Multi HEM-3 and RTR Summary Programs User's Guide

Instructions for using the Human Exposure Model Version 1.55
for Multiple Facility Modeling with
Risk & Technology Review Summary Programs

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Note about this Version

This User's Guide dated April 2019 is for an updated Version 1.55 of Multi HEM-3, which was first released in 2017. The primary updates include: a newer AERMOD version (v.18081) than available in 2017; a correction within Multi HEM-3's code for the emission units of buoyant line sources, in accordance with 2018 AERMOD updates by the Environmental Protection Agency; and an option to use an acute high value other than the default maximum modeled acute concentration.

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1. Introduction

The Human Exposure Model (HEM-3) is a streamlined yet rigorous tool you can use to estimate ambient concentrations, human exposures and health risks that may result from air pollution emissions from complex industrial facilities. HEM-3 has been implemented in two versions: a single-facility version (Single HEM-3), and a community and sector version for modeling multiple facilities (Multi HEM-3). This guide addresses Multi HEM-3. You can use Multi HEM-3 to model multiple facilities in a community or region, or across the entire U.S. and its territories, as in the Risk & Technology Review (RTR) assessments of entire source categories and sectors.

In RTR assessments, Multi HEM-3 is used to model emissions and the resulting ambient concentrations from hundreds of facilities, located thousands of miles away from each other, and to predict the potential exposures and inhalation health risks posed by these emissions. Multi HEM-3 can accommodate facilities with overlapping zones of impact. An add-on module to Multi HEM-3 containing the RTR Summary Programs is also available for download and described in this guide. You can use these programs to further summarize the cancer risk and noncancer health effects for your modeled group of facilities as a whole.

The Multi HEM-3 User's Guide is not intended to be a stand-alone reference to Multi HEM-3. This guide assumes you have some knowledge and experience with Single HEM-3 (EPA 2019). Both Single HEM-3 and Multi HEM-3 operate under the same general principles. Essentially, Multi HEM-3 provides a platform for running the single-facility version multiple times for two or more (even hundreds of) facilities. In both versions, source location and emissions data are input through a set of Excel™ spreadsheets. Single HEM-3 includes multiple input screens or graphical user interfaces (GUIs) for the selection of various modeling options. In Multi HEM-3, a control file (spreadsheet) replaces many of these GUI input screens. Therefore, you should have access to and be familiar with the more extensive user's guide for Single HEM-3 entitled *The HEM-3 User's Guide, Instructions for using the Human Exposure Model Version 1.5 (AERMOD version) for Single Facility Modeling,* also prepared by SC&A (formerly EC/R) for the EPA (EPA 2019). The Single HEM-3 User's Guide provides more in-depth descriptions of the inputs, methodology, calculations, outputs, and limitations associated with the model than are provided by this guide. The Single HEM-3 User's Guide and model, the Multi HEM-3 User's Guide and model, and the RTR Summary Programs are available for download from the EPA's Fate, Exposure, and Risk Analysis (FERA) website at http://www.epa.gov/fera/risk-assessment-and-modeling-human-exposure-model-hem.

Multi HEM-3, like Single HEM-3, uses the American Meteorological Society – U.S. EPA Regulatory Model (AERMOD) for dispersion modeling and runs AERMOD as a compiled executable program. It is important, therefore, that you have access to AERMOD's model documentation, available at EPA's Support Center for Regulatory Atmospheric Modeling website at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod. The EPA's modeling guidance indicates that AERMOD represents the state-of-the-science in dispersion modeling and is recommended for most industrial source modeling applications for air toxics (EPA 2005).

AERMOD was developed under the auspices of the American Meteorological Society - EPA Regulatory Model Improvement Committee (AERMIC) as summarized on EPA's AERMOD webpage (see above link). The AERMOD model, documentation and AERMOD's preprocessors AERMET, AERMAP, AERSURFACE and BPIPPRM are all available for download from EPA's AERMOD webpage. AERMOD can handle a wide range of different source types that may be

associated with an industrial source complex, including stack (non-capped and capped vertical and horizontal point) sources, area sources, complex area (polygon) sources, volume sources, line sources and buoyant line sources. AERMOD can also optionally model deposition with or without plume depletion and other complex plume processes such as building downwash. HEM-3 runs AERMOD as many times as is necessary to address the gaseous pollutants and particulate matter emitted from each modeled facility. Although a standard HEM-3 run involves running AERMOD, HEM-3 will also accept user-supplied dispersion modeling results or monitoring data (instead of running AERMOD) for the concentrations of HAP and other toxic air pollutants. Using the concentration results predicted by AERMOD based on facility emissions (or provided via user-supplied concentration data), HEM-3 estimates and outputs the inhalation cancer and noncancer health risks at surrounding receptors.

This Multi HEM-3 User's Guide, in addition to the Single HEM-3 User's Guide, is designed to provide all the information you will need to run Multi HEM-3. However, some of the options for running Multi HEM-3 draw on advanced features of AERMOD. If you are unfamiliar with the AERMOD dispersion model, you may need to refer to the AERMOD User's Guide to develop some of the inputs needed by Multi HEM-3. This is particularly true for some of the more complex modeling options, such as deposition and plume depletion, building downwash, complex source configurations and temporal factors used to vary emissions. This version 1.55 of Multi HEM-3 incorporates AERMOD Version 18081, which is described in the April 2018 AERMOD User's Guide (EPA 2018a).

This manual provides an overview of the inputs and outputs of Multi HEM-3 and the RTR Summary Programs, along with detailed instructions for installing and running the model and add-on module. The following topics are addressed in each Section:

- Section 2 describes the main features of Multi HEM-3.
- Section 3 provides instructions for downloading and installing Multi HEM-3 and the RTR Summary Programs from the EPA's website.
- Section 4 describes the facility and emission inputs required to run Multi HEM-3, as well as optional input files for more sophisticated modeling runs.
- Section 5 provides step-by-step instructions for running Multi HEM-3, including a brief description of the processing performed by Multi HEM-3 during the run.
- Section 6 describes post processing procedures, and the individual facility and multiple facility risk estimate outputs produced by Multi HEM-3.
- Section 7 explains what quality assurance checks should be performed on the Multi HEM-3 outputs prior to running the RTR Summary Programs.
- Section 8 provides instructions for running the RTR Summary Programs.
- Section 9 describes the RTR Summary Programs' outputs.
- Section 10 provides step-by-step instructions for using the Multi HEM-3 and RTR Summary Program outputs to summarize the risk results for the modeled facilities.
- Section 11 discusses source category versus facility-wide modeling runs.

- Section 12 provides a brief discussion on using Multi HEM-3 to model source categories with more than 500 facilities.
- Section 13 discusses potential error messages you may encounter when running Multi HEM-3, and how to respond to these messages.
- Section 14 lists references cited in this guide.

2. Main Features of Multi HEM-3

Multi HEM-3 performs three main operations: dispersion modeling, estimation of population exposure, and estimation of human health risks. To perform these calculations, Multi HEM-3 draws on three data libraries, which are provided with the model. The first is a library of meteorological data used for dispersion calculations collected from over 800 stations in the U.S. and its territories. The second library of census block internal point ("centroid") locations and populations provides the basis for human exposure calculations. The model includes census data from both the 2000 and the 2010 Census, so you can base your Multi HEM-3 modeling run on either census. The census library also includes the elevation of each census block. Note that elevation is included by default in the dispersion calculations, although you have the option of excluding elevation from your run. Finally, a third library of pollutant unit risk estimates (UREs) and reference concentrations (RfCs) is used to calculate population risks and health hazards. These risk factors and RfCs are based on the latest values recommended by the EPA for hazardous air pollutants (HAP) and other toxic air pollutants (EPA 2018b). The Single HEM-3 User's Guide provides more detailed descriptions of the data libraries required by the model (EPA 2019).

Multi HEM-3 estimates cancer risks and noncancer "risks" (hazard indices) due to inhalation exposure at census block locations surrounding the modeled facilities, at circular polar grid coordinates emanating out from the facility centers, and at other user-defined receptor locations that you may specify. These predicted health risk estimates are generally conservative with respect to the modeled emissions because they are not adjusted for attenuating exposure factors (e.g., indoor/outdoor concentration ratios, daily hours spent away from the residential receptor site, years spent living elsewhere than current residential receptor site).

Cancer risks are computed using the EPA's UREs for HAP and other toxic air pollutants. The resulting estimates reflect the risk of developing cancer for an individual breathing the ambient air at a given receptor site 24 hours per day over a 70-year lifetime. Noncancer "risk" is estimated using hazard quotients (HQs) and hazard indices for 14 "target" organs or systems and, like the cancer risk estimates, are not adjusted for attenuating exposure factors. The HQ for a given chemical and receptor site is the ratio of the ambient concentration of the chemical to the RfC at which (and below which) no adverse effects are expected. The chronic hazard index (HI) for a given target organ is the sum of HQs for substances that affect that organ. Target organ-specific hazard indices (TOSHIs) are computed for the following 14 organ systems: the respiratory system; the liver; the neurological system; developmental effects; the reproductive system; the kidneys; the ocular system; the endocrine system; the hematological system; the immunological system; the skeletal system; the spleen; the thyroid; and whole body effects.

Optionally, you can also use Multi HEM-3 to estimate acute (short-term, hourly) concentrations for each chemical and receptor site, including the location of the highest acute concentration for each chemical emitted from the facility. In addition, the model outputs a listing of the associated acute benchmarks for each pollutant (below which certain acute adverse effects are not

expected). From these acute concentrations and benchmarks, you can use the RTR Summary Programs to compute the ratio of the highest acute concentration to the associated benchmark to determine the maximum acute HQ for each pollutant of concern.

Multi HEM-3 identifies receptor locations at which the predicted lifetime cancer risk, chronic noncancer hazard indices and (optionally) acute concentrations are highest. For these locations, the model gives the concentrations of different chemicals from various emission sources driving the overall cancer risks, chronic hazard indices, and acute concentrations. You can also use Multi HEM-3 to estimate the numbers of people exposed to various cancer risk levels and HI levels. In addition, Multi HEM-3 provides estimates of the average cancer risks, average hazard indices, and the predicted annual cancer incidence for people living within different distances of the modeled emission sources. See the single-facility HEM-3 User's Guide (EPA 2019) for an overview of HEM-3's methodology and calculations, and detailed descriptions of the risk and hazard outputs produced by the model.

For every modeled facility, Multi HEM-3 produces the risk and hazard results that Single HEM-3 produces specific to each facility (as noted in Section 6.1). However, Multi HEM-3 also combines and summarizes these results into additional consolidated output files that include a row of results for each modeled facility. See Section 6.2 for a discussion of these multi-facility files. Similarly, the RTR Summary Programs produce additional outputs of combined and summarized results that are useful in capturing the potential risks and hazards, as well as the pollutant and emission source drivers of these risks and hazards, for an entire source category modeled under the EPA's RTR program. See Section 9 for a discussion of these additional RTR Summary Program outputs.

2.1 Differences between Current and Previous Multi HEM-3 Versions with the RTR Summary Programs

HEM was originally developed as a screening tool for exposure assessment in the 1980s. The original model was upgraded to run in a Windows™ environment and several versions of Multi HEM-3 have been released by the EPA prior to this Version 1.55, including in 2007 and in 2014. The 2014 Multi HEM-3 version (with RTR Summary Programs) included many upgrades and enhanced capabilities compared to the 2007 version. Likewise, this Multi HEM-3 version with RTR Summary Programs includes enhancements compared to the 2014 version. These enhancements are listed below and summarized in Table 1.

- We updated Multi HEM-3 by incorporating the latest AERMOD version (18081) for dispersion modeling. The 2014 version used AERMOD version 13350.

- We updated the met data. The meteorological data that Multi HEM-3 draws upon has been updated to the most recent data available, 2016 met data. The 2014 HEM-3 version was based on 2011 met data.

- We made the met library editable by the user. Multi HEM-3's met library is now in an Excel™ spreadsheet form that you can edit to change the existing met station data, to add new met station data and/or to delete existing met station data.

- We incorporated into Multi HEM-3 a more sophisticated modeling of deposition and depletion, in keeping with the array of options provided in AERMOD. Wet and dry deposition may be modeled for both particles and gaseous emissions, and deposition can be modeled with or without plume depletion. In addition, the gas parameter default

values have been updated with more recently-available values and the gas parameter file may now be edited in Excel™ to allow the user to supply or alter pollutant-specific values, in keeping with future availability and updates.

- We added the line and buoyant line source types, as well as capped and horizontal point source types. Multi HEM-3 now allows you to use line, buoyant line, capped point and horizontal point source types in addition to point (non-capped vertical), area, volume, and polygon source types. Line source types can be useful in modeling airport runway emissions, for example, while buoyant line source types can represent roof vents. Capped and horizontal point source types allow more options for modeling stack sources.

- We allow users to name their user receptors (with up to 10 characters) and Multi HEM-3 now identifies user receptors by their name in the output files and maps. User receptors were identified nondescriptly in the 2014 Multi HEM-3.

- We enhanced Multi HEM-3's KML output to display target organ-specific hazard indices (TOSHIs) in the polar receptors and user receptors, in addition to the Census block receptors. The 2014 Multi HEM-3 KML output displayed TOSHIs only for the Census block receptors.

- We allow more precise acute multipliers of your emissions; acute multiplier values with two-decimal precision may now be entered. The 2014 Multi HEM-3 required integer values.

- We allow the user to instruct Multi HEM-3/AERMOD which acute concentration value to report at each receptor (e.g., the 98th percentile), instead of only using the maximum modeled acute concentration. (Note: This feature is available only in Multi HEM-3; Single HEM-3 always uses the maximum acute concentration as the highest reported.)

- We provide an additional (7th) temporal profile for varying source-specific emission rates. This additional profile (MHRDOW) allows 864 different factors to be entered to vary emission rates by month, hour, and day type (weekday, Saturday, Sunday).

- We allow users to output HEM-3 files in comma separated values (.CSV) format, in addition to database format (.DBF). The 2014 HEM-3 did not include the .CSV format option.

- We allow input files to have two (bold-faced) header rows instead of one. The two header rows enable grouping and better explanation of fields (e.g., in the Facility List Options and Emissions Location input files).

- We added the Census block ID to the Multi HEM-3 output facility_max_risk_and_hi.xlsx for the maximum cancer risk receptor as well as for all 14 TOSHI receptors.

- We added a "Reset" button to the first user input screen of Multi HEM-3. This allows an interrupted run to be cleared and modeling to begin again at the first facility.

- We added a column to the Multi HEM-3 output facility_max_risk_and_hi.xlsx, to indicate whether the facility was run as a rural or an urban dispersion environment.

- We allow the user to label the group of facilities to be modeled by Multi HEM-3 so that the Multi HEM-3 output files are automatically labeled with this acronym or prefix for ease of reference.

- We revised Multi HEM-3 so that all Excel™ model outputs are now .xlsx version files. The 2014 HEM-3 output files in .xls version.

- We added the receptor ID – whether Census block, user receptor, or polar receptor's angle and distance – to the RTR Summary Program output acute_impact_flags_all.xlsx, to indicate where the highest acute concentration occurs for each pollutant.

- We enhanced the RTR Summary Program that produces the category_max_risk_and_hi.xlsx output so that the output now lists, in addition to MIR information, the max TOSHI values and locations for all 14 target organs, as well as provides the facilities that impact those maximum noncancer receptors. The previous version of the RTR Summary Program provided this information for the MIR and max cancer receptor only.

- We added a new RTR Summary Program "Multipathway Tier 2" that provides the populated receptor names (i.e., block ID or user receptor name) and locations for overall maximum risk (from all modeled HAP) as well as for the 3 receptor locations of maximum risk specific to Arsenic (grouped), PAHs (grouped) and Dioxins/Furans (grouped). This summary program also provides the names and locations for the populated receptor closest to the facility in eight directions (octants) surrounding each facility. Finally, the program also provides the 4 total inhalation risk values (based on all modeled HAPs, Arsenic, PAHs and Dioxins/Furans) at each of these MIR and octant receptor locations.

- We revised the RTR Summary Programs to allow any version of Excel™ spreadsheets, including .xlsx, as input files. The previous version of the RTR Summary Programs allowed only .xls input files. In addition, the RTR Summary Programs now output files in either .xls or .xlsx, depending on the version of Excel installed on your computer.

Table 1. Summary of Key Improvements for 2019 Multi HEM-3 versus 2014 Multi HEM-3

Model Feature	2019 HEM-3 (Version 1.55)	2014 HEM-3
Dispersion Modeling	AERMOD (v.18081)	AERMOD (v.13350)
Met Data	Based on 2016 met data	Based on 2011 met data
Met Library	Met library is in an Excel™ format, editable by user	Met library was not editable by user
Deposition & Depletion	Both particle and gaseous deposition modeled; deposition and depletion de-coupled so deposition can be modeled with or without plume depletion; gas parameter file defaults updated and file now editable in Excel™	Deposition and depletion coupled so that plume is automatically depleted if deposition modeled; gas parameter file not editable in Excel™

Model Feature	2019 HEM-3 (Version 1.55)	2014 HEM-3
Source Types	Point (vertical non-capped, capped and horizontal), area, volume, polygon, line and buoyant line	Point (vertical non-capped only), area, volume and polygon
User Receptor Identification	User may name discrete user receptors; name identifies user receptor in outputs	User receptors identified as non-descript “User-p”
Display of TOSHIs	Census block, polar and user-receptor TOSHIs are displayed in KML™ map	TOSHIs only displayed for Census blocks in KML™ map
Acute Multiplier	Values with two-decimal precision allowed	Only integer values allowed
Acute High Value	User can specify what high value to use for acute	Used only the maximum as the highest reported acute
Temporal Profiles	7 profiles for varying source-specific emission rates based on temporal scales	6 profiles for varying source-specific emission rates based on temporal scales
CSV Option for Multi HEM-3 Output Files	Output files in .CSV format is optional (in addition to .DBF)	Output files in .DBF format; .CSV format not included
Additional Header Row	Input files allow two (bolded) header rows, enabling better explanation of fields	Input files allowed only one header row
Census Block ID	The facility_max_risk_and_hi output file contains the census block ID for the max cancer receptor and all 14 max TOSHI receptors	The facility_max_risk_and_hi output file did not contain the census block ID for each receptor listed
Reset Run Option	Runs can be reset to clear data and begin at the first facility. Runs can also re-commence with facility being modeled during interruption.	No reset button was provided; an interrupted run would re-commence modeling at facility being modeled during interruption
Rural or Urban Run	The facility_max_risk_and_hi output file lists the dispersion environment used to model each facility, whether rural (R) or urban (U)	The facility_max_risk_and_hi output file did not display whether the facility was run in a rural or urban dispersion environment, requiring referral to AERMOD.out
Labeling of Multi HEM-3 Outputs	User can indicate a 30 character label to be applied automatically to Multi HEM-3 outputs for ease of reference	No automatic labeling option of Multi HEM-3 outputs was provided; user had to manually re-name outputs

Model Feature	2019 HEM-3 (Version 1.55)	2014 HEM-3
Multi HEM-3 Excel™ Outputs	All Excel™ HEM-3 outputs are .xlsx version files	All Excel™ HEM-3 outputs were .xls version files
Receptor ID in Acute Output	The RTR Summary Program output acute_impact_flags identifies the census block, user receptor or polar receptor for each data row	The RTR Summary Program output acute_impact_flags did not identify the receptor where the max acute concentration occurs
Enhanced RTR Summary Program Output	The category_max_risk_and_HI.xlsx output provides MIR and TOSHI information based on all facilities impacting the max cancer and noncancer receptors	The category_max_risk_and_HI.xlsx output provided (only) MIR information based on all facilities impacting the max cancer receptor
New RTR Summary Program for Multipathway Analysis	A new RTR Summary Program "Multipathway Tier 2" provides the populated receptor IDs, locations and values of maximum risk for Arsenic, PAHs and Dioxins/Furans. The program also provides the IDs, locations and risk values of the receptors closest to each facility in eight directions.	This RTR Summary Program had not yet been developed when the 2014 HEM-3 was released
Excel™ Version Flexibility	The RTR Summary Programs accept any version of Excel™ spreadsheets, including .xls and .xlsx and output files in either .xls or .xlsx, depending on the version of Excel installed	The RTR Summary Programs accepted only .xls Excel™ inputs and outputs were also in .xls

3. Installing Multi HEM-3 and the RTR Summary Programs

Download the Multi HEM-3 model and the RTR Summary Programs from EPA's HEM Download webpage at http://www.epa.gov/fera/download-human-exposure-model-hem. This site includes general installation instructions and links to install Single HEM-3, Multi HEM-3 and the RTR Summary Programs.

Installation of Multi HEM-3 consists of several steps including downloading the Multi HEM-3 model, downloading the RTR Summary Programs module, and downloading the data libraries required by Multi HEM-3. These data libraries include a chemical health effects library with toxicity value files (dose response and target organ endpoint spreadsheets); a census population and elevation library (for the 2010 and the 2000 Census); and a meteorological

library (characterizing weather patterns around the nation). The contents of each of the three data libraries are described in Section 2 of the Single HEM-3 User's Guide (EPA 2019).

