Test 3 – 13:00, April 26, 1999</td>
<td>D-7</td>
</tr>
<tr>
<td>D.8</td>
<td>SF₆ – Test 3 – 14:00, April 26, 1999</td>
<td>D-8</td>
</tr>
<tr>
<td>D.9</td>
<td>SF₆ – Test 3 – 15:00, April 26, 1999</td>
<td>D-9</td>
</tr>
<tr>
<td>D.10</td>
<td>SF₆ – Test 3 – 16:00, April 26, 1999</td>
<td>D-10</td>
</tr>
<tr>
<td>D.11</td>
<td>SF₆ – Test 4 – 13:00, April 27, 1999</td>
<td>D-11</td>
</tr>
<tr>
<td>D.12</td>
<td>SF₆ – Test 4 – 15:00, April 27, 1999</td>
<td>D-12</td>
</tr>
<tr>
<td>D.13</td>
<td>SF₆ – Test 4 – 16:00, April 27, 1999</td>
<td>D-13</td>
</tr>
<tr>
<td>D.14</td>
<td>SF₆ – Test 5 – 12:00, May 02, 1999</td>
<td>D-14</td>
</tr>
<tr>
<td>D.15</td>
<td>SF₆ – Test 5 – 16:00, May 02, 1999</td>
<td>D-15</td>
</tr>
<tr>
<td>D.16</td>
<td>SF₆ – Test 6 – 13:00, May 07, 1999</td>
<td>D-16</td>
</tr>
<tr>
<td>D.17</td>
<td>SF₆ – Test 6 – 17:00, May 07, 1999</td>
<td>D-17</td>
</tr>
<tr>
<td>D.18</td>
<td>SF₆ – Test 7 – 01:00, May 08, 1999</td>
<td>D-18</td>
</tr>
</tbody>
</table>
APPENDIX D: CALMET WIND FIELDS DURING SELECTED HOURS OF SF\textsubscript{6} EXPERIMENT

Figure D.1 SF\textsubscript{6} – Test 1 – 13:00, April 19, 1999
Figure D.2  SF₆ – Test 1 – 14:00, April 19, 1999
Figure D.3  SF₆ – Test 1 – 15:00, April 19, 1999

Reference Vectors
0.22 6.59
Figure D.4  SF$_6$ – Test 2 – 13:00, April 23, 1999

Reference Vectors
6.6 12.68
Figure D.5  SF$_6$ – Test 2 – 14:00, April 23, 1999
Figure D.6  SF₆ – Test 2 – 15:00, April 23, 1999
Figure D.7  SF₆ – Test 3 – 13:00, April 26, 1999
Figure D.8  SF₆ – Test 3 – 14:00, April 26, 1999

Reference Vectors
0.57  9.61
Figure D.9  SF₆ – Test 3 – 15:00, April 26, 1999
Figure D.10  $\text{SF}_6$ – Test 3 – 16:00, April 26, 1999
Figure D.11  SF₆ – Test 4 – 13:00, April 27, 1999
Figure D.12  SF₆ – Test 4 – 15:00, April 27, 1999
Figure D.14  SF₆ - Test 5 - 12:00, May 02, 1999

Reference Vectors
0.83  10 45
Figure D.15  SF₆ – Test 5 – 16:00, May 02, 1999
Figure D.16  SF$_6$ – Test 6 – 13:00, May 07, 1999

Reference Vectors
3.73  11.93
Figure D.17  SF₆ – Test 6 – 17:00, May 07, 1999
Figure D.18  SF₆ – Test 7 – 01:00, May 08, 1999