Follow the steps below to download the Multi HEM-3 model, data libraries, and the RTR Summary Programs:

1. From the HEM Download Page, click the "Multi HEM-3" executable under *Software available for download*, and select "run" to begin the installation program for Multi HEM-3 (**Note**: It may be necessary to run the installer with administrator privileges – right click the icon and select "run as administrator"). The default location to install Multi HEM-3 is "C:\Multi_HEM3\." You can change this location by clicking the "Change..." button and indicating an alternate location. (Note: this alternate folder location should not include a period "." in its name. If you wish to use a period, use an underscore "_" instead.) The basic files needed to run Multi HEM-3 will be placed in the selected folder. A number of subfolders for the data libraries will also be created, including a *Reference* folder for the chemical health effects library, *Census_2000* and *Census_2010* folders for the census libraries, and a *MetData* folder for the meteorological library. The "Installing Multi HEM3" screen is displayed while the files are being copied to the destination folder. When the installation is complete, the "InstallShield Wizard Completed" window appears. The *MetData* folder and *Census_2000* and *Census_2010* folders created as part of the installation will automatically be populated with the meteorological station data and census block files needed to run the template input files—which are provided to illustrate sample input files for a Multi HEM-3 run and which you can edit to create Multi HEM-3-ready inputs (as described further in Section 4).

2. Upon installation, Multi HEM-3's Reference folder includes a Dose Response Library and Target Organ Endpoints table, which were current as of May 2017. To check for updated versions, click the "Toxicity Value Files" link under *Input Files for HEM-3* on the HEM Download Page) to download (1) the *Dose_Response_Library.xlsx* reference file containing the cancer UREs, the noncancer RfCs, and the acute benchmarks for various HAP; and (2) the *Target_Organ_Endpoints.xlsx* reference file, which contains a listing of the noncancer target organ endpoints impacted by various HAP. Note: After copying these files to the Reference folder and unzipping them, check that these files are up-to-date for your modeling purposes. You should also consult EPA's Dose Response Assessment webpage (EPA 2018b) to determine if more recent versions are available.

3. Upon installation, Multi HEM-3's Census folders include the census files necessary to run the template/sample files only. To obtain the full census files, click the "Nationwide 2010 Census files" link and/or the "Nationwide 2000 Census files" link under the *Census Files* subheading of *Input Files for HEM-3* (on the HEM Download Page) to download all state census files. Copy these files into the *Census_2010* and *Census_2000* folders, as appropriate, and unzip. [Note: Do not mix-and-match Census 2010 files with Census 2000 files. If you need only Census 2010 or only Census 2000 data for modeling purposes (not both), then download only the census year needed and place all census files from that year in the correct census folder.] When modeling a facility in one state, Multi HEM-3 may require census files from a neighboring state, depending on the location of the facilities and the radial distance modeled surrounding each facility. This possibility is increased when modeling multiple facilities across the U.S. Therefore, you should copy all state census files into the appropriate Census folder, not only the files for those states in which the modeled facilities are located, including the Census_key.dbf file. **It is important to use the Census_key.dbf file associated with the state file(s)**

you are using to model; using state census files not associated with the Census_key file will cause erroneous modeling results.

4. Upon installation, Multi HEM-3's MetData folder includes the meteorological files necessary to run the template/sample files only. To obtain the full set of nationwide meteorological files, click the "Nationwide meteorological files" links, under the *Meteorological Files* subheading of *Input Files for HEM-3* (on the HEM Download Page) to download all meteorological station files. Copy these files into the *MetData* folder and unzip. Similar to the census files, you should download all meteorological station files, not just a subset of the meteorological data files.

   Note that when you download the Multi HEM-3 model, the installation package will place an Excel™ spreadsheet named "metlib_AERMOD.xlsx" in your C:\Multi_HEM3\Reference folder. This spreadsheet lists all the SFC and PFL met stations that are provided in the nationwide meteorological data files (those available on the HEM Download Page on the date you download the model). You can edit this spreadsheet to include additional met station files of your own choosing, but you must provide the new met station data as both SFC and PFL files in your C:\Multi_HEM3\MetData folder. Be careful that the SFC and PFL file names match the new rows you have added to the metlib_AERMOD.xlsx spreadsheet in your Reference folder. You can also edit the information provided in the rows of this spreadsheet, or delete met station entries/rows entirely.

5. Finally, click the "RTR Summary Programs" executable under *Software available for download* (on the HEM Download page). Select "run" to begin the installation program for the RTR Summary Programs. You can use these programs to extract specific risk estimate results from the Multi HEM-3 outputs. You can copy the RTR Summary Programs into the same directory containing Multi HEM-3, but in a different folder (e.g., named "RTR Summaries").

4. Multi HEM-3 Inputs

Multi HEM-3 is designed to be launched from the Windows™ desktop via user-friendly input screens. These graphical user interface (GUI) input screens primarily allow you to point Multi HEM-3 to the required and optional inputs files and to specify certain modeling options for the run. The model accepts input files created in any version of Excel™. You will use Excel™ input files to specify the desired modeling options and the emissions and source configurations of the facilities to be modeled.

The following is a list of general rules you should follow for all input files:

- Use a separate Excel™ workbook for each input file and use only one input file worksheet (spreadsheet) per workbook. Ensure your Microsoft Office™ Trust Center settings allow Excel™ version 5 and higher to be fully opened and operational (i.e., not in protected view only).

- Match columns with the format specified for the input file. You can use the template input files (provided in your Inputs_Multi folder) and substitute actual data for template data. Delete any extra lines of template data.

- Do not insert columns between data columns. Multi HEM-3 will read these and any extra hidden columns as data.

- Use one or two (not more than two) header rows at the top of each spreadsheet file for all required and optional input files. **Make the header rows bold-faced**, so that Multi HEM-3 recognizes them as header rows and not data.

- Do not include text in numerical data fields (for instance "<0.001"). Multi HEM-3 may read these fields as 0s (zeroes) or may accept only a portion of the number.

- Enter latitudes and longitudes in decimal degrees. Multi HEM-3 will also accept Universal Transverse Mercator (UTM) coordinates. You must enter coordinates in 1983 North American Datum (NAD83) geographic projection system format. Do not use 1927 North American Datum (NAD27) formatted data. If inputs locations are based on the NAD27, convert to NAD83 before use.

- **Match the units used for parameters**, such as emission rates and stack parameters, **with the units given in the file's format guidelines** provided in the following sections (for example: meters/second, meters, tons/year, etc.). Proper units are also included in the header rows of the template input files.

4.1 Required Input Files

A minimum of three input files are required to run Multi HEM-3: the Facility List Options file; the HAP Emissions file; and the Emissions Location file. These three files contain a listing of the facilities and modeling options for the current run, a listing of the HAP emitted from each facility, and the location and configuration of emission sources at each facility to be modeled. **To aid you in creating these files, templates for each are provided in your Inputs_Multi folder of the installed Multi HEM-3** (and are noted in the following subsections in parentheses). In addition to these three required input files, optional input files may also be used when running Multi HEM-3, depending on the modeling options you choose. See Section 4.2 for a description of these optional input files.

4.1.1 Facility List Options File

The Facility List Options Excel™ file is the primary driver specifying the parameters and options of the model run and is unique to the Multi HEM-3 version. Instead of specifying parameters and selecting options from input screens as in the Single HEM-3 version, you indicate most options in this file (e.g., parameters such as the modeling radius and overlap distance, as well as options such as modeling of acute concentrations, building downwash, deposition). The Facility List Options file contains one row for every facility that will be run with the various modeling options listed as columns for each facility row. **If you use all default modeling options, the only field requiring input is the facility ID**, which can be up to 30 characters long. All other fields have defaults which are employed when the field in the Facility List Options file is left blank. Note: the model also employs the respective default value when the user enters a 0 for any of the numerical fields in the Facility List Options input file (i.e., Max distance, Modeling distance, Radials, Circles, Overlap distance, Hours and Acute Multiplier).

Table 2 shows the fields included in the Facility List Options file. As noted above, these fields are columns in the actual *Facility_List_Options.xlsx* input file that you must provide to Multi HEM-3, and each row is for a different facility as identified by the Facility ID. The rows in Table 2 are shown in the same column order required by HEM-3 in the input file. You should consult the

Single HEM-3 User's Guide (EPA 2019) for more detail on each of these parameters and options. (For a template, see *Template_Multi_Facility_List_Options.xlsx* in your Inputs_Multi folder.)

Note: **Take care when filling out the Facility List Options File, as this file drives and controls the modeling run. To avoid error, this file must be consistent with your other input files.** For example, if you indicate a mixture of particles and gases/vapor in the Percent Particulate column of your HAP Emissions input file and you wish to model deposition, then the Phase of your emissions entered in the Facility List Options file must be "B" for both (regardless of whether you choose to model deposition/depletion for particles only or for vapor only). Furthermore, **any mismatch between this file and options selected on user interface screens (GUIs) will cause an error in the modeling run**. For example, the modeling options you indicate in this file should be consistent with how you complete the model's Screen 2 (and Screen 2a), for options including user receptors, building downwash and deposition/depletion.

Table 2. Fields in the Facility List Options Input File (Required)

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Facility ID		You must enter an alphanumeric string (up to 30 characters long) identifying the facility being modeled. This field is mandatory; all other fields have default values when blank.
Met Station	Met station selected by model as closest to the facility	The name of the meteorological surface station (e.g., NAME02.SFC, up to 20 characters long) to be used by AERMOD when modeling each facility. The met station closest to facility is chosen, unless you specify a name.
Rural/Urban	D for default	Used to set the type of dispersion environment for AERMOD. "R" indicates rural land use surrounding the facility; "U" indicates urban land use; and "D" indicates the default setting under which the model will find the nearest Census block to the facility center and determine whether that Census block is located in an urbanized area as designated by the 2010 Census. [Note: The default setting when using the 2000 Census is always rural.]
Max distance	50,000 meters	The outside max radius of the modeling domain in meters (must be ≥ the modeling distance and ≤ 50,000 meters).
Modeling distance	3,000 meters [Note: no entry or an entry of 0 will default to 3,000 meters]	The cutoff distance (in meters) for individual modeling of ambient impacts at census blocks; beyond this distance ambient impacts are interpolated rather than explicitly modeled. [Note: For polygon source types, set the modeling distance > the largest distance across the polygon.]
Radials	16	The number of radials in the polar receptor network emanating from the facility center (must be ≥ 4).
Circles	13	The number of concentric circles in the polar receptor network, centered on the facility center (must be ≥ 3).
Overlap distance	30 meters [Note: no entry or an entry of 0 will default to 30 meters]	The distance (in meters) measured from each emission source at a facility at and below which a source and receptor are considered to be overlapping. Must be an integer value ≥ 1 meter and ≤ 500 meters.

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Acute	N	Selecting “Y” directs the model to include short-term (acute) concentration calculations and hazard predictions. If left blank, acute impacts are not estimated in the model run.
Hours	1-hour	The short-term (acute) averaging period that AERMOD will use for ambient concentrations. The averaging period options are: 1, 2, 3, 4, 6, 8, 12 and 24-hr. The default is 1-hr.
Elevations	Y	Elevations of receptors are accounted for by default; entering an “N” excludes elevations from the model run.
Acute Multiplier	10	The acute multiplier applied to the average annual emission rate and used to approximate the short-term emission rate (e.g., 10 times the rate entered in the HAP Emissions file). Note: Multi HEM-3 also assumes that this short-term rate can occur at the same time as the worst case meteorological conditions. Two-decimal precision is accommodated; minimum value is 1.00
First ring distance (ring1)	Calculated by model to be just outside the source locations, but not less than 100 m from facility center	The distance to the first ring (circle) of the polar network as measured from the facility center. You can override the default distance calculated by Multi HEM-3 to fit the size and shape of the facility properties to be modeled.
Deposition (dep)	N	Deposition is not modeled by default; entering “Y” directs the model to calculate deposition in the model run (particle, vapor, or both as designated below) and provide the deposition flux in the output files. Note: you may model deposition with or without plume depletion (below).
Depletion (depl)	N	Depletion is not modeled by default; entering “Y” directs the model to deplete the plume by the calculated deposition flux. Note: You may enter “Y” here even if you chose “N” for deposition; in that case the model will internally calculate deposition flux to deplete the plume, but will not provide the deposition flux values in the output files. (This option saves space, if you do not need the deposition flux.)
Phase	B [Note: this field should accurately reflect your emissions, regardless of what kind of deposition/depletion is desired.]	This field is required when calculating deposition/depletion, but it merely describes your emissions, not what type of deposition/depletion will be modeled. The default value “B” indicates that emissions are both particle and vapor. Enter “P” for deposition/depletion modeling only if emissions are 100% particle. Enter “V” for deposition/depletion modeling only if emissions are 100% vapor. Note that the phase entered here must be consistent with the percent particulate in your HAP Emissions file.
Particle Deposition (pdep)	NO	The value “WD” directs the model to incorporate both wet and dry deposition for particles. Use “WO” for wet only; use “DO” for dry only; use “NO” (or leave blank) if not modeling deposition of particles.

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Particle Depletion (pdepl)	NO	The value “WD” directs the model to incorporate both wet and dry deposition for particles (when depleting the plume). Use “WO” for wet only; use “DO” for dry only; use “NO” (or leave blank) if not considering deposition of particles (when depleting the plume).
Gaseous Deposition (vdep)	NO	The value “‘WD” directs the model to incorporate both wet and dry deposition for gaseous (vapor) pollutants; use “WO” for wet only; use “DO” for dry only; use “NO” (or leave blank) if not modeling deposition of gaseous pollutants.
Gaseous Depletion (vdepl)	NO	The value “WD” directs the model to incorporate both wet and dry deposition for gaseous pollutants (when depleting the plume). Use “WO” for wet only; use “DO” for dry only; use “NO” (or leave blank) if not considering deposition of gaseous pollutants (when depleting the plume).
All Receptors	Y	The default “Y” directs the model to calculate results for all receptors by pollutant and source. Enter “N” to direct the model to output pollutant and source contributions for the max populated and max off-site receptors only (to conserve space, if results are not needed for every receptor).
User receptors	N	Select “Y” to include user receptors in a separate input file. User receptors are not included by default. Note: if you are modeling using user receptors, user receptor information must be provided in a separate input file.
Building Downwash (bldg_dw)	N	Select “Y” to include building downwash calculations in the model run. Building downwash is not included by default. Note: if you are modeling building downwash, building dimension information must be provided in a separate input file.
Urban Population	None; only needed if “U” specified in Rural/Urban field	If you indicate “U” for urban land use (in Rural/Urban field above), then you must provide model with the urban population size, otherwise leave blank. Note: If you specify “U” in the Rural/Urban field but provide no urban population value in this field, the model will re-set your “U” to default.
FASTALL	N	Entering “Y” directs the model to use AERMOD’s control option FASTALL, which conserves model run time by simplifying AERMOD’s dispersion algorithms. FASTALL is not used by default.

4.1.2 HAP Emissions File

The HAP Emissions Excel™ file includes **emissions in tons per year for each HAP emitted from modeled sources, for all facilities listed in the Facility List Options file**. The file is the same as the one used in the single HEM-3 version, with the addition of the facility ID in the first column. Figure 1 shows the Format Guidelines for the HAP Emissions file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide for more detail (EPA 2019).[1] (For a template, see *Template_Multi_HAP_emissions.xlsx* in your Inputs_Multi folder.)

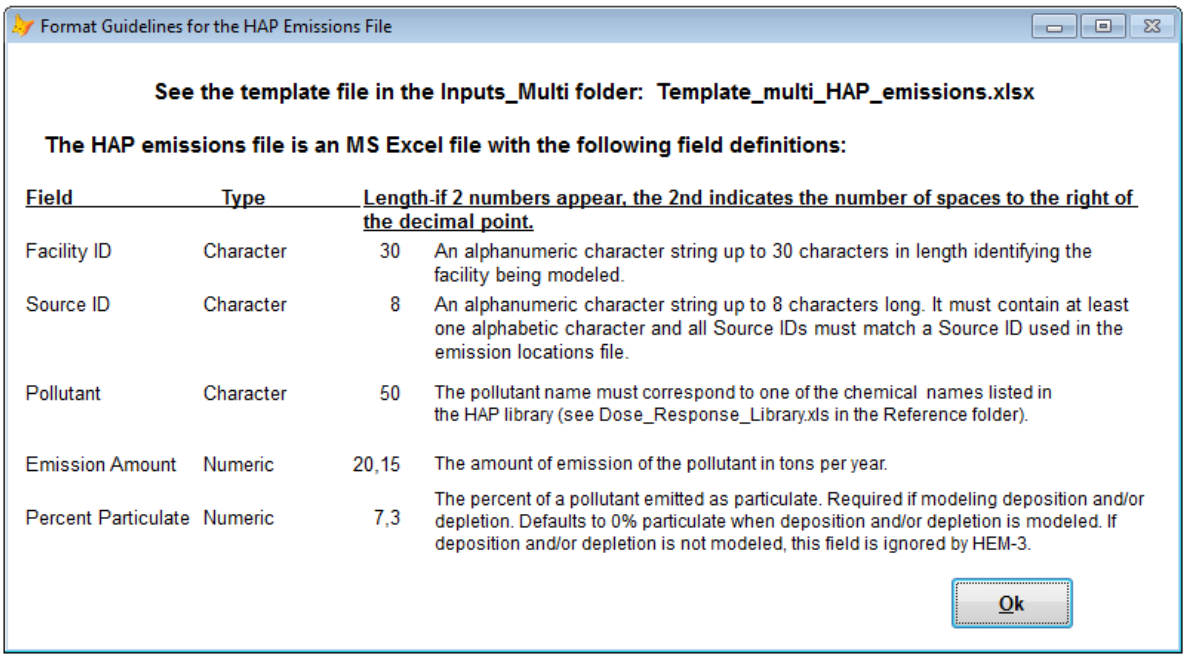


Figure 1. Format Guidelines for the HAP Emissions File (Required)

Note: **the HAP Emissions File must be consistent with your other input files**. For example, all the Facility IDs listed in the Facility List Options file must be present in this file. Those Facility IDs plus the Source IDs must also match what's in the Emissions Location File (discussed next). Furthermore, if modeling deposition/depletion, the Percent Particulate column in your HAP Emissions File must be consistent with the Phase column of your Facility List Options file, as well as the Particle Size File (discussed under Optional Input Files in Section 4.2).

4.1.3 Emissions Location File

The Emissions Location Excel™ file includes **emission source locations and types** (e.g., the latitude and longitude of a stack) **for all Source IDs listed in the HAP Emissions File, for all facilities listed in the Facility List Options File**. The file is the same one used in the Single HEM-3 version, with the addition of the Facility ID in the first column. Figure 2 shows the format guidelines for the Emissions Location file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. Note that Multi HEM-3 will calculate source

[1] When preparing the HAP Emissions and Emissions Location input files of Multi HEM-3, incorporate a two-letter source type code somewhere in the source ID (e.g., EL for equipment leaks, ST for storage tanks). This two-letter source type identifier is needed if the Source Type Histogram RTR Summary Program will be run after Multi HEM-3, as described in Section 8.

elevations based on surrounding census block elevations, if you leave the elevation field blank for all sources. If you provide an elevation for one source, you should provide an elevation for all sources (because if there are a mix of blanks and numbers, Multi HEM-3 will interpret blanks as 0 elevation). See the Single HEM-3 User's Guide for more detail (EPA 2019).[1] (For a template, see *Template_Multi_emissions_ location.xlsx* in your Inputs_Multi folder.)

Additional input files may be required, depending on the types of sources you indicate in the Emissions Location File. For example, if you include a polygon source (or sources) in the Emissions Location file, the Multi HEM-3 model will also require you to provide a polygon vertex file. Likewise, if you include a buoyant line source (or sources) in the Emissions Location file, Multi HEM-3 will also require you to provide a buoyant line parameter file. These additional input files are described in Section 4.2.

Format Guidelines for the Emission Locations File

See the template files in the Inputs_Multi folder: Template_Multi_emissions_location.xlsx

The emissions locations file is an MS Excel file with the following field definitions:

Field	Type	Length-if 2 numbers appear, the 2nd is the number of spaces to the right of the decimal point.	
Facility ID	Character	30	An alphanumeric string up to 30 characters in length identifying the facility being modeled.
Source ID	Character	8	Source ID is a unique alphanumeric character string up to 8 characters long. It must contain at least one letter. No spaces or typographical symbols are allowed.
Coordinate System	Character	1	UTM zone where the source is located if coordinate system = U (blank if coordinate system = L).
x-coordinate	Numeric	15,6	UTM east coordinate, in meters (if Coordinate System=U) or decimal longitude (if System=L) of center of point or volume sources, or first vertex of polygon sources, or first point of line and buoyant line sources**. If longitude, 5 decimal places (corresponds to 1 meter accuracy) is recommended.
y-coordinate	Numeric	15,6	UTM north coordinate, in meters (if Coordinate System=U) or decimal latitude (if System = L) of center of point or volume sources, or first vertex of polygon sources, or first point of line and buoyant line. sources**. If latitude, 5 decimal places (corresponds to 1 meter accuracy) is recommended.
UTM Zone	Numeric	2,0	UTM zone where the source is located (if Coordinate System = U).
Source Type	Character	1	Type of Source*: P = vertical point, C = capped point, H = horizontal point, A = area, V = volume, I = polygon, N = line, B = buoyant line
x-dimension	Numeric	7,0	The x-dimension length, in meters for area sources, and the width for line sources.
y-dimension	Numeric	7,0	The y-dimension length, in meters for area sources.
Angle	Numeric	5,2	Angle of rotation, for area sources. Between 0 and 90 for area sources. Defauts to zero if left blank.
Lateral	Numeric	9,2	Initial lateral/horizontal dimension (in meters), for volume sources.
Vertical	Numeric	9,2	Initial vertical dimension (in meters), for volume sources. Optional for area, polygon & line sources.
Release Height	Numeric	7,2	Height of release (in meters) for area, volume, polygon, line and bouyant line sources.
Stack Height	Numeric	7,3	Release height above ground (in meters) for all point source types.
Diameter	Numeric	7,3	Diameter of stack (in meters) for all point source types.
Velocity	Numeric	12,7	Velocity at which emissions are released from the stack (in meters/second) for all point source types.
Temperature	Numeric	7,2	Temperature of the emissions (in Kelvin) for all point source types.
Elevation	Numeric	6,0	Elevation above sea level in meters at the source location. Use when modeling terrain effects and user-specified elevations are desired. Optional, HEM-3 will calculate if left blank for all sources.
x-coordinate2	Numeric	15,6	Second X coordinate for line and buoyant line sources. UTM east coordinate, in meters (if Coordinate System=U) or decimal longitude (if System=L) of ending point of line and buoyant line sources. If longitude, 5 decimal places (corresponds to 1 meter accuracy) is recommended.
y-coordinate2	Numeric	15,6	Second Y coordinate for line and buoyant line sources. UTM north coordinate, in meters. (if Coordinate System=U) or decimal latitude (if System=L) of the ending point of line and buoyant line sources. sources**. If latitude, 5 decimal places (corresponds to 1 meter accuracy) is recommended.

*Source types for which the parameter is needed: A=area, P=vertical point, C=capped point, H=horizontal point, V=volume, N=Line, I (Capital "i")=polygon, B=buoyant line. For additional information on these variables, please see the AERMOD User's Guide.

**Start/end coordinates for buoyant line sources must be entered in order from West to East, and from South to North. Incorrect ordering of these parameters will result in an AERMOD error stating "Input buoyant line sources not in correct order".

Ok

Figure 2. Format Guidelines for the Emissions Location File (Required)

Note: If this is your first time running Multi HEM-3, **it is highly recommended that you first run the model with the Facility List Options, HAP Emissions, and Emissions Location template input files provided**, as practice, and to confirm that Multi HEM-3 installed properly on your computer. These template input files are provided in your Inputs_Multi folder.

4.2 Optional Input Files

In addition to the Facility List Options, HAP Emissions, and Emissions Location required input files, you may need to use the input files described in this section for certain source types (**polygons** and **buoyant lines**) or to include more advanced modeling options in your run (**user receptors, deposition/depletion, building downwash or temporal variations**). Following this section, Section 5 *Running Multi HEM-3* provides instructions for supplying the required and optional input files to Multi HEM-3 during your modeling run.

- **User Receptors File**

  (See *Template_Multi_user_receptors.xlsx* in the Inputs_Multi folder) – This file is required if you want to include user-defined receptors in addition to census block and polar grid receptors for one or more facilities. The file includes the location (latitude / longitude or UTM) of the user-defined receptor, its elevation and the type of receptor (populated such as a house or school, facility boundary, monitor). It is the same file used in Single HEM-3, with the addition of the facility ID in the first column. For Multi HEM-3, **no two facilities may have the same Receptor ID (name); Receptor IDs must be unique**. Figure 3 shows the format guidelines for the user receptors file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. Note: If you are modeling terrain effects (i.e., you left a blank or a "Y" in the elevation column of the Facility List Options file) and you choose not to provide a value for elevation in the user-defined receptors file, Multi HEM-3 will calculate the elevation of the user receptor(s) based on the surrounding elevations provided in the census database. In general, you should either provide an elevation for all sources and receptors or leave the elevation field blank for all sources and receptors, as noted for the Emissions Location file. See the Single HEM-3 User's Guide for more detail (EPA 2019).

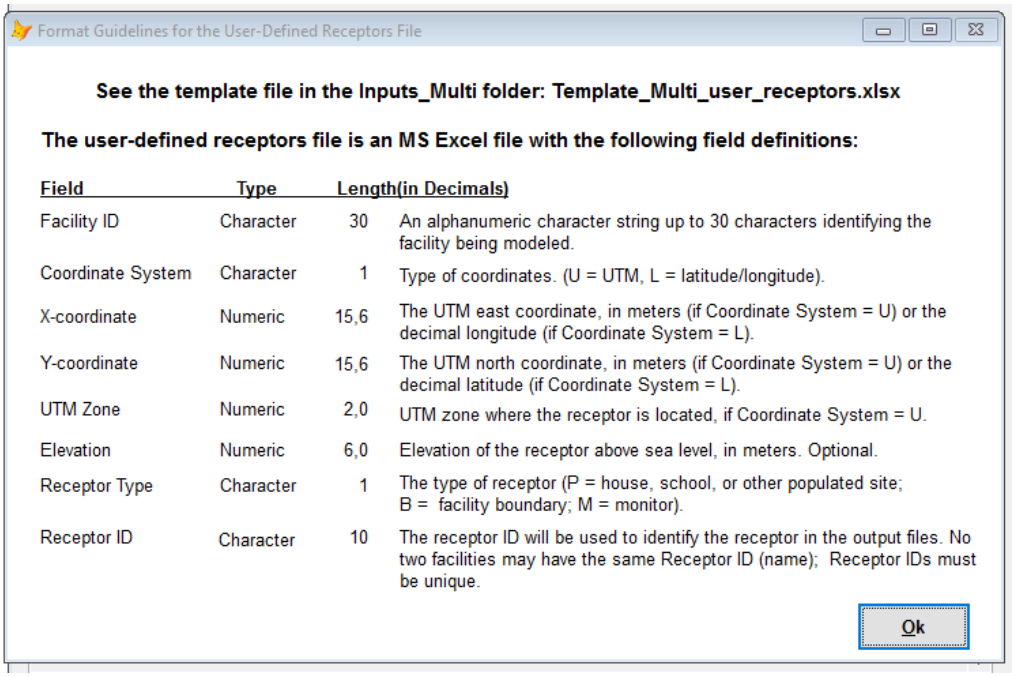


Figure 3. Format Guidelines for the User Receptors File (Optional)

- **Polygon Vertex File**

  (See *Template_Multi_polygon_vertex.xlsx* in the Inputs_Multi folder) – This file is required if one or more of the sources in your Emissions Location file has a polygon configuration (rather than a point, area, volume, line or buoyant line configuration). Polygons are useful for complex source configurations at a facility and when modeling census tracts as sources (e.g., for mobile source emission estimates based on tract data). The file contains information regarding the locations of the polygon vertices and includes a separate record for each vertex of the polygon. The polygon vertex file is the same one used in Single HEM-3, with the addition of the facility ID in the first column. Figure 4 shows the format guidelines for the polygon vertex file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) for more detail.

  Note that when modeling large sources configured as polygons (e.g., census tracts), the modeling distance you enter in the *Facility_List_Options.xlsx* file should be greater than the largest distance across the polygon, to ensure discrete modeling of all census blocks within the polygon.[2]

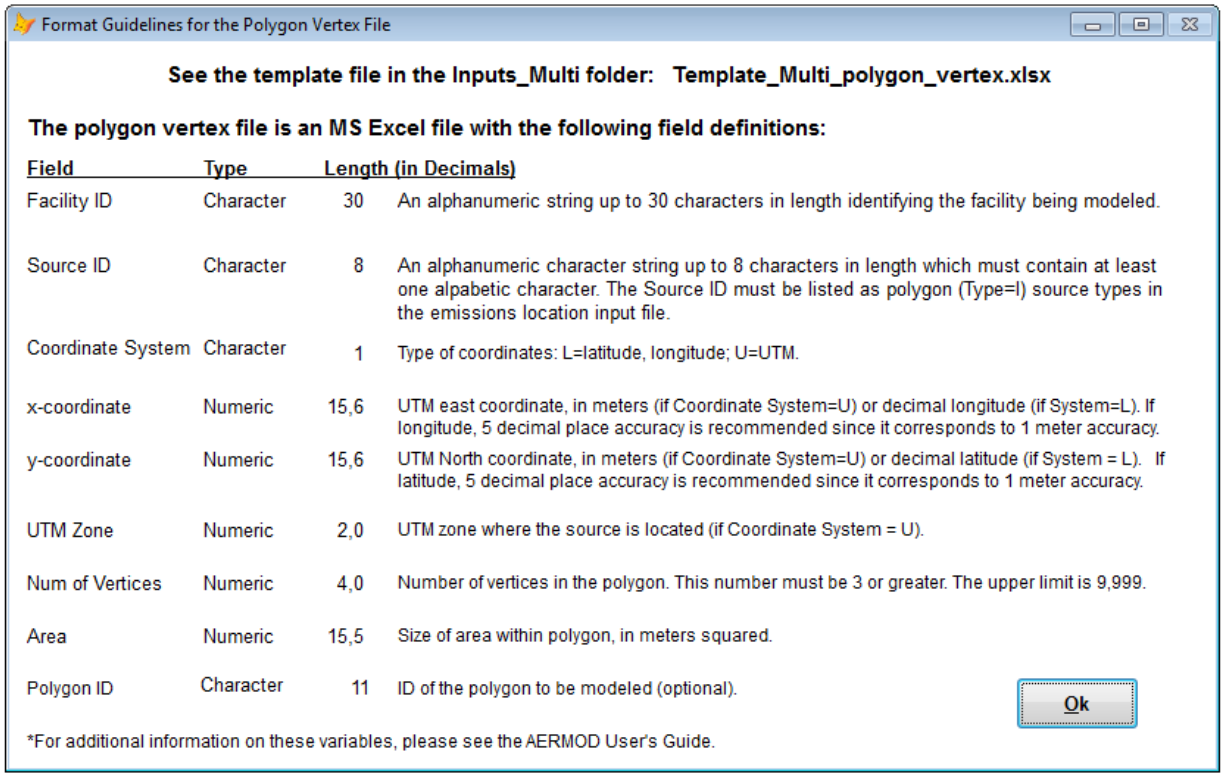


Figure 4. Format Guidelines for the Polygon Vertex File (Required for Polygon Sources)

[2] Unlike other sources, when polygons are modeled by Multi HEM-3, the overlap function—which typically ensures that impacts (e.g., risk) are not calculated as overlapping with a source—is disabled. This allows the impacts for a polygon source (e.g., mobile source emissions modeled uniformly across a census tract) to be calculated within the polygon being modeled.

- **Buoyant Line Source Parameters File**

  (*See Template_Multi_BuoyantLineParameters.xlsx* in the Inputs_Multi folder*)* – This file is required if one or more of the sources in your Emissions Location file is a buoyant line configuration (rather than a point, area, volume, polygon or line configuration). Buoyant line source types are useful in simulating continuous rooftop vents in which emissions are released at non-ambient (increased) temperature and non-negligible velocity. This file contains information regarding the parameters of the buoyant line source. The buoyant line source parameters file is the same one used in Single HEM-3, with the addition of the facility ID in the first column. Figure 5 shows the format guidelines for the buoyant line source parameters file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail.

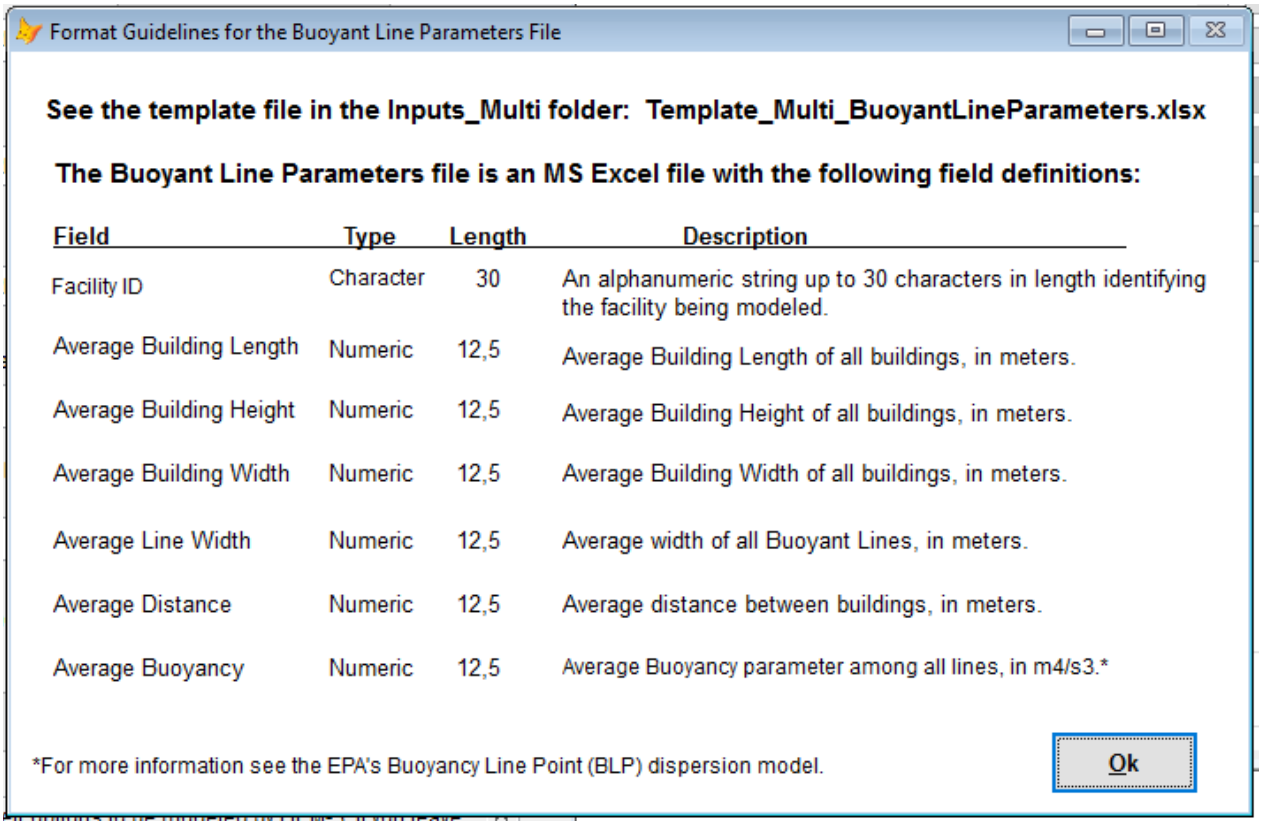


Figure 5. Format Guidelines for the Buoyant Line Source Parameters File (Required for Buoyant Line Sources)

- **Building Downwash File**

  (See *Template_Multi_bldg_dimensions.xlsx* in the Inputs_Multi folder) – To model the effects of downwash around a building, you will need to supply a file containing information on the configuration of that building. This input file contains several building dimensions including the height of the building, the projected width of the building perpendicular to the direction of air flow, the length in direction of air flow, and the distance from the source (e.g., stack) to the center of the upwind face of the building, both parallel to and perpendicular to the direction of air flow. You will need to provide these parameters for 36 wind directions at increments of 10 degrees. You can use the EPA's Building Profile Input Program (BPIP) to make these calculations. The BPIP is available for download from the www.epa.gov/ttn/scram/dispersion_related.htm webpage of EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website. Figure 6 shows the format guidelines for the building dimensions file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See also the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail.

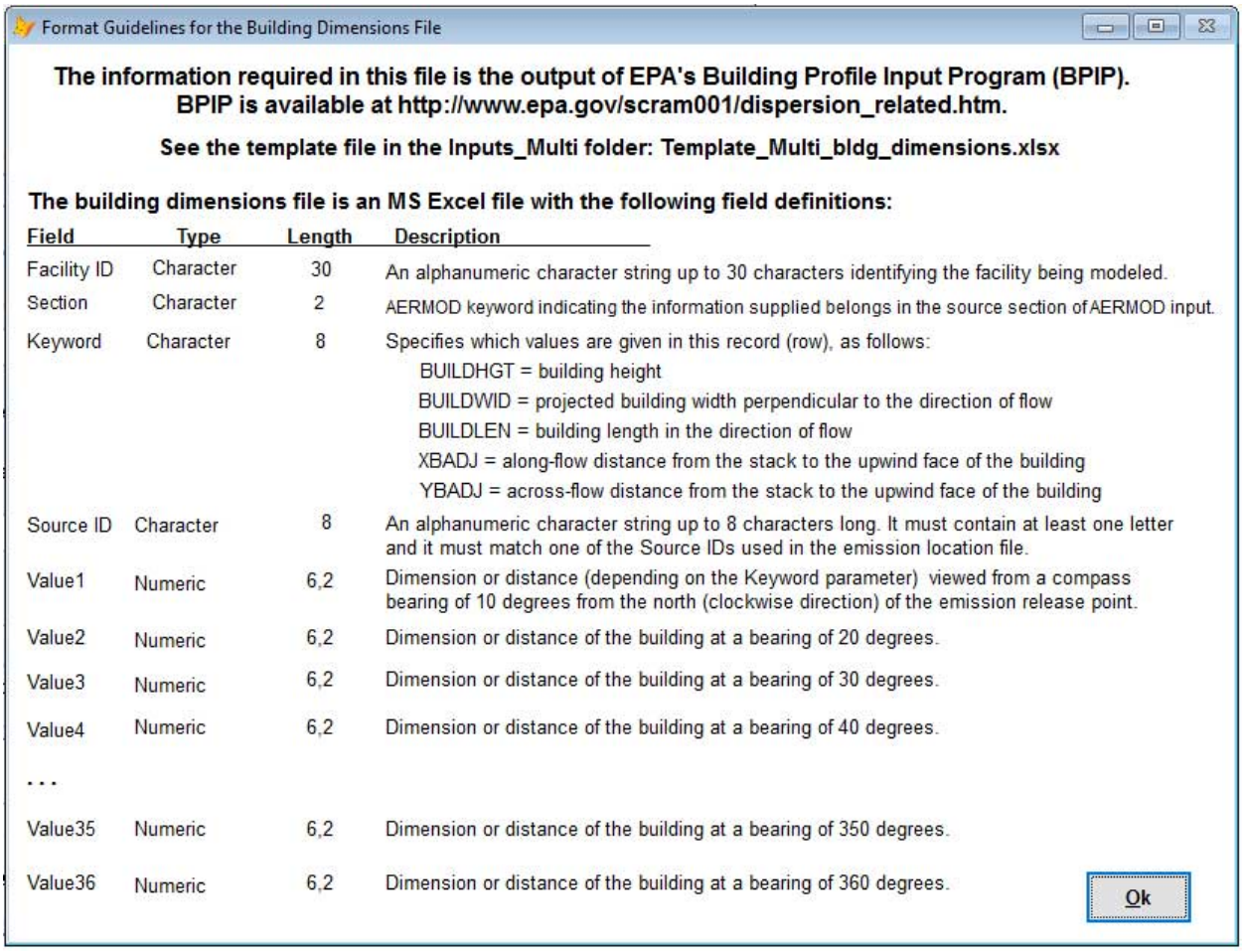


Figure 6. Format Guidelines for the Building Dimensions File (Required for Building Downwash)

- **Particle Size File**

  (See *Template_Multi_particle_data.xlsx* in the Inputs_Multi folder) – To model **deposition and/or depletion of particulate pollutants**, you will need to supply a particle size distribution file. This input file contains a separate record for each particle size range emitted by each emission source (except sources that emit 100% vapor/gas), including an average particle diameter for the size range, the percentage that the size range represents in terms of the total mass of particulate matter from the given emission source, and the average density of the particles in the size range. You must specify particulate information separately for each source that emits particles. Figure 7 shows the format guidelines for the particle size file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail.

  Note: **The Particle Size File must be consistent with the Percent Particulate column of your HAP Emissions File regarding what Source IDs must be included.** If you wish to model deposition/depletion, then any Source ID in your HAP Emissions File with a percent particulate greater than (other than) 0% must be included as a Source ID in this Particle Size File. Otherwise, a modeling run error will result. Also note that the Mass Fraction percentages for each included Source ID must sum to 100%.

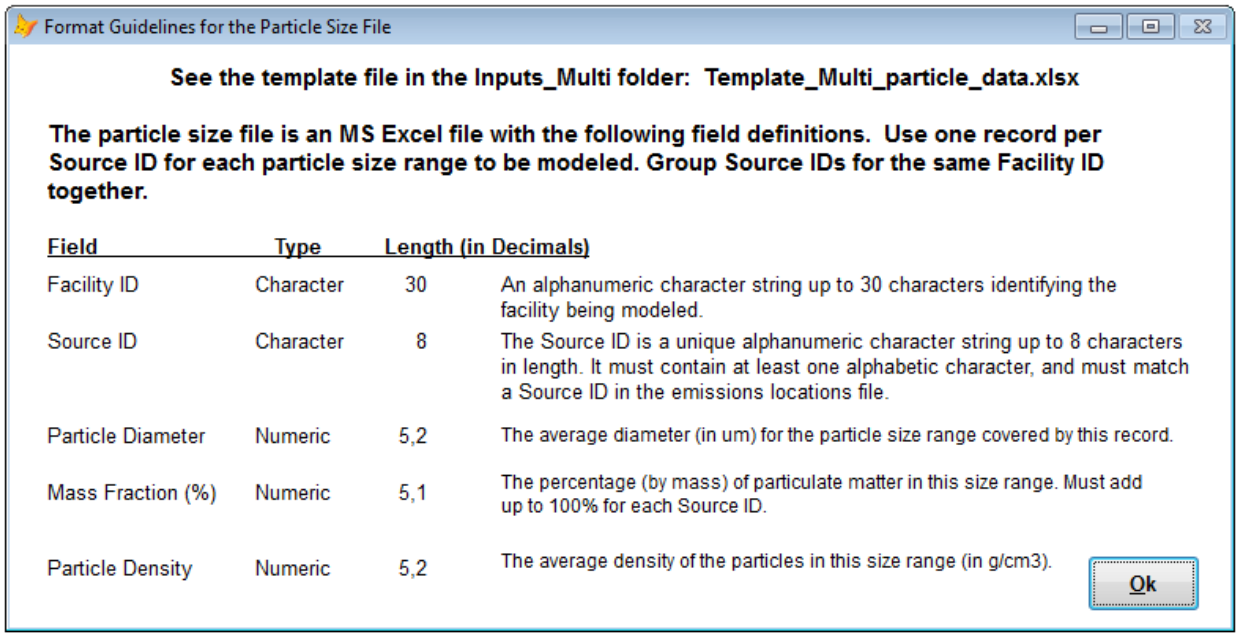


Figure 7. Format Guidelines for the Particle Size File (Required for Particle Deposition)

- **Land Use File**

  (See *Template_Multi_landuse.xlsx* in the Inputs_Multi folder) – To model **dry deposition and/or depletion of gaseous (vapor) pollutants**, you will need to supply a file containing information on the land use and vegetation surrounding that facility. This input file includes codes characterizing the average land use and vegetation for 36 directions from the emission source(s) at increments of 10 degrees. These codes correspond to: urban land with no vegetation (1), agricultural land (2), rangeland (3), forest (4), grassy suburban land (5), forested suburban land (6), water bodies (7), mostly desert or barren land (8) and non-forested wetlands (9). Figure 8 shows the format guidelines for the land use file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail.

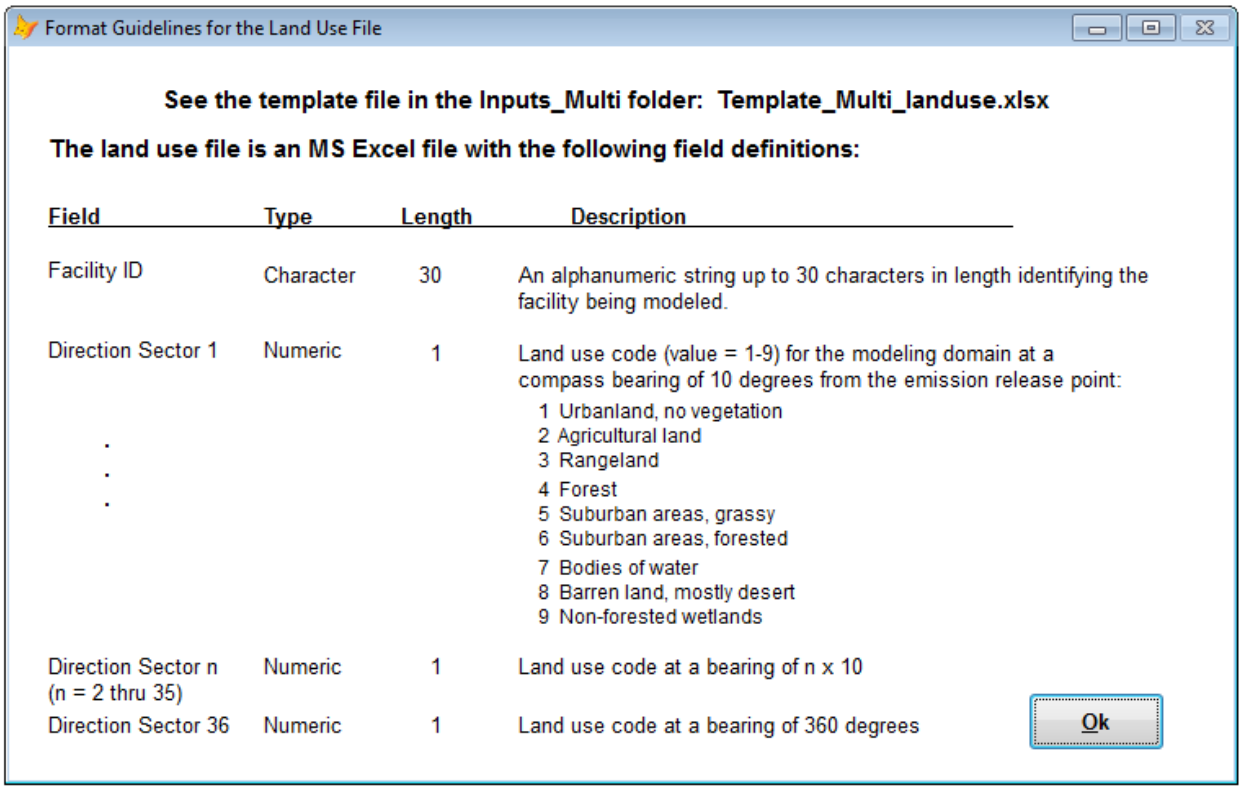


Figure 8. Format Guidelines for the Land Use File (Required for Dry Gaseous Deposition)

- **Month-to-Season Assignment File**

  (See *Template_Multi_seasons.xlsx* in the Inputs_Multi folder) – To model **dry deposition and/or depletion of gaseous (vapor) pollutants**, in addition to the Land Use file, you will also need to supply a file containing information on the typical stage of vegetation in the modeled region during each month of the year. This input file associates each month (M01 for January through M12 for December) with a season code: midsummer with lush vegetation (1); autumn with unharvested crop land (2); late autumn after frost and harvest, or with no snow (3); winter with snow on the ground (4); and transitional spring with partial green coverage or short annuals (5). Figure 9 shows the format guidelines for the seasons file, provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail.

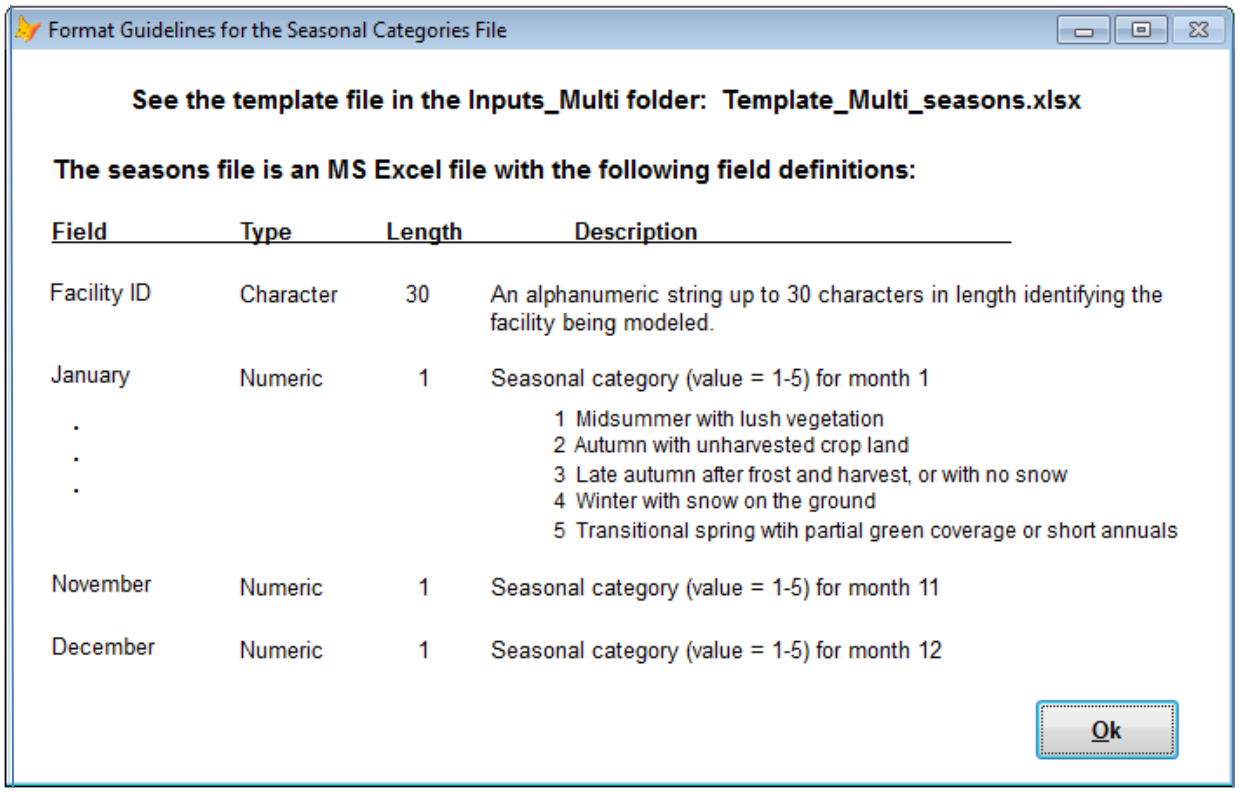


Figure 9. Format Guidelines for the Month-to-Seasons File (Required for Dry Gaseous Deposition)

- **Temporal Variation Files**

  (See *Template_Multi_temporal_'Variation'.xlsx*, in the Inputs_Multi folder) – These optional files contain a series of **temporal factors that allow you to vary the emission inputs based on different time scales** such as season, month, day of the week, and hour of day; **or based on wind speed**. Figure 10 shows the format guidelines for the temporal variations file(s), provided as part of Multi HEM-3's screen instructions, including a description of all fields in this input file. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for more detail. Temporal variation factors allowed by AERMOD and Multi HEM-3 include the following:

  - SEASON – emission rates vary seasonally (Winter = Dec., Jan., Feb.; Spring = Mar., Apr., May; Summer = Jun., Jul., Aug.; Fall = Sep., Oct., Nov.); number of factors is 4;
  - MONTH – emission rates vary monthly, number of factors is 12;
  - HROFDY – emission rates vary by hour of the day, number of factors is 24;
  - SEASHR – emission rates vary by season (4) and hour-of-day (24); number of factors is 96;
  - SHRDOW – emission rates vary by season (4), hour of day (24), and type of day of week (weekday, Sat, Sun) (3), number of factors is 288;
  - SHRDOW7 – emission rates vary by season (4), hour of day (24), and days of the week (7), number of factors is 672;
  - MHRDOW – emission rates vary by month (12), hour of day (24) and type of day of week (weekday, Sat, Sun) (3), number of factors is 864; and
  - WSPEED – emission rates vary by wind speed (user-defined or default upper bounds in meters/second of 1.54, 3.09, 5.14, 8.23, 10.8 and no upper bound), number of factors is 6.

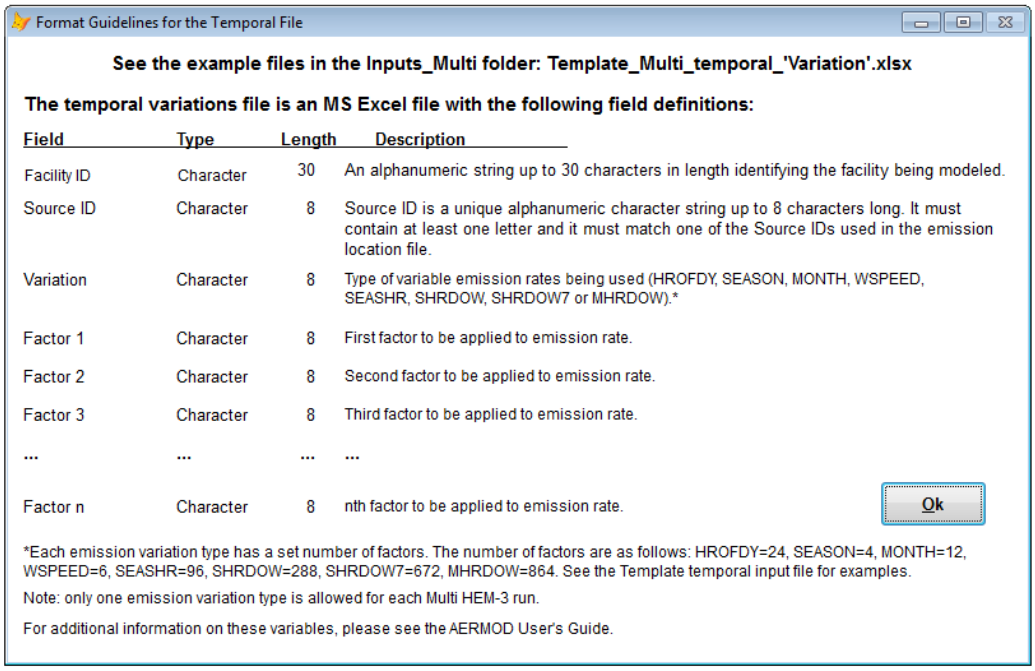


Figure 10. Format Guidelines for Temporal Variations Input File (Optional)

5. Running Multi HEM-3

To launch Multi HEM-3, double-click on *Multi_Hem3.exe* or click on your desktop shortcut (if you created one) to *Multi_Hem3.exe*. Typically, you would use Multi HEM-3 to run HEM-3 in the "multi" mode, for modeling more than one facility. To model emissions from only one facility using Multi HEM-3, you would prepare the file Facility List Options file with only the facility ID that you want to model; then run Multi HEM-3 using that file as one of the inputs. The format of your input files must remain the same as the inputs used in the Multi HEM-3 modeling runs (described in Section 4). Alternatively, you can use Single HEM-3 (EPA 2019) to model a single facility.

Multi HEM-3 is designed to run via user-friendly input screens that will prompt you to provide the required and optional input files. The initial title screen (depicted below) requires no inputs; simply click the *Next* button.

The next screen displayed, ***Dose Response Files*** shown in Figure 11, provides the dates of the dose response and target organ endpoints (toxicity value) files included in the Multi HEM-3 model you downloaded (which are not necessarily the same as shown). For future runs, to ensure you have the most recent file versions, you should again check EPA's HEM download webpage (https://www.epa.gov/fera/download-human-exposure-model-hem) for the date listed next to the "Toxicity Value Files" link. EPA regularly updates these files. If EPA's update is more recent than the dates shown on the ***Dose Response Files*** screen (for the files included in the Multi HEM-3 you downloaded), click *Exit* on this screen. Then download the newer files from EPA's HEM download webpage (from the link above), or manually modify the files in your Multi HEM-3's Reference folder based on updated values from EPA's HEM download page or from EPA's Dose Response Assessment webpage (EPA 2018b). Then restart the model.

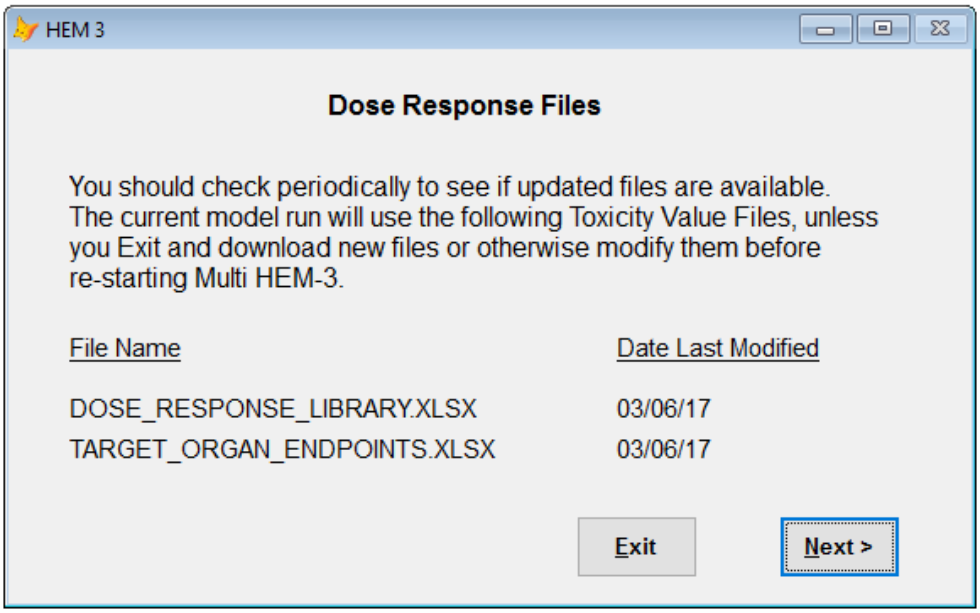


Figure 11. Dose Response Files Update Screen

You will have the option on each subsequent input screen of continuing by clicking the ***Next*** button, closing the program by clicking the ***Exit*** button, or accessing an electronic version of this Multi HEM-3 User's Guide by clicking the ***Help*** button.

Screens requiring you to provide input files contain instructions on the required formats for the files. To access these instructions, click on the ***View Format Guidelines*** button above each input box. These format guidelines are also provided in Section 4. Click on the *Browse* button next to the input box to select the file path and name from the computer's directory rather than entering the information manually. Multi HEM-3 contains three input screens requiring Yes/No answers as well as pathnames to input files. If modeling deposition, an additional screen will appear requiring input file pathnames. These screens are discussed below.

5.1 Providing Required Input Files

On screen ***1. Required Input Files***, shown below in Figure 12, you must provide the required input files by entering the path and file name or browsing and selecting the appropriate files. As described in Section 4.1, three files are required, beginning with the model's driver file listing the facilities and options to be modeled (*Facility_List_Options.xlsx*), followed by the pollutant emission rate file (*HAP_Emissions.xlsx*), and the emission source location file (*Emissions_Location.xlsx*). A fourth file (*Polygon_Vertex.xlsx*) is required via this screen only if any sources are configured and designated as polygons (source type upper case i or 'I') in the Emissions Location file. A fifth file (*BuoyantLineParameters.xlsx*) is required via this screen only if any sources are configured and designated as buoyant lines (source type 'B') in the Emissions Location file. Additional instructions are displayed at the bottom of this screen when each of the input boxes is clicked. More details about each of these files are provided in Section 4, and in the Single HEM-3 User's Guide (EPA 2019).

On this first screen, you will select the census year to be used in the modeling run (2010 or 2000). The census data set you select will affect where impacts such as risk are estimated (at the block "centroids"), the population used for calculating impacts such as cancer incidence, and the modeled population exposed to various risk and hazard levels.

At the bottom of this screen you can also choose to output the DBF files in CSV format. Selecting 'Yes' in response to this question directs Multi HEM-3 to duplicate all DBF formatted output files as CSV formatted files, which will increase the amount of disk space required. Note: **if your computer does not have the FoxPro™ programming language software installed, you should choose 'Yes' to output the DBF files in CSV format**.

Finally, this first screen includes a "Reset" button that allows an interrupted run to be cleared and modeling to begin anew at the first facility. This button is useful if you wish to make a change to the Facility List Options file that will apply to all facilities (e.g., you wish to model acute impacts but forgot to enter "Y" for every facility in the acute column of the Facility List Options file). The Reset button is also useful in the event of an interrupted run caused by an error in the input files.

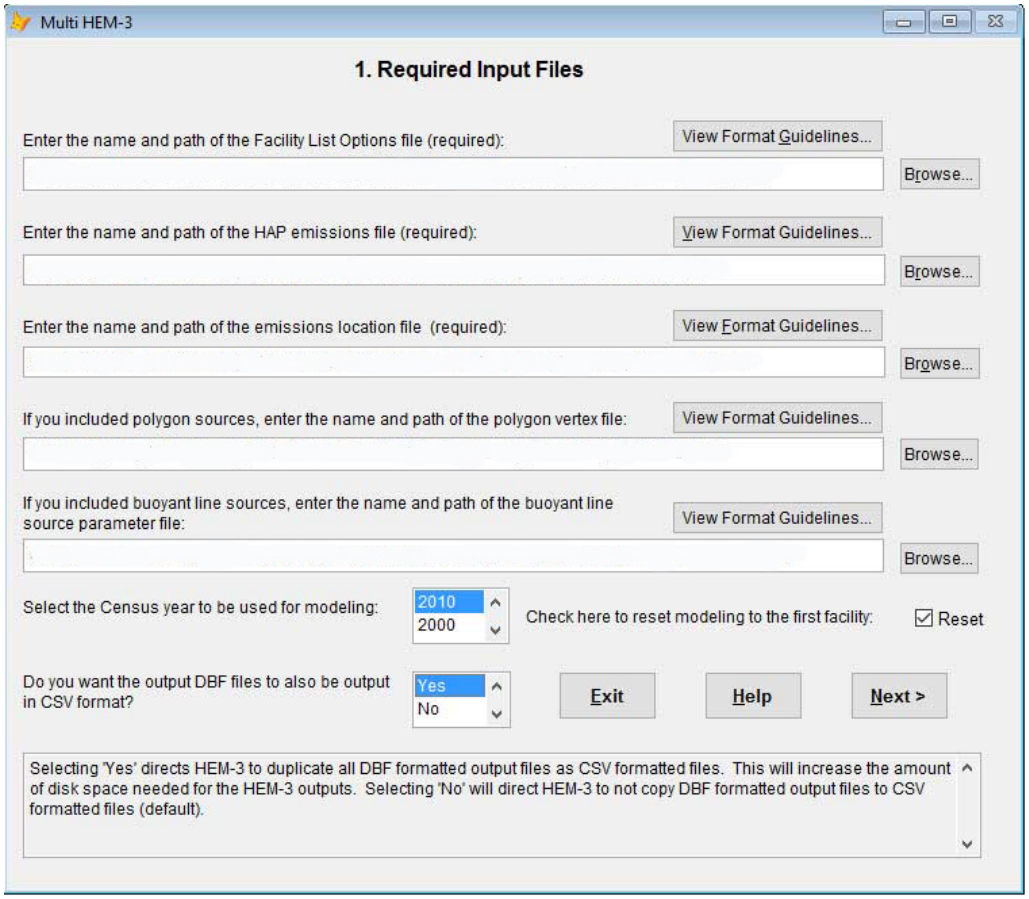


Figure 12. Screen 1 - Required Input Files

5.2 Providing Optional Input Files

On screen ***2. Optional Input Files***, shown below in Figure 13, you can provide optional input files for a more refined modeling run, as indicated in your Facility List Options file. These modeling options will be included in the model run *only* if you entered a **Y** (for Yes) in the *Facility_List_Options.xlsx* file column under each respective field (acute, deposition/depletion, user receptors, building downwash). If you have not entered a **Y** in each field, answering 'Yes' on the optional input files screen (Figure 13) will not suffice to include the option in the model run.

Furthermore, if you have entered **Y** in the *Facility_List_Options.xlsx* file field(s) for user receptors, building downwash or deposition/depletion, then you must provide the respective optional input file(s) using this screen, or change the *Facility_List_Options.xlsx* field(s) to **N** for Multi HEM-3 to successfully run.

If you have chosen to model acute concentrations, you can skip this box (leave it blank) if you wish to use the maximum predicted acute value for the modeled acute concentrations at each receptor, which is the default. If you wish to use a value other than the maximum (e.g., the 98th or 99th percentile), then enter the value in the text box. The number you enter must be an integer and is dependent on the number of hourly values in the modeled run. For example, if you want the 98th percentile acute value used from a dataset of 8,760 hourly values (in one year), then enter 175 in this text box, which is the truncated product of 0.02 x 8760. Similarly, if you want to use the 99th percentile acute value, then enter 87 in the text box, which is the truncated product of 0.01 x 8760. (Note: Using a high acute value other than the maximum default is a feature available only in Multi HEM-3; it is not available in Single HEM-3.)

From this screen, you can also label the group of facilities (sector) being modeled (e.g. PetRef for Petroleum Refineries). Enter your sector label after the last question on this screen; you may use up to 30 characters. Although this label is optional, it is recommended in order to readily identify which group of facilities or sector/source category the output files represent, as well as to clarify which files will be summarized by the RTR Summary Programs. Note: Your sector label will be applied to the Multi HEM-3 output files discussed in Section 6.2.

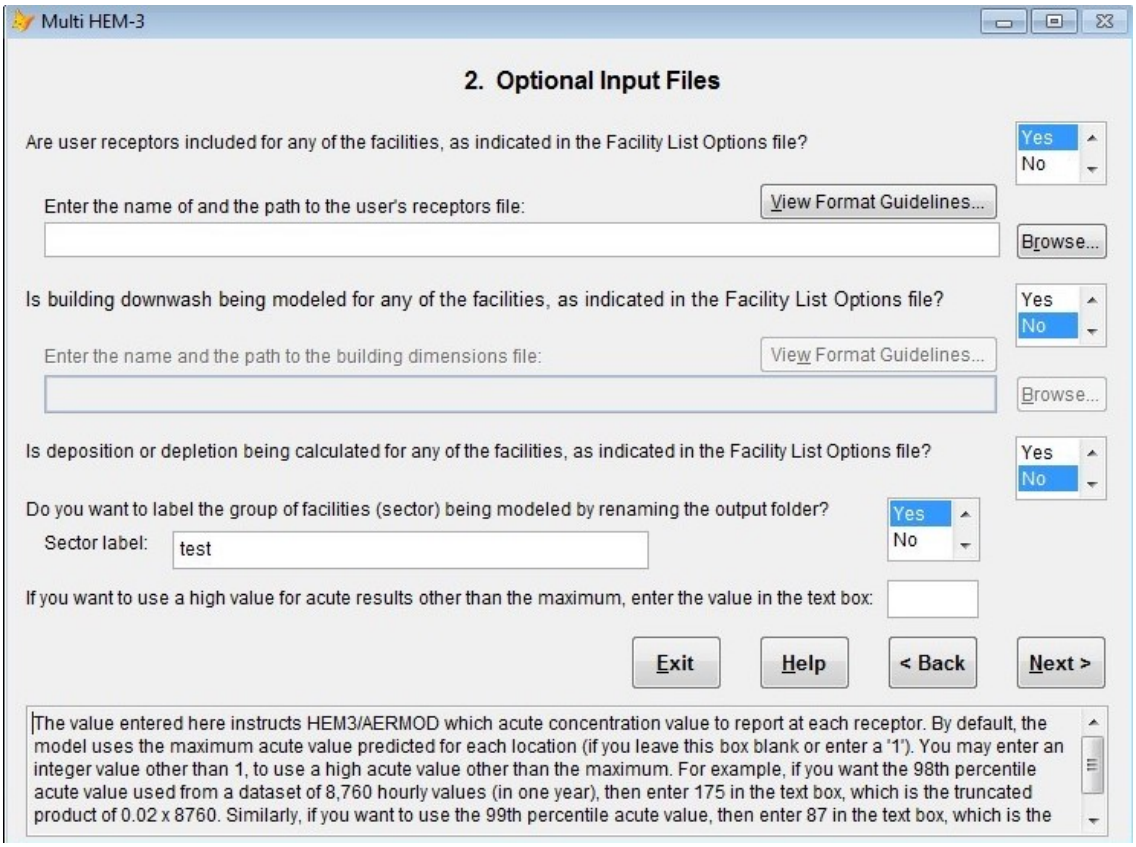


Figure 13. Screen 2 - Optional Input Files

5.2.1 Providing User Receptor and Building Dimensions Input Files

If you indicated user receptor modeling in the *Facility_List_Options.xlsx* file for any facility, select **Yes** in the first Yes/No toggle on the Optional Input Files screen (Figure 13) to specify the path and file name of the user receptor input file. If you are not modeling user-defined receptors, no input is required.

If you indicated building downwash modeling in the *Facility_List_Options.xlsx* file for any facility, select **Yes** at the second Yes/No toggle to enter a building dimensions file for the modeling of building downwash (by AERMOD). Click on the *View Format Guidelines* next to each input file request box for more information about these files. Further information is also available in Section 4 of this guide and in in the single HEM-3 User's Guide (EPA 2019).

5.2.2 Providing Deposition and Depletion Input Files

Use the third Yes/No toggle on Screen 2 to confirm whether or not you indicated in your *Facility_List_Options.xlsx* file that deposition and/or depletion are to be modeled in the run for any facility. (Deposition and/or depletion will only be modeled if you indicated this in the appropriate columns of your Facility_List_Options.xlsx file for one or more facilities.)

Select **No** on the third Yes/No toggle of Screen 2 (Figure 13) if you have not indicated deposition and depletion in the *Facility_List_Options.xlsx* file for any facility, then click *Next*. This will take you to *Screen 3. Specify Temporal Variations (Optional)* where you can specify temporal variations to be applied to the emission inputs and also request that temporal variations be shown in more detailed concentration outputs, as described in Section 5.3

Select **Yes** on the third Yes/No toggle of Screen 2 if you indicated in the Facility_List_Options.xlsx file that deposition and/or depletion are to be modeled for one or more facilities. Deposition with plume depletion generally reduces the ambient inhalation impacts from the emission source by removing pollutants from the plume. Air concentrations will be depleted as pollutants are deposited to the ground. Deposition without plume depletion will not affect the air concentrations, but will provide a deposition flux in the outputs. [Once the run completes, you can use this modeled deposition flux as an input to a separate multi-pathway model such as the Total Risk Integrated Methodology (TRIM) (EPA 2018c).] If you chose in your *Facility_List_Options.xlsx* to model depletion only for any facility, deposition algorithms will still be used to deplete the plume but the deposition flux will not be provided in the outputs. This is useful if you wish to deplete the plume but do not need the deposition flux, as it conserves computer storage space. See the Single HEM-3 User's Guide (EPA 2019) and the AERMOD User's Guide (EPA 2018a) for a more detailed discussion on all of HEM-3's available options for modeling deposition and/or depletion using AERMOD.

Selecting **Yes** to the deposition or depletion question on Screen 2 will take you to Screen ***2a. Specify Files for Deposition and Depletion***, shown below in Figure 14. Here you will enter the names of the additional input files needed for deposition modeling. Multi HEM-3 uses AERMOD to calculate deposition and depletion effects for particulate matter, gaseous (vapor) pollutants, or both, as indicated in the *Facility_List_Options.xlsx* fields. You have the option of modeling dry-only, wet-only, or both wet and dry deposition and/or depletion. (See Table 2 regarding the *Facility_List_Options.xlsx* file for the deposition and depletion options available to you in AERMOD, via the HEM-3 model.)

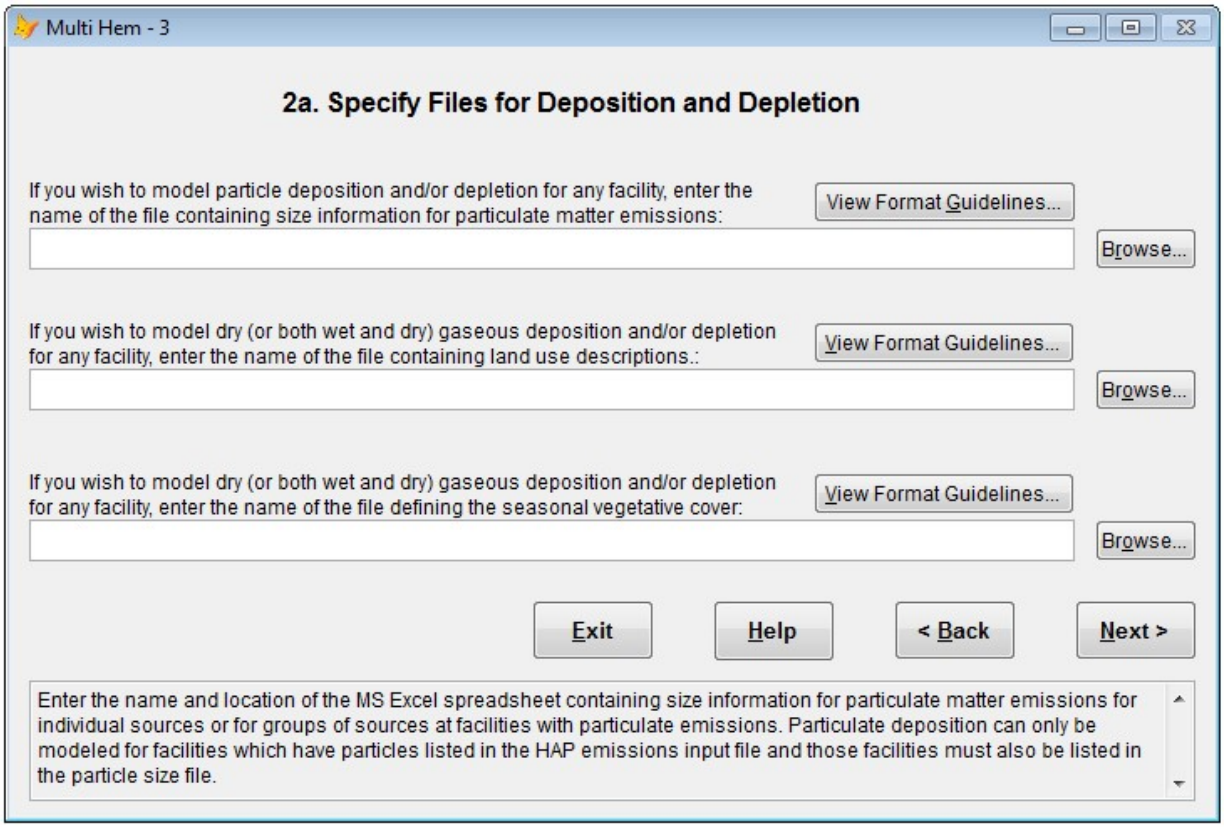


Figure 14. Screen 2a – Specify Files for Deposition and Depletion

Enter the name(s) and location(s) of your deposition-related input files on Screen ***2a. Specify Files for Deposition and Depletion*** (Figure 14). The input files you provide should be consistent with the type of deposition you indicated in the *Facility_List_Options.xlsx* fields. For particulate deposition and/or depletion, a particle size distribution input file is needed. For gaseous (vapor) dry deposition and/or depletion, land use and month-to-season input files are needed. Click on the *View Format Guidelines* next to each input file request, for more information about these files. Further information is also available in Section 4 of this guide, in the Single HEM-3 User's Guide (EPA 2019) and in the AERMOD User's Guide (EPA 2018a). After providing the appropriate input files, click *Next* at the bottom of the screen to be taken to Screen ***3. Specify Temporal Variations (Optional)***, described below in Section 5.3.

5.3 Specifying Optional Temporal Variations

Use screen ***3. Specify Temporal Variations (Optional)*** to apply temporal variations in the emission inputs AERMOD uses. You can also use this screen (Figure 15) to show hourly and seasonal resolution in the ambient concentration outputs AERMOD produces. [**Note**: Unlike other options in Multi HEM-3, the temporal option does not have a controlling field value in the *Facility_List_Options.xlsx* file, but rather is controlled by the answers you provide on Screen 3.]

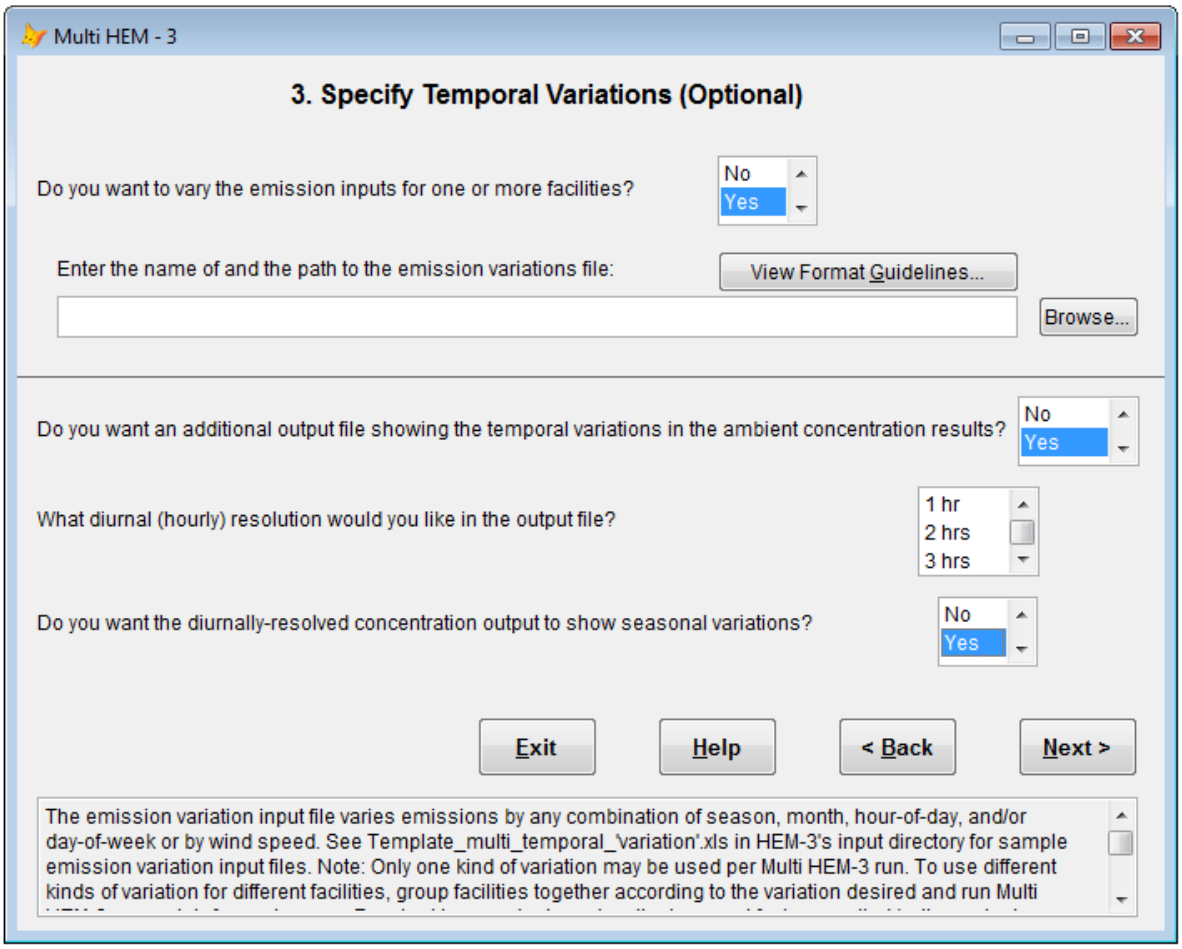


Figure 15. Screen 3 - Specify Temporal Variations (Optional)

From Screen ***3. Specify Temporal Variations (Optional)***, you can:

- Choose to include a temporal variations input file that varies the emissions AERMOD uses from specific sources and facilities by different user-supplied time scales (e.g., by season, month, hour of day, day of week), or by different wind speeds (6 ranges).

- Direct Multi HEM-3 to provide an output file from AERMOD displaying diurnal and/or seasonal variations (based on meteorological fluctuations and/or the user-supplied temporal variations specified above) in the ambient concentration results.

To vary the emission inputs, select **Yes** on the first Yes/No toggle on this screen (Figure 15), then enter the path and file name of the temporal variation file. This file contains factors that Multi HEM-3 (via AERMOD) will apply to vary the emissions based on different time scales or wind speeds. Click on the *View Format Guidelines* button next to the input file request for more information about this file. Further information on this file is also provided in Section 4.2 of this guide, in the Single HEM-3 User's Guide (EPA 2019) and in the AERMOD User's Guide (EPA 2018a).

Note that for short-term emission rates, the factors applied by the temporal variations file will compound the acute multiplier specified in your *Facility_List_Options.xlsx* file. For example, the

factors you supply in the temporal variations file will be multiplied by an acute multiplier of 10—if you chose to use the default acute multiplier—to derive the short-term emission rate. Therefore, if you apply hour-of-day temporal factors for example, you may want to set the acute multiplier to 1 (in the *Facility_List_Options.xlsx* file), unless it is reasonable to assume that the short-term rate may still exceed the hour-of-day factors by an additional multiple.

To produce additional output files (*temporal.csv* and *temporal.dbf*) showing temporal variations based on the supplied emission variation factors above and/or meteorological variations inherent in the met data AERMOD uses, select **Yes** on the second Yes/No toggle on this screen (Figure 15). Then choose the diurnal (hourly) resolution in the output file. The diurnal resolutions available are: 1-hour (24 concentrations per 24 hours); 2-hour (12 concentrations per 24 hours); 3-hour (8 concentrations per 24 hours); 4-hour (6 concentrations per 24 hours); 6-hour (4 concentrations per 24 hours); 8-hour (3 concentrations per 24 hours); 12-hour (2 concentrations per 24 hours); or 24-hour (1 concentration per 24 hours).

To show seasonal variations in the diurnally-resolved concentration outputs, select **Yes** on the third Yes/No toggle. Note: If you direct Multi HEM-3 to show seasonal resolution in the outputs, then the number of concentrations which will be output in the *temporal.csv* and *temporal.dbf* files will equal 4 (seasons) times the number of concentrations that the selected resolution produces (e.g., 4 x 24 or 96 concentrations if you select a 1-hour resolution with seasonal variations).

You can select the output option(s) on Screen ***3. Specify Temporal Variations*** (Figure 15) alone or in combination with the input option(s). If you select only the output option—not in combination with a temporal variation file—then the temporal variations in the ambient concentration outputs will reflect the effects of meteorological fluctuations calculated by AERMOD (based on meteorological data provided by the relevant met station files). If you select the output option(s) in combination with your temporal variation input file(s), then the temporal variations in the ambient concentration outputs will result from applying to the emissions both meteorological fluctuations and the time or wind speed factors you provided in the temporal variation input file.

Click *Next* at the bottom of Screen ***3. Specify Temporal Variations*** to initiate the Multi HEM-3 run, which is described further in Section 5.4 below.

5.4 Multi HEM-3 Processing

Multi HEM-3 begins by calculating certain modeling parameters based on the inputs, such as the facility center, the population density, and the placement of the polar grid network. Multi HEM-3 also uses the defined modeling domain to retrieve the relevant census block data from the census database (either 2000 or 2010). After Multi HEM-3 creates an input file for AERMOD based on the calculated modeling parameters, Multi HEM-3 initiates AERMOD. Once AERMOD is running, Multi HEM-3 closes. On the task bar, you will see that a disk operating system (DOS) window is active. Note: this open DOS window indicates that AERMOD is running. Do not close this window unless you want to abort the current run.

To gauge how long AERMOD will run for a given facility, open the DOS window to view the output messages from AERMOD. These show what day of the year AERMOD is currently processing. Modeling run times can vary significantly from one facility to another based on the number and complexity of each facility's sources, the specific modeling options chosen for each facility, and the receptor/population density in each facility's modeling domain.

After AERMOD finishes modeling a facility, the DOS window will close, Multi HEM-3 will restart, and processing of the AERMOD output files for that facility begins. Once Multi HEM-3 has processed the AERMOD output files for the given facility, the files which Multi HEM-3 has created will be copied to that facility's output folder.

Multi HEM-3 will then start processing inputs for the next facility. During the AERMOD and Multi HEM-3 processing, your computer will intermittently display the DOS window on the task bar or a Microsoft Visual FoxPro® pop-up window. Processing will require minutes to hours depending on the modeling parameters noted above, although during the run you can use your computer for other purposes.

When Multi HEM-3 has processed/modeled all facilities the following message appears: **Multi HEM-3 has completed successfully. Click 'OK' to end the program**. Click **OK** to end Multi HEM-3. All output files are automatically placed in a folder labeled with the sector name you provided on Screen 2 as *hem3_output_sectorname*. If you chose not to create a sector label on Screen 2, Multi HEM-3 will place all output files in a generic 'output' folder it creates, located in the Multi HEM-3 directory.

At the beginning of the model run, the complete HAP Emissions file contents and the complete Emissions Location file contents are read into a DBF file and compared to ensure the Source IDs match. If there are any Source IDs in one file that are not in the other, your computer will display an error message showing which source IDs from which facility are not matched. Multi HEM-3 will then end. Correct the omission or discrepancy in the input file(s) before re-running the model.

The calculations section of the Single HEM-3 User's Guide (EPA 2019) provides more detail regarding the dispersion modeling calculations that Multi HEM-3 implements using AERMOD, as well as the post-dispersion modeling cancer risk and noncancer hazard calculations performed by Multi HEM-3 to generate its outputs. These outputs are discussed next, in Section 6.

6. Post Processing Procedures and Multi HEM-3 Outputs

If you chose to supply a sector (facility group) label on Screen 2 *Optional Input Files*, your output files will be in a folder labeled *hem3_output_sectorname*. In this case, you can skip the steps listed below.

If you chose not to supply a sector (facility group) label on Screen 2, you must implement one of the two following options, after Multi-HEM-3 has completed processing all facilities listed in the *Facility_List_Options.xlsx* file:

1) Copy all of the files in the Multi HEM-3 'output' folder to another folder; or

2) Rename the Multi HEM-3 'output' folder more specifically by incorporating a short identifier relevant to the run (e.g. *output_Petro* or *Petro_output* if the run modeled petroleum manufacturing facilities).

If you want to keep the outputs somewhere other than under the Multi HEM-3 folder, choose option 1. If you want to keep all Multi HEM-3 outputs with the Multi HEM-3 program, choose option 2. Multi HEM-3 will create a new 'output' folder the next time it is run. **Note:** you should not rename any of the individual Multi HEM-3 output files. The RTR Summary Programs require

the files to adhere to the naming convention used by Multi HEM-3. Running of the RTR Summary Programs is discussed in Section 8.

6.1 Individual Facility Outputs

Multi HEM-3 uses each facility ID to automatically create facility subfolders under your sector labelled folder (or "output" folder) in the Multi HEM-3 directory. All output files associated with an individual facility are placed in the subfolder with its corresponding facility ID as each subfolder's name. The facility-specific outputs provide modeled results relevant to location-specific risk including the maximum individual risk (MIR) for each facility, target-organ specific hazard indices (TOSHI), and concentration, as well as modeled incidence and the population count exposed to various risk and TOSHI levels. These output files are described in more detail in the outputs section of the Single HEM-3 User's Guide (EPA 2019) and include the following default files:

- maximum_indiv_risks.xlsx
- maximum_offsite_impacts.xlsx
- cancer_risk_exposure.xlsx
- noncancer_risk_exposure.xlsx
- risk_breakdown.xlsx
- incidence.xlsx
- input_selection_options.xlsx
- overlapping_source_receptors.xlsx
- block_summary_chronic.dbf
- ring_summary_chronic.dbf
- all_inner_receptors.dbf
- all_outer_receptors.dbf
- all_polar_receptors.dbf
- allreceptors_risk.kml
- source_locations.kml
- aermod.out

If you optionally chose to model acute impacts for any facility by entering **Y** in the Acute column of the *Facility_List_Options.xlsx* input file, the individual facility output subfolder will also include the following files:

- acute_bkdn.xlsx
- acute_chem_pop.xlsx
- acute_chem_unpop.xlsx

Finally, if you opted for additional output files showing temporal variations (when prompted on the bottom half of the *Specify Temporal Variations* screen, Figure 15), temporal.csv and temporal.dbf output files will also be provided in each facility subfolder. The temporal.csv output is a comma delimited text file which may be readily imported and converted into an Excel™ spreadsheet.

All of the above listed output files are specific to an individual facility and do not summarize the entire group (or source category/sector) of modeled facilities as a whole. Review the Single HEM-3 User's Guide (EPA 2019) for a more detailed description of the content in each of the facility-level files. The *input_selection_options.xlsx* output file in each facility subfolder is also helpful to review regarding the input parameters upon which each facility's outputs are based.

6.2 Multiple Facility Outputs

In addition to the individual facility outputs listed above, Multi HEM-3 produces four summary output files, based on the results for the entire group (or source category/sector) of modeled facilities. These multi-facility outputs are updated after the output files for the individual facilities have been created and essentially concatenate the individual facility results into group-wide summary files. In each of these four XLSX files, Multi HEM-3 writes one row of information for each facility upon completion of that facility's individual modeling run. The four summary XLSX output files created by Multi HEM-3 are described below, including a listing of the fields (columns) in each file and an abbreviated screenshot of each file.

- ***Facility_max_risk_and_HI.xlsx*** – This Multi HEM-3 output file provides the maximum modeled risk and hazard index results for every facility as well as additional facility-specific modeling results, including:

    - a listing of all facility IDs modeled;
    - the cancer risk at the receptor that experiences the highest risk in the modeled radius around each facility (i.e., facility-specific MIR);
    - whether or not the MIR (max cancer risk) is interpolated from nearby receptors[3];
    - the type of receptor where the MIR (max cancer risk) occurs (e.g., census block, polar grid, user-defined receptor);
    - the latitude and longitude of the MIR (cancer) receptor;
    - the census block ID of the MIR receptor (or user receptor ID, if applicable);
    - the 14 TOSHIs at the receptors that experience the maximum TOSHI for each facility including: whether or not the TOSHI value is interpolated, the receptor type(s) where the max TOSHIs occur, the latitude and longitude for certain max TOSHI receptors (e.g., respiratory, neurological), and the census block ID of each TOSHI receptor (or user receptor ID, if applicable);
    - the population, if any, excluded from the modeling run because of any census block centroid(s) located within the overlap distance around each emission source (and therefore considered on facility property)[4]
    - the cancer incidence (predicted excess cancers per year due to modeled emissions) at each facility;
    - the file name of the meteorological station used in the modeling of each facility;
    - the distance (in kilometers) from the facility center to the meteorological station used in the modeling run;
    - the latitude and longitude location of the facility center calculated by Multi HEM-3;
    - the dispersion environment used by HEM-3 for modeling each facility – rural or urban.

    Figure 16 shows a sample *Facility_max_risk_and_HI.xlsx*, which has been abbreviated to fit on the page by excluding 13 of the 14 TOSHI values and associated columns. The TOSHIs modeled by Multi HEM-3 can impact the following organs and organ systems: respiratory; liver; neurological; developmental; reproductive; kidney; ocular; endocrine; hematological; immunological; skeletal; spleen; thyroid; and whole body. In the example shown in Figure 16, only respiratory HI is shown, which is commonly the highest TOSHI

[3] An interpolated MIR generally suggests that the modeling distance should be increased and the facility remodeled.

[4] A value in the population overlap field generally indicates that the facility should be remodeled (e.g., with a smaller overlap distance specified) to ensure that the population associated with the census block centroid(s) is accounted for.

level based on the dispersion and inhalation modeling performed by AERMOD and Multi HEM-3. Regarding modeled risk in this example, two facilities show a cancer risk in the second column (of Figure 16) greater than 1 in a million (i.e., greater than 10^{-6} or E-06).

- ***Facility_cancer_risk_exp.xlsx*** – This Multi HEM-3 output file lists the facilities by ID, their corresponding latitudes and longitudes (of the calculated facility centers), and the population exposed to different cancer risk levels, including:

    - the number of people from each facility exposed to a cancer risk level greater than or equal to 1 x 10^{-3}, designated as "pop_ge_eneg3" in the column header (which may also be expressed as a risk of 1 in 1,000 or 1,000 in a million);
    - the number of people from each facility exposed to a cancer risk level greater than or equal to 1 x 10^{-4}, designated as "pop_ge_eneg4" in the header (which may also be expressed as a risk of 1 in 10,000 or 100 in a million);
    - the number of people from each facility exposed to a cancer risk level greater than or equal to 1 x 10^{-5}, designated as "pop_ge_eneg5" in the header (which may also be expressed as a risk of 1 in 100,000 or 10 in a million);
    - the number of people from each facility exposed to a cancer risk level greater than or equal to 1 x 10^{-6}, designated as "pop_ge_eneg6" in the header (which may also be expressed as a risk of 1 in 1,000,000 or 1 in a million);
    - the number of people from each facility exposed to a cancer risk level greater than or equal to 1 x 10^{-7}, designated as "pop_ge_eneg7" in the header (which may also be expressed as a risk of 1 in 10,000,000 or 0.1 in a million).

  Figure 17 shows a sample *Facility_cancer_risk_exp.xlsx* for the same run that produced the *Facility_max_risk_and_HI.xlsx* shown in Figure 16. In this example 1,468 people residing near one facility and 142 people residing near another facility experience a modeled risk greater than or equal to 1 in a million. The other three facilities modeled do not result in any surrounding populations experiencing a risk greater than or equal to 1 in a million; consistent with the risk (MIR) results shown in the second column of the *Facility_max_risk_and_HI.xlsx* output shown in Figure 16. Note that each row of this output file is facility-specific and does not reflect the impacts of multiple facilities with overlapping modeling domains (which may impact the same receptor).

- ***Facility_toshi_exp.xlsx*** – This Multi HEM-3 output file lists the facilities by ID and the number of people with a TOSHI greater than 1 for each facility and for each of the 14 TOSHIs currently modeled by Multi HEM-3. Figure 18 shows a sample *Facility_toshi_exp.xlsx* for the same run that produced the Multi HEM-3 outputs shown in Figures 16 and 17. In this example, no people surrounding any of the modeled facilities are predicted to experience a TOSHI greater than 1. [Note: Because the convention of one significant figure is employed, an HI greater than 1 equates mathematically to an HI greater than or equal to 1.5.]

- ***Facility_tox_weighted_emissions.xlsx*** – This Multi HEM-3 output file lists the toxicity-weighted emissions for each facility. Toxicity weightings for cancer risk are expressed in terms of the product of the URE in lifetime cancer risk per µg/m^3 and emissions in tons/year, and are computed by summing this product for every chemical emitted at a facility. Toxicity-weighted emissions for noncancer risk are expressed in terms of the ratio of emissions in tons/year to the RfC in mg/m^3, and are computed separately for each target organ by summing these ratios for each chemical. Figure 19 shows a sample *Facility_tox_weighted_emissions.xlsx* for the same run that produced the Multi HEM-3 outputs shown in Figures 16, 17, and 18.

Multi HEM-3 will also provide two Excel™ output files listing the dose response values and target organ endpoints used for modeling the pollutants in the respective Multi HEM-3 run. These output files are named *Dose_response_library.xlsx* and *Target_organ_endpoints.xlsx*. Two additional DBF output files are also created when the Multi HEM-3 run has completed successfully: *Faclist.dbf* and *HAP_library.dbf*. *Faclist.dbf* is a list of all facility IDs that were modeled by Multi HEM-3 for the current source category/sector. *HAP_library.dbf* is the DBF version of the *Dose_response_library.xlsx* file from the HEM-3 "Reference" folder.

Note: Do not change the names of the facility-level or Multi HEM-3 output files (discussed above), as these files are referenced by their specific names when running the RTR Summary Programs described in Section 8.

1	facil_id	mx_can_rsk	can_rsk_ interpltd	can_rcpt_type	can_lat	can_lon	can_blk	respiratory_hi	[59 TOSHI columns]	pop_overlp	incidence	metname	km_to_ metstation	fac_center _lat	fac_center _lon	rural_ urban
2	48005NEI12810	9.0286E-07		Census block	31.342	-94.706	480059801001074	0.007086817	...		4.95422E-05	Shreveport, LA	148	31.338	-94.713	R
3	15003NEIART$10736	3.0319E-06		Census block	33.145	-91.972	150039504011013	0.203390104	...		0.000105232	LittleRock, AR	176	33.139	-91.966	R
4	13093NEI46838	4.0436E-06		Census block	32.091	-83.82	130930512003001	0.033039428	...		1.64535E-05	Atlanta, GA	181	32.079	-83.79	R
5	17161NEI56034	0		na	na	na	na	0.000564176	...		0	Moline, IL	37	41.754	-90.29	U
6	21111NEI32872	4.4105E-07		Census block	38.181	-85.753	211118463257981	0.003461951	...		9.96017E-05	Louisville, KY	2	38.181	-85.753	U

Facility_max_risk_and_HI

Figure 16. Sample Facility_max_risk_and_HI Multi HEM-3 Output (abbreviated)

1	facility_id	lat	lon	level3	pop_ge_eneg3	level4	pop_ge_eneg4	level5	pop_ge_eneg5	level6	pop_ge_eneg6	level7	pop_ge_eneg7
2	48005NEI12810	31.338	-94.713	0.001	0	0.0001	0	0.00001	0	0.000001	0	0.0000001	8075
3	05003NEIART$10736	33.139	-91.966	0.001	0	0.0001	0	0.00001	0	0.000001	1468	0.0000001	11925
4	13093NEI46838	32.079	-83.79	0.001	0	0.0001	0	0.00001	0	0.000001	142	0.0000001	1642
5	17161NEI56034	41.754	-90.29	0.001	0	0.0001	0	0.00001	0	0.000001	0	0.0000001	0
6	21111NEI32872	38.181	-85.753	0.001	0	0.0001	0	0.00001	0	0.000001	0	0.0000001	6688

Facility_cancer_risk_exp

Figure 17. Sample Facility_cancer_risk_exp Multi HEM-3 Output

1	facility_id	level1	resp_hi	liver_hi	neuro_hi	develop_hi	repro_hi	kidney_hi	ocular_hi	endo_hi	hema_hi	immune_hi	skel_hi	spleen_hi	thyroid_hi	wholeb_hi
2	48005NEI12810	Greater than 1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	05003NEIART$10736	Greater than 1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	13093NEI46838	Greater than 1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	17161NEI56034	Greater than 1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	21111NEI32872	Greater than 1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Facility_toshi_exp

Figure 18. Sample Facility_toshi_exp Multi HEM-3 Output

1	facility_id	cancer_risk	respiratory	liver	neuro	developmental	reproductive	kidney	ocular	endoc	hemato	immunological	skeletal	spleen	thyroid	wholebody
2	48005NEI12810	0.000026754	0.21	0.001075	0	0.00414875	0	0	0	0	0	0	0	0	0	0
3	05003NEIART$10736	0.00021437	5.254081633	0.02625	0	0.0035925	0	0	0	0	0	0	0	0	0	0
4	13093NEI46838	0.000016074	0.149160998	0.00305	0.00009	0.0006775	0	0	0	0	0	0	0	0	0	0
5	17161NEI56034	0	0.092928571	0	0	0.0024875	0	0	0	0	0	0	0	0	0	0
6	21111NEI32872	0.00000819	0.064285714	0	0	0.00004	0	0	0	0	0	0	0	0	0	0

Facility_tox_weighted_emissions

Figure 19. Sample Facility_tox_weighted_emissions Multi HEM-3 Output

7. Quality Assurance Checks and Multi HEM-3 Reruns

If you did not choose a sector label on Screen 2. Optional Input Files, be sure to rename the Multi HEM-3 'output' folder, as instructed in Section 6. You should do this before initiating the quality assurance (QA) checks and possible remodeling runs described in this section. The name you choose should be relevant to the run (e.g., *Petro_output* if the run modeled petroleum manufacturing facilities). If you do not rename the output folder, any Multi HEM-3 facility reruns, which may be necessary as described below, will cause your original outputs to be overwritten.

There are several QA checks that you should perform after Multi HEM-3 has completed running and before you run the RTR Summary Programs, to determine if any of the facilities need to be remodeled. Open and check the *Facility_max_risk_and_HI.xlsx* file to:

- ensure that the number of facilities modeled in column A equals the number of facilities in the input files (e.g., *Facility_List_Options.xlsx*);
- ensure that the maximum cancer risk values in column B occur at census block or populated user-defined receptors rather than at unpopulated polar grid (or boundary or monitor) receptors, as noted in column D; and
- ensure that the TOSHI values in the various HI columns occur at census block or populated user-defined receptors rather than at unpopulated polar grid (or boundary or monitor) receptors.

The cancer risk and noncancer TOSHI checks described above are especially important for facilities of interest, such as those facilities with relatively high cancer risk or TOSHI values in the modeled set. If these QA checks fail, rerun Multi HEM-3 (as described below) for the facilities that failed one or more of the QA checks, before running the RTR Summary Programs. Rerunning Multi HEM-3 for such facilities will ensure that all facilities in the group or source category are modeled and that the modeled maximum risk and TOSHI values occur at populated receptors (i.e., where people reside).

Follow these steps to rerun a facility and ensure the MIR or the maximum TOSHIs occur at census block or populated user receptors, to correct situations when the MIR or the maximum TOSHIs occur at a polar grid receptor[5]. First, look at the *facilityname_allreceptors_risk.kml* file located in the individual facility subfolder. Opening this file will start Google Earth™, if it is installed on your computer. Figure 20 shows a sample Google Earth™ KML output file.

Zoom in on the facility center and turn on the polar grid (by checking the box next to "Polar receptors" in the Places key) so the polar grid receptor at which the MIR or TOSHI value occurs is also visible.

Next, find the census block centroid closest to the MIR polar receptor. Use the 'ruler' tool to measure the distance (in meters) from the census block centroid to the facility center. Round this distance up enough to ensure that a census block centroid near the current polar MIR receptor will be closer to the facility center than this revised first polar ring when the facility is

[5] The MIR or maximum TOSHIs can occur at a polar grid receptor if there is a census block receptor located within the overlap distance of the plant boundary. In this case, Multi HEM-3 will select the closest receptor to the plant boundary (i.e., census block, user-defined, or polar) to estimate the MIR at a location nearest to the population inside the overlap distance that has been excluded.

rerun, as explained further below. Follow these steps for all facilities of interest requiring remodeling.

To rerun the facility or facilities, create a copy of the input file *Facility_List_Options.xlsx*. Be careful to name the new file so that it is obvious it is not the original *Facility_List_Options.xlsx* file (e.g., *QA1_Facility_list_options.xlsx* to indicate it is the first QA run). Delete the rows for the facilities that do NOT have to be rerun.

Next, under the column heading 'ring1', enter the value determined from the above instructions (i.e., the distance in meters between the facility center and the census block centroid closest to the MIR polar receptor, rounded up). Save these changes and close the file.

Start Multi HEM-3. When prompted for the required input files, use the new *QA1_Facility_list_options.xlsx* file. Multi HEM-3 will then run only the facilities with revised first ring distances. This "bumping out" of the first polar ring will ultimately allow Multi HEM-3 to choose a populated census block receptor as the MIR or TOSHI receptor, because the first polar ring of polar receptors will be more distant from the facility center than the closest census block centroid. When the new 'output' folder has been generated by the rerun, rename the *Facility_max_risk_and_HI.xlsx* output as *QA1_Facility_max_risk_and_HI.xlsx*. You should also change the 'output' folder name generated by this run to 'output_QA1' or 'QA1_output' in case additional QA runs are necessary.

Once you have rerun the facility or facilities, check the outputs to determine if the relevant MIR or TOSHI is now at a census block receptor by opening the *QA1_Facility_max_risk_and_HI.xlsx* file. If the MIR or TOSHI is still at a polar grid receptor, repeat the above steps (starting with opening the *facilityname_allreceptors_risk.kml* file and this time using the identifier *QA2* for the naming convention). Make the first ring of the polar grid even farther from the plant center than in the first adjustment.

Once you have successfully adjusted the distance so that the MIR and maximum TOSHIs occur at census block receptors, copy the most recent facility rows from all *QA_Facility_max_risk_and_HI.xlsx* files (e.g., *QA1…*, *QA2…*, *QA3…*) into the original *Facility_max_risk_and_HI.xlsx* file. Open both files and replace the row for the adjusted facility in the original *Facility_max_risk_and_HI.xlsx* file with the new row from the *QA_Facility_max_risk_and_HI.xlsx* file.

Perform this row replacement for each remodeled facility, using the most recent QA run applicable to that facility. Copy the most recent facility output subfolder (including all its revised contents) to the location of the original facility output and overwrite the original subfolder for each remodeled facility.

Finally, a facility may require remodeling (using the steps described above) if the maximum risk and/or TOSHI values of that facility are interpolated, rather than explicitly modeled. The *Facility_max_risk_and_HI.xlsx* output indicates interpolated maximum risk values in column C (if blank, the value is not interpolated) and maximum TOSHI values in the columns to the right of each TOSHI value (e.g., column I for respiratory HI). Generally, a value is interpolated if the maximum receptor is located outside of the modeling distance within which receptors are explicitly modeled (e.g., at a default value of 3,000 m or 3 km). This can occur if a modeled facility is located in a sparsely populated area, where there are no census block centroids within the modeling distance (e.g., 3 km) of the facility center.

Open the *facilityname_allreceptors_risk.kml* file located in the individual facility subfolder to determine if a facility with an interpolated maximum risk and/or TOSHI should be remodeled with an increased modeling distance. The KML file will show where the closest census block centroids are located. If the facility is one of interest or concern (for example, if its risk or a TOSHI is considered high), the modeling distance should be increased to include the census block centroid(s). Use Google Earth's™ ruler tool to determine the new modeling distance. Remember to round up this distance slightly before remodeling the facility in a QA run, as previously described. If the risk and all TOSHIs are considered low—and if the reason for the low values is that the facility is located in a sparsely populated area—you may decide that remodeling is not necessary.

An interpolated maximum risk or TOSHI value may also occur if one or more of the emission sources is mislocated – for example, with an incorrect latitude or longitude that places a source too far from the actual facility location and other modeled sources. This interpolated situation requires remodeling to correct the location inaccuracy. If one or more source is mislocated (as determined by opening and viewing the *facilityname_allreceptors_risk.kml* file), perform a QA rerun for that facility using a corrected Emissions Location file (and a corrected polygon vertex file and/or buoyant line parameters file, if the misplaced source is configured as a polygon or buoyant line source).

In general, the image of each facility's emission sources and receptors overlaid on a Google Earth™ satellite map (i.e., the *facilityname_allreceptors_risk.kml* file) is a powerful tool for QA checks of the inputs and modeling parameters that Multi HEM-3 uses. Figure 20 below shows a sample Google Earth™ output map of emission sources and receptors with both census block and polar grid receptors turned on. Emission sources are evident in the center of the polar grid network, and the red "X" denotes the MIR cancer receptor that occurs at a census block centroid. Red indicates a receptor with a modeled total cancer risk greater than or equal to 100 in a million. Yellow indicates risk greater than or equal to 20 but less than 100 in a million. Green indicates a risk less than 20 in 1 million.

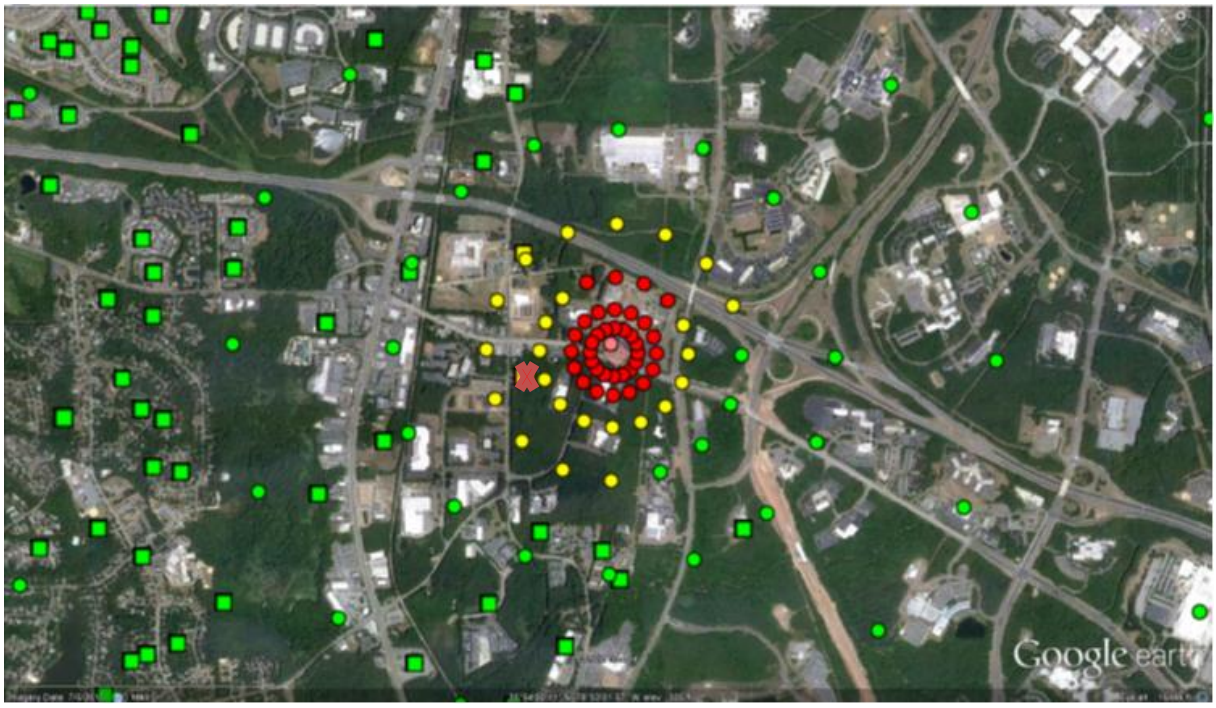


Figure 20. Sample Allreceptors_Risk.kml Multi HEM-3 Output

Open and view each KML file, even if all maximum risk and TOSHI values listed in the *Facility_max_risk_and_HI.xlsx* output occur at census block centroids and no values are interpolated, to perform a QA check of each image. Determine if sources are mislocated or misaligned enough to require remodeling and if the surrounding populations are represented well enough by the census block centroids (if not, you may need to remodel using user-defined receptors).

This QA check of each KML image is highly recommended. Even a QA check of a KML image that shows nothing amiss may prove useful. That is, if nothing looks amiss in the KML image but the maximum risk and TOSHI values seem too high to be reasonable, this may indicate an error in the emission amounts or pollutant names provided in the HAP Emissions input file.

Once you have performed all QA checks and runs, you are ready to run the RTR Summary Programs, as described below in Section 8. Remember, **the RTR Summary Programs need as inputs the final *Facility_max_risk_and_HI.xlsx* and the *faclist.dbf* outputs as well as several facility-level outputs** (depending on the HEM-3 options selected and which RTR Summary Programs you run). **Therefore, facility-level and Multi HEM-3 output files should not be renamed**.

8. Running RTR Summary Programs

After Multi HEM-3 has run and created the facility and summary output files described in Section 6, and after you perform the QA checks and adjustments on the Multi HEM-3 outputs described in Section 7, you can use the RTR Summary Programs to extract and further summarize results from the Multi HEM-3 outputs.

The RTR Summary Programs produce outputs that report the maximum cancer risk and the overall incidence considering emissions from all modeled facilities in the group (source category or sector). These programs also identify the category-wide pollutant and source type drivers of cancer risk, incidence, and noncancer hazard indices and estimate the category-wide population exposed to various risk and TOSHI levels. The category-wide histograms showing population exposed to various risk levels is provided both overall (considering all sources) and broken down by source type. The RTR Summary Programs identify the populated block receptor of maximum risk for the entire group of modeled facilities, as well as the sector-level TOSHI for all modeled blocks, accounting for emissions from all facilities.

Furthermore, if you chose the option to model acute concentrations and impacts as part of the Multi HEM-3 run, you can use the RTR Summary Programs to report category-wide acute concentrations and hazard quotients based on various acute benchmarks. Finally, you can readily determine the locations and values of maximum impact for Arsenic compounds, PAHs and Dioxins/Furans for each modeled facility (e.g., for use in a multipathway analysis), as well as the locations of the populated receptors closest to each modeled facility in eight directions. Section 9 includes more details regarding each of the RTR Summary Program outputs.

Double-click on the file *rtr.exe* or click on your desktop short-cut (if you created one) to start the RTR summary programs. The summary programs module consists of two main screens. The initial title screen requires no inputs; simply click the *Next* button to proceed to the ***RTR Summary Programs*** screen. On the ***RTR Summary Programs*** screen, shown below in Figure 21, you will indicate the location of the Multi HEM-3 outputs to be used as inputs for the RTR Summary Programs. Then, from this screen, you can launch the specific RTR Summary Programs to be applied to the Multi HEM-3 outputs.

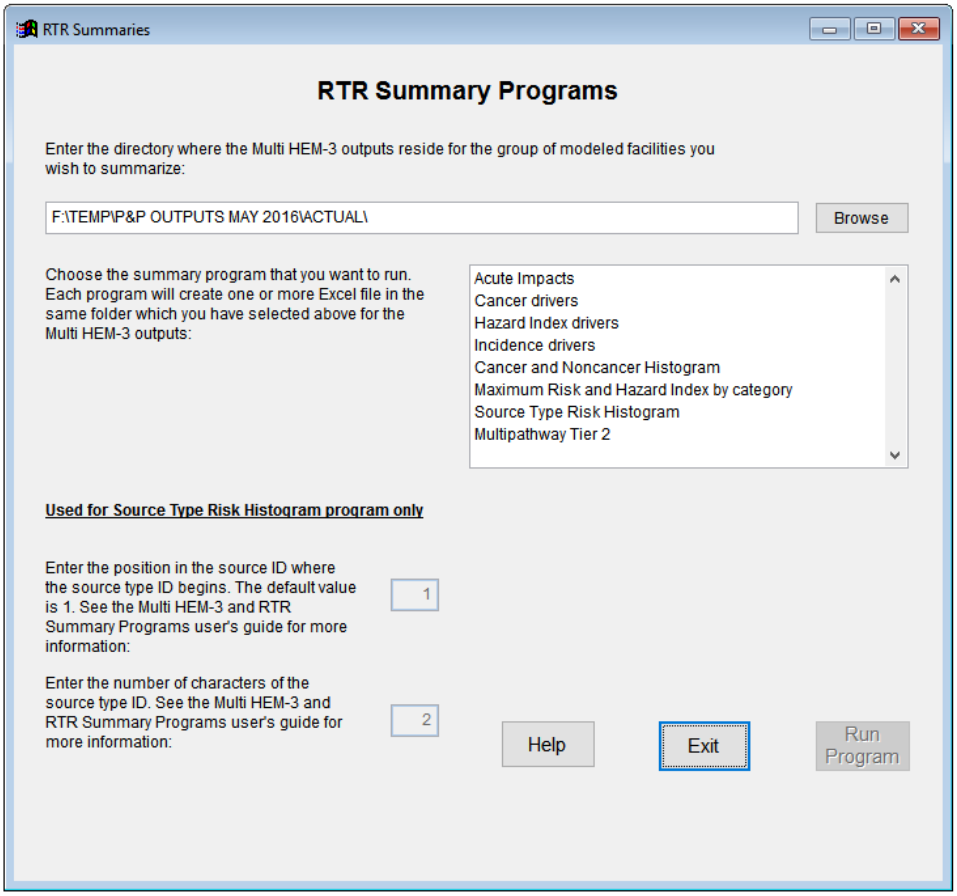


Figure 21. RTR Summary Programs Screen

- The first input box on the screen prompts you to provide the location of the Multi HEM-3 output files to be used as inputs in the RTR Summary Program runs. Click on the *Browse* button next to the box to select the directory path from the location in your computer or type in the directory path information. Note: This path will be saved and appear as the default the next time you start the RTR Summary Programs module (e.g., to run the next Summary Program).

- The second input box lists the RTR Summary Programs available to be run. You can select from eight programs, which summarize different aspects of the Multi HEM-3 outputs. These are:
    - Acute Impacts
    - Cancer Drivers
    - Hazard Index Drivers
    - Incidence Drivers
    - Cancer and Noncancer Histogram
    - Maximum Risk and Hazard Index by Category
    - Source Type Risk Histogram (additional input needed, as described below)
    - Multipathway Tier 2

  Choose the program you want to run by clicking on it (from list in Figure 21). Your selection will be highlighted. Next, click on the ***Run Program*** button. You can select only one program at a time. A message box will appear once the program has completed.

When running the ***Source Type Risk Histogram*** program, two additional bits of information are required indicating where in the source identification (source ID) naming scheme the emission type (or "source type ID") is located. Your source IDs should include characters that indicate the general source type of the particular source, as noted in the footnote to the HAP Emissions and Emissions Location input files in Section 4.1. For example, you might indicate fugitive emissions in the source ID as FG, while you might indicate process stack emissions by the characters PS in the same location of another source ID. You might use numbers in the source ID following these source types to indicate the particular source (e.g., FG001 or PS001).

To instruct the ***Source Type Risk Histogram*** program where to find the source type in each of your source IDs, you must enter a number from 1 to 8 in the third input box on the *RTR Summary Programs* screen indicating where in the source ID the designation for the source type ID begins. The default position is 1. Next, in order to indicate to the program where the source type ID ends (within the source ID), you must also enter the number of characters (from 1 to 8) in the source ID dedicated to indicating the source type. The default length is 2 characters. For example, if your HAP Emissions and Emissions Location input files include the source ID FG001, you would enter a 1 in the third text box to indicate that the source type ID begins in location 1 of the source ID; and you would enter a 2 in the fourth text box to indicate that 2 characters of the source ID are dedicated to describing the source type. (In this example, the "001" of "FG001" refers to the specific source rather than merely the source type.) Note that what may be entered in the fourth text box is related to what you enter in the third text box. For example, if you enter an 8 in the third text box – meaning that the source type ID portion of the source ID begins with the 8th (last) character of the source ID – then the source type ID can only be 1 character long (which you would enter in the fourth text box), because the source ID in its entirety is 8 characters long.

Before running the **Multipathway Tier 2** program, you may wish to edit the pollutant crosswalk spreadsheet that was placed in the *Reference* folder of your *RTR Summaries* directory (located at *RTR Summaries/Reference/Pollutant_CrossWalk.xlsx*). This spreadsheet provides a list of individual pollutant names that are currently designated as Arsenic compounds, PAHs, and Dioxins/Furans. You may edit this spreadsheet by deleting or adding rows (to alter what individual pollutants are included in the groupings) but the "HEM3 Chemical Name" listed in the spreadsheet must match exactly a pollutant name in Multi HEM-3's Dose Response Library. **Note also that the Multipathway Tier 2 summary program and the Source Type Risk Histogram summary program require that the *All Receptors* files be generated by Multi HEM-3.** The generation of the *All Receptors* output files is the default in the Facility List Options input file, so even if this column is left blank, the *All Receptors* files will be generated. However, if you entered **N** in the All Receptors column of the Facility List Options prior to running Multi HEM-3, the Multipathway Tier 2 and Source Type Risk Histogram RTR Summary Programs cannot be run.

Note also that to use the Acute Impacts RTR Summary Program, there must be acute results in the Multi HEM-3 outputs. This means that you must have entered a **Y** in the acute column of the Facility List Options input file, before running Multi HEM-3, for one or more of the modeled facilities. As noted in Section 4.1, a blank in the acute column of the Facility List Options is interpreted by Multi HEM-3 as a default of **N** (for no modeling of acute effects).

The output files of the RTR Summary Programs will be stored in the Multi HEM-3 Output folder with the naming scheme *Sector/SourceCategoryName_output file name.xlsx*. For instance, the output of the Cancer Drivers program for the oil and natural gas (ONG) example would be named *ONG_cancer_drivers.xlsx*.

9. RTR Summary Program Outputs

The 8 RTR Summary Programs described above create 11 summary Excel™ output files, which are listed and briefly described below. Following the listing, Figures 22 through 32 provide sample screenshots for these RTR summary program output files.

- ***Sector/SourceCategoryName_sector_mir_incidence.xlsx***

  Provides the sector incidence for the source category/sector as a whole, and the maximum risk ("sector MIR") occurring at a populated census block or user receptor taking into account multiple facility impacts on receptors located near more than one modeled facility. See Figure 22.

- ***Sector/SourceCategoryName_category_max_risk_and_hi.xlsx***

  Provides the Federal Information Processing Standards (FIPS) code; census block or user receptor ID; and receptor population with the maximum modeled risk and maximum modeled hazard indices in the source category/sector. This summary also lists the facility ID(s) of the facility or facilities that contribute to the sector max risk and sector max TOSHIs at these receptors. Note: This category max risk and HI will equal the highest facility-specific risk and HI listed in the *Facility_max_risk_and_HI.xlsx* Multi HEM-3 output file, except when multi-facility impacts on the same receptor cause the max risk and HI for the entire source category/sector to be greater than the highest facility-specific risk and HI. It should also be noted that user receptors are considered populated receptors of interest, but are assigned a population of 0 in the absence of official Census information. See Figure 23.

- ***Sector/SourceCategoryName_histogram_risk.xlsx***

  Lists the number of people and facilities in the source category at different cancer risk levels (e.g., < 10^{-6} or less than 1 in 1 million, >= 10^{-6} or greater than or equal to 1 in 1 million, >=10^{-5} or greater than or equal to 10 in 1 million, >=10^{-4} or greater than or equal to 100 in 1 million). Note: This program produces population estimates with the one significant figure rounding convention that the EPA has adopted for risk levels. Multiple impacts on the same receptor (from facilities located close to one another) may cause the population numbers from this file to differ from the population numbers provided by the *Facility_cancer_risk_exp.xlsx* Multi HEM-3 output file. See Figure 24.

- ***Sector/SourceCategoryName_histogram_hi_part.xlsx***

  Lists the number of people (P) and facilities (F) in the source category at different HI levels (e.g., <= 1, >1, > 10) for a partial list of HI types of interest (respiratory, neurological, reproductive). Note: this program produces population estimates with the one significant figure rounding convention that the EPA has adopted for HI levels. Multiple impacts on the same receptor (from facilities located close to one another) may cause the population numbers from this file to differ from the population numbers provided by the *Facility_toshi_exp.xlsx* Multi HEM-3 output file. See Figure 25.

- ***Sector/SourceCategoryName_incidence_drivers.xlsx***

  Lists the pollutants emitted and the incidence associated with each individual pollutant for the source category as a whole. See Figure 26.

- ***Sector/SourceCategoryName_cancer_drivers.xlsx***

  Lists the facilities by ID; the MIR modeled at each facility from all pollutants and emission sources acting on the receptor; the predominant pollutant(s) and emission source(s) contributing to at least 90% of that facility's MIR; and the cancer risk associated with each of those pollutant-emission source combinations. See Figure 27.

- ***Sector/SourceCategoryName_hi_drivers.xlsx***

  Lists the facilities by ID; the HI type or TOSHI (respiratory, neurological, liver, etc.); the maximum TOSHI value at each facility from all pollutants and emission sources, the predominant emission source and pollutant combinations contributing to the maximum TOSHI; the pollutant- and source-specific TOSHI value for the maximum receptor; and the percentage each emission source-pollutant combination contributes to the maximum TOSHI. See Figure 28.

- ***Sector/SourceCategoryName_sourcetype_histogram_sorted.xlsx***

  Provides a table showing the maximum cancer risk by emission source type for the category; the number of people estimated at various risk levels (e.g., >= 1 in 1 million, >= 10 in 1 million, >= 100 in 1 million) attributable to each emission source type; and the incidence attributable to each emission source type. See Figure 29.

- ***Sector/SourceCategoryName_acute_impact_flags_all.xlsx***

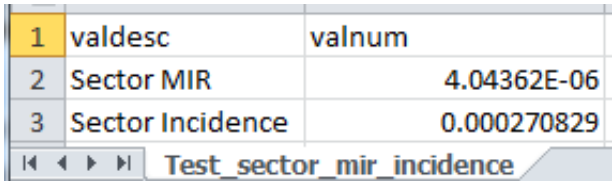
  Lists the facilities by ID; every modeled pollutant emitted and that pollutant's highest modeled acute concentration at each facility (in mg/m^3); the 1-hour dose-response values for each pollutant based on six acute (short term exposure) benchmarks (REL, AEGL1, AEGL2, ERPG1, ERPG2 and IDLH); the hazard quotient (HQ) based on the ratio of the pollutant's acute concentration to the dose-response values for the six benchmarks; and the receptor ID at which this max acute concentration occurs (whether FIPS and block ID for a census block receptor, user receptor ID, or distance and angle for a polar receptor). For a definition of each acute benchmark, see the Outputs section of the Single HEM-3 User's Guide (EPA 2019). The acute_impact_flags summary output is available only if you entered **Y** in the acute column of the Facility List Options input file prior to modeling. Note: The pollutant concentration is provided in mg/m3 in this output (not $\mu g/m^3$ as in Multi HEM-3) because the benchmark values are based on mg not µg). See Figure 30 for an abbreviated sample screenshot.

- ***Sector/SourceCategoryName_multipathway_tier2.xlsx***

  Lists the Sector/Source Category label; the facilities by ID; whether the facility was modeled as an urban or rural dispersion environment; whether the receptor in a given output row is an MIR or the closest receptor to the facility center in a specific octant direction (E, N, NE, NW, S, SE, SW, W); the chemicals the MIR is attributable to (All HAP, As for Arsenic, PAH, or D/F for Dioxins/Furans); whether the closest octant receptor is at a Census block centroid or a discrete user receptor; the FIPS plus Bock ID of the Census block receptors; the latitude and longitude location of the receptor; the population of the receptor; the total inhalation risk of that receptor (for all HAP); the total inhalation risk of that receptor attributable to Arsenic compounds; the total inhalation risk of that receptor attributable to PAHs; and the total inhalation risk of that receptor attributable to Dioxins/Furans. See Figure 31.

- ***Sector/SourceCategoryName_mir_hi_allreceptors.csv***

  Lists every populated Census block and user receptor modeled, including its FIPS and Block or user receptor ID, longitude and latitude, population, sector-level risk, sector-level risk rounded to one significant figure, and sector-level respiratory HI, neurological HI and reproductive HI. This output also provides a facility count of the number of facilities contributing to each receptor's sector-level risk value. The facility count is useful in determining which blocks are impacted by emissions from multiple facilities. This file is produced as a .DBF and as a .CSV, which can be readily converted to an Excel™ spreadsheet. See Figure 32 for an .XLSX spreadsheet converted from a .CSV output.



	valdesc	valnum
1	valdesc	valnum
2	Sector MIR	4.04362E-06
3	Sector Incidence	0.000270829

Test_sector_mir_incidence

Figure 22. Sample Sector_MIR_Incidence RTR Summary Output

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	RISK_TYPE	FIPS	BLOCK	POPULATION	RISK										
2	mir	36045	0613001004	126	4.8218E-07										
3	respiratory	36045	0613001004	126	0.003784775										
4	liver	36045	0613001004	126	0.00016653										
5	neurological	37165	0104001092	16	0.115473556										
6	developmental	36045	0613001004	126	2.37305E-05										
7	reproductive			0	0										
8	kidney			0	0										
9	ocular			0	0										
10	endocrine			0	0										
11	hematological			0	0										
12	immunological			0	0										
13	skeletal			0	0										
14	spleen			0	0										
15	thyroid			0	0										
16	whole body			0	0										
17	Facilities Impacting mir Block	Facilities Impacting respiratory Block	Facilities Impacting liver Block	Facilities Impacting neurological Block	Facilities Impacting developmental Block	Facilities Impacting reproductive Block	Facilities Impacting kidney Block	Facilities Impacting ocular Block	Facilities Impacting endocrine Block	Facilities Impacting hematological Block	Facilities Impacting immunological Block	Facilities Impacting skeletal Block	Facilities Impacting spleen Block	Facilities Impacting thyroid Block	Facilities Impacting whole body Block
18	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259	3604511259
19															

Figure 23. Sample Category_Max_Risk_and_HI RTR Summary Output

1	risklevel	pop	faccnt
2	< 1e-6	2083442	3
3	>= 1e-6	1610	2
4	>= 1e-5		0
5	>= 1e-4		0
6	>= 1e-3		0

Test_histogram_risk

Figure 24. Sample Histogram_Risk RTR Summary Output

1	hilevel	p_resp	f_resp	p_neur	f_neur	p_rpro	f_rpro
2	>1000	0	0	0	0	0	0
3	> 100	0	0	0	0	0	0
4	> 10	0	0	0	0	0	0
5	> 1	18	1	0	0	0	0
6	<= 1	5875757	3	5875775	4	5875775	4

Test_histogram_hi_part

Figure 25. Sample Histogram_HI_Part RTR Summary Output

1	pollutant	incidence
2	Acetaldehyde	3.072E-07
3	Formaldehyde	0.000270522
4	Lead compounds	0
5	Maleic anhydride	0
6	Methanol	0
7	Phenol	0
8	Triethylamine	0

Test_incidence_drivers

Figure 26. Sample Incidence_Drivers RTR Summary Output

	facname	mir	pollname	cancer_rsk	rsk_contrb	source_id
2	05003NEIART$10736	3.03186E-06	Formaldehyde	6.2103E-07	20.48	MEWW0032
3	05003NEIART$10736	3.03186E-06	Formaldehyde	4.1801E-07	13.79	MERP0001
4	05003NEIART$10736	3.03186E-06	Formaldehyde	1.40941E-07	4.65	MESH0027
5	05003NEIART$10736	3.03186E-06	Formaldehyde	1.40941E-07	4.65	MESH0028
6	05003NEIART$10736	3.03186E-06	Formaldehyde	1.40941E-07	4.65	MESH0029
7	05003NEIART$10736	3.03186E-06	Formaldehyde	1.40941E-07	4.65	MESH0030
8	05003NEIART$10736	3.03186E-06	Formaldehyde	1.25683E-07	4.15	MERP0004
9	05003NEIART$10736	3.03186E-06	Formaldehyde	1.13245E-07	3.74	MESH0007
10	05003NEIART$10736	3.03186E-06	Formaldehyde	1.11866E-07	3.69	MESH0008
11	05003NEIART$10736	3.03186E-06	Formaldehyde	7.97531E-08	2.63	MESH0011
12	05003NEIART$10736	3.03186E-06	Formaldehyde	7.97531E-08	2.63	MESH0013
13	05003NEIART$10736	3.03186E-06	Formaldehyde	7.97531E-08	2.63	MESH0015
14	05003NEIART$10736	3.03186E-06	Formaldehyde	7.72161E-08	2.55	MESH0012
15	05003NEIART$10736	3.03186E-06	Formaldehyde	7.3679E-08	2.43	MESH0016
16	05003NEIART$10736	3.03186E-06	Formaldehyde	7.3679E-08	2.43	MESH0017
17	05003NEIART$10736	3.03186E-06	Formaldehyde	7.3679E-08	2.43	MESH0018
18	05003NEIART$10736	3.03186E-06	Formaldehyde	6.19336E-08	2.04	MESH0024
19	05003NEIART$10736	3.03186E-06	Formaldehyde	6.19336E-08	2.04	MESH0025
20	05003NEIART$10736	3.03186E-06	Formaldehyde	6.19336E-08	2.04	MESH0026
21	05003NEIART$10736	3.03186E-06	Formaldehyde	6.03462E-08	1.99	MEEL0014
22	13093NEI46838	4.04362E-06	Formaldehyde	3.68609E-06	91.16	MEEL0001
23	17161NEI56034	0	None	0	0	None
24	21111NEI32872	4.41053E-07	Formaldehyde	3.26975E-07	74.14	MESH0003
25	21111NEI32872	4.41053E-07	Formaldehyde	1.14077E-07	25.86	MESH0004
26	48005NEI12810	9.0286E-07	Formaldehyde	7.98194E-07	88.41	MEST0002
27	48005NEI12810	9.0286E-07	Formaldehyde	9.01073E-08	9.98	MESH0003

Test_cancer_drivers

Figure 27. Sample Cancer_Drivers RTR Summary Output

	facname	hi_type	hi_total	srcid	pollname	poll_hi	poll_hipct
2	FACILITY1	Respiratory HI	1.926522489	MESH0002	Maleic anhydride	1.662206507	86.28
3	FACILITY1	Respiratory HI	1.926522489	MESH0002	Maleic anhydride	0.106214178	5.51
4	FACILITY1	Liver HI	0.007369729	MESH0011	Phenol	0.005095489	69.14
5	FACILITY1	Liver HI	0.007369729	MEST0009	Phenol	0.000860618	11.68
6	FACILITY1	Liver HI	0.007369729	MESH0007	Phenol	0.000229859	3.12
7	FACILITY1	Liver HI	0.007369729	MEST0010	Phenol	0.000214285	2.91
8	FACILITY1	Liver HI	0.007369729	MESH0013	Phenol	0.000172113	2.34
9	FACILITY1	Liver HI	0.007369729	MEST0009	Phenol	0.00016079	2.18
10	FACILITY1	Developmental HI	0.000104187	MERP0004	Methanol	5.17805E-05	49.7
11	FACILITY1	Developmental HI	0.000104187	MERP0001	Methanol	4.68289E-05	44.95
12	FACILITY2	Respiratory HI	0.010661982	MEST0002	Formaldehyde	0.009308649	87.31
13	FACILITY2	Respiratory HI	0.010661982	MESH0003	Formaldehyde	0.001097888	10.3
14	FACILITY2	Liver HI	6.72457E-05	MESH0003	Phenol	6.72457E-05	100
15	FACILITY2	Developmental HI	0.001355088	MEST0008	Methanol	0.001312178	96.83
16	FACILITY3	Respiratory HI	0.398959369	MESP0003	2,4-Toluene diisocyanate	0.356122467	89.26
17	FACILITY3	Respiratory HI	0.398959369	MESK0004	2,4-Toluene diisocyanate	0.039177306	9.82
18	FACILITY3	Neurological HI	0.000122443	METR0001	p-Xylene	5.12074E-05	41.82
19	FACILITY3	Neurological HI	0.000122443	METR0005	p-Xylene	3.39627E-05	27.74
20	FACILITY3	Neurological HI	0.000122443	METR0001	n-Hexane	1.14191E-05	9.33
21	FACILITY3	Neurological HI	0.000122443	METR0005	n-Hexane	7.57357E-06	6.19
22	FACILITY3	Neurological HI	0.000122443	METR0001	Styrene	5.87012E-06	4.79
23	FACILITY3	Neurological HI	0.000122443	METR0001	Toluene	5.12074E-06	4.18
24	FACILITY3	Developmental HI	1.05943E-05	METR0001	Ethyl benzene	6.36971E-06	60.12
25	FACILITY3	Developmental HI	1.05943E-05	METR0005	Ethyl benzene	4.22463E-06	39.88
26	FACILITY3	Immunological HI	0.028306959	METR0001	Benzene	0.01701919	60.12
27	FACILITY3	Immunological HI	0.028306959	METR0005	Benzene	0.011287769	39.88
28	FACILITY3	Whole body HI	0.000474322	METR0001	Acetonitrile	0.00028518	60.12
29	FACILITY3	Whole body HI	0.000474322	METR0005	Acetonitrile	0.000189142	39.88
30	FACILITY4	Respiratory HI	0.052479908	MESP0003	2,4-Toluene diisocyanate	0.047627047	90.75

Test_hi_drivers

Figure 28. Sample HI_Drivers RTR Summary Output

1	Created on Wednesday, September 12, 2012 @ 1:09pm					
2	Prepared by EC/R Inc.					
3						
4	Sector MIR = 4 (in a million)					
5	**Test Maximum Risk by Emission Source Type**					
6		**EL**	**SH**	**ST**	**WW**	**RP**
7	**Cancer Risk**					
8	***Maximum (in 1 million)***	4	2	0.8	0.6	0.5
9	***Number of people***					
10	>= 100 in 1 million	0	0	0	0	0
11	>= 10 in 1 million	0	0	0	0	0
12	>= 1 in 1 million	142	360	0	0	0
13						
14	**Incidence**	1.87608E-05	0.000166312	4.49854E-05	1.42884E-05	2.64554E-05
15						
16						
17						
18						
19						
20						

Risk Sheet2 Sheet3

Figure 29. Sample Sourcetype_Histogram_Sorted RTR Summary Output

facid	pollutant	conc_mg	rel	aegl_1_1h	[4 other benchmark columns]	hq_rel	hq_aegl1	[4 other HQ columns based on 4 other benchmarks]	[4 columns indicating Receptor ID - block ID, user receptor ID, or distance and angle for polar receptor]
05003NEIART$10736	Formaldehyde	2.14972726	.055000000	1.10000000	...	39.08595018	1.954297509	...	...
05003NEIART$10736	Maleic anhydride	3.859246233	.000000000	.000000000	...	0	0	...	...
05003NEIART$10736	Methanol	0.266241437	28.0000000	690.000000	...	0.009508623	0.000385857	...	...
05003NEIART$10736	Phenol	1.323073382	5.80000000	58.0000000	...	0.2281161	0.02281161	...	...
13093NEI46838	Acetaldehyde	0.004339166	.470000000	81.0000000	...	0.009232268	5.357E-05	...	...
13093NEI46838	Formaldehyde	0.967457753	.055000000	1.10000000	...	17.59014097	0.879507048	...	...
13093NEI46838	Lead compounds	2.39097E-07	.000000000	.000000000	...	0	0	...	...
13093NEI46838	Methanol	2.312921054	28.0000000	690.000000	...	0.082604323	0.003352059	...	...
13093NEI46838	Phenol	0.288286189	5.80000000	58.0000000	...	0.049704515	0.004970452	...	...
17161NEI56034	Methanol	0.507239005	28.0000000	690.000000	...	0.018115679	0.000735129	...	...
17161NEI56034	Triethylamine	0.033161706	2.80000000	.000000000	...	0.011843466	0	...	...
21111NEI32872	Formaldehyde	0.046264793	.055000000	1.10000000	...	0.841178053	0.042058903	...	...
21111NEI32872	Methanol	0.030153883	28.0000000	690.000000	...	0.001076924	4.37013E-05	...	...
48005NEI12810	Formaldehyde	0.032116041	.055000000	1.10000000	...	0.583928013	0.029196401	...	...
48005NEI12810	Methanol	24.62154026	28.0000000	690.000000	...	0.879340724	0.035683392	...	...

Test_acute_impact_flags_all

Figure 30. Sample Acute_Impact_Flags_All RTR Summary Output (abbreviated)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Src Cat	Facility ID	Rural/ Urban	Octant or MIR	Chem, Centroid, or Discrete	Fips + Block	Lat	Lon	Population	Total Inhalation Cancer Risk	Total Inhalation AS Cancer Risk	Total Inhalation PAH Cancer Risk	Total Inhalation D/F Cancer Risk
2	PP2_GRP1_	01001110011734935	U	MIR	All HAP	010010208011056	32.42669	-86.46707	4	2.718E-06	1.964E-08	8.995E-08	1.189E-10
3	PP2_GRP1_	01001110011734935	U	MIR	As	010010208011056	32.42669	-86.46707	4	2.718E-06	1.964E-08	8.995E-08	1.189E-10
4	PP2_GRP1_	01001110011734935	U	MIR	PAH	010010206002038	32.4322	-86.46348	7	1.912E-06	1.887E-08	9.074E-08	1.247E-10
5	PP2_GRP1_	01001110011734935	U	MIR	D/F	010010207001083	32.43214	-86.45929	41	1.799E-06	1.886E-08	8.968E-08	1.268E-10
6	PP2_GRP1_	01001110011734935	U	E	Centroid	010010207001097	32.41664	-86.45753	4	1.473E-06	1.61E-08	8.126E-08	1.127E-10
7	PP2_GRP1_	01001110011734935	U	N	Centroid	010010208011008	32.42915	-86.46895	19	2.094E-06	1.762E-08	8.264E-08	1.117E-10
8	PP2_GRP1_	01001110011734935	U	NE	Centroid	010010208011056	32.42669	-86.46707	4	2.718E-06	1.964E-08	8.995E-08	1.189E-10
9	PP2_GRP1_	01001110011734935	U	NW	Centroid	010010206002014	32.43326	-86.47965	1	1.017E-06	1.18E-08	5.916E-08	8.338E-11
10	PP2_GRP1_	01001110011734935	U	S	Centroid	011010060003003	32.35913	-86.46613	362	2.52E-07	4.238E-09	2.369E-08	3.71E-11
11	PP2_GRP1_	01001110011734935	U	SE	Centroid	011010060002008	32.39948	-86.43344	6	5.617E-07	8.112E-09	4.367E-08	6.665E-11
12	PP2_GRP1_	01001110011734935	U	SW	Centroid	010010208011043	32.38553	-86.49652	12	3.341E-07	5.306E-09	2.934E-08	4.522E-11
13	PP2_GRP1_	01001110011734935	U	W	Centroid	010010208011006	32.41929	-86.4954	39	1.467E-06	1.742E-08	8.721E-08	1.248E-10

Figure 31. Sample Multipathway_Tier2 RTR Summary Output

	A	B	C	D	E	F	G	H	I	J	K
1	fips	block	lon	lat	population	mir	rndmir	hi_resp	hi_neur	hi_rpro	faccnt
2	54057	107002010	-79.0532235	39.4770058	2	3.52793E-06	0.000004	0.132795538	0.001836	0.000933	1
3	24001	22002062	-79.0514304	39.4841405	15	3.62617E-06	0.000004	0.125693592	0.001606	0.000968	1
4	1001	208011056	-86.4670665	32.4266935	4	2.73035E-06	0.000003	0.12297539	0.001605	1.21E-05	2
5	24001	22002085	-79.059975	39.4750204	4	2.87223E-06	0.000003	0.100442075	0.001464	0.000771	1
6	24001	22002088	-79.0599523	39.4754696	8	2.57834E-06	0.000003	0.091716928	0.001356	0.000689	1

Test_mir_HI_allreceptors_

Figure 32. Sample MIR_HI_Allreceptors RTR Summary Output

10. Using the Outputs to Summarize Risk Results

This section contains an overview on using the Multi HEM-3 and RTR Summary Program outputs to report the cancer risks, noncancer hazards and acute impacts posed by a group or sector/source category of modeled facilities.

Step 1: Open the *Facility_max_risk_and_HI.xlsx* output to obtain the facility-specific MIR in column B (mx_can_rsk), as well as the facility-specific maximum TOSHI values in each of their respective columns. [Note: the highest facility-specific maximum is not necessarily the overall source category/sector maximum based on concurrent emissions from the entire group of modeled facilities. Multi-facility impacts on the same receptor (from facilities located close to one another) are not accounted for in the *Facility_max_risk_and_HI.xlsx* output file, because each row of this output file is specific to each individual facility.]

Step 2: Open the *Sector/SourceCategoryName_sector_mir_incidence.xlsx* output to obtain the sector MIR in row 2 (based on concurrent emissions from the entire source category/sector of facilities), and the sector incidence in row 3. Open the *Sector/SourceCategoryName_category_maxrisk.xlsx* to identify the census block experiencing the sector MIR, including the block's population. [Note: These two output files report the source category/sector MIR occurring at a populated census block receptor; these outputs will therefore not report the highest risk if the location of highest risk is at a user-defined receptor). Thus the sector MIR will be equal to or greater than the highest facility MIR found in Step 1, except when the highest facility-specific MIR does not occur at a census block receptor. The sector MIR will equal the highest facility-specific census block risk listed in the *Facility_max_risk_and_HI.xlsx* file if there are not multiple impacts from more than one facility on the maximum receptor for the sector as a whole. As noted above, emissions from nearby facilities may impact the same receptor, which sometimes happens when modeling large source categories/ sectors. In these cases, the sector MIR will be higher than the highest facility-specific census block risk.]

Step 3: Open *Sector/SourceCategoryName_cancer_drivers.xlsx* to obtain the pollutant and emission source type driving the modeled risk. To report the cancer drivers, use the HAP from column C (pollname) and the source type from column F (source_id) for *all* rows associated with the facility showing the highest risk. The MIR value from this highest facility will equal that listed in the *Facilty_max_risk_and_HI.xlsx* file from Step 1. Note: This output does not account for 100% of the modeled risk, but rather provides those pollutant-emission source combinations that contribute at least 90% to the facility's MIR (from one or more pollutant-emission source combinations, depending on how many combinations are needed to describe 90% of the modeled risk at each facility).

Step 4: Open *Sector/SourceCategoryName_histogram_risk.xlsx* to obtain the number of people and facilities at various risk levels. The total population within the modeling domain (by default a 50-kilometer radius around each facility or your user-specified radius) equals the sum of cells B2 + B3. This histogram output counts facilities based on modeled risk at populated census block and user receptors. Consequently, this file's facility count numbers will be in accord with the manual counting of facilities at each risk level from the *Facility_max_risk_and_HI.xlsx* file. Note: This output is based on the one significant figure rounding convention adopted by the EPA.

Step 5: Open *Sector/SourceCategoryName_hi_drivers.xlsx* to obtain the pollutant and emission source driving the TOSHI. To report the HI drivers, use the HAP from column E (pollname) and the source from column D (src_id) for all rows associated with the facility showing the highest total TOSHI in column C. The TOSHI value from this highest facility should equal the TOSHI value listed in the *Facilty_max_risk_and_HI.xlsx* file from Step 1. [Note: This output does not account for 100% of the modeled TOSHI, but rather provides those pollutant-emission source combinations that contribute at least 90% to the facility's total TOSHI.]

Step 6: Open *Sector/SourceCategoryName_histogram_hi_part.xlsx* to obtain the number of people (p) and facilities (f) with TOSHI > 1. These numbers are based on the one significant figure rounding convention.

Step 7: Open *Sector/SourceCategoryName_incidence_drivers.xlsx* to obtain the sector-wide incidence attributable to each pollutant. You can also use this file to calculate the percentage each HAP contributes to the sector-wide incidence by determining the ratio of the pollutant-specific incidence to the total incidence. (Calculate the total incidence by summing all pollutant-specific incidences in this file; this total will equal the sector incidence reported above in Step 2.)

Step 8: Open *Sector/SourceCategoryName_sourcetype_histogram.xlsx* to obtain the number of people at various risk levels for each emission source type, and the incidence attributable to each source type. This output also shows the sector MIR (which will equal the sector MIR provided in the *SourceCategoryAcronym_sector_mir_incidence.xlsx* file in Step 2).

Step 9: Open *Sector/SourceCategoryName_acute_impact_flags_all.xlsx*, if you modeled acute impacts, to obtain the hazard quotients (HQs) based on various benchmarks for each pollutant of interest, as well as the highest acute concentration for each HAP. You can perform a manual count using this output file to determine the number of facilities with an HQ >= 1.5 for any benchmark. [Note: An HQ >=1.5 is the mathematical definition of "greater than 1" when using the one significant figure rounding convention.] This output file also provides (in the far right columns) the Receptor ID experiencing the highest acute concentration for each pollutant at every modeled facility.

For additional details regarding the modeling results for each of the facilities in the group or sector/source category, open the individual facility subfolders in the output folder. Section 6.1 contains a list of these facility-specific output files. These files are described in more detail in the outputs section of the Single HEM-3 User's Guide (EPA 2019).

11. Sector/Source Category versus Facility-wide Modeling

The instructions provided in this guide for running Multi HEM-3 and the RTR Summary Programs to estimate the cancer risks, noncancer hazards and acute impacts posed by sector/source category emissions can also be used for modeling on a facility-wide basis. “Facility-wide” denotes all emission processes at an individual facility, not only those emission processes at the facility that are regulated by the EPA under a specific source category or sector.

In some cases, the facility-wide emissions are identical to the source category or sector emissions (i.e., all facility processes are regulated under the same source category or sector). Generally however, there are differences between the sector/source category and facility-wide emission inputs (and therefore outputs), because typically more than one source category or sector is regulated by the EPA at a given facility. Therefore, the facility-wide inputs will have more emission sources and often more pollutants for some of the facilities. With more emission sources, the facility center location may be different from that in the source category run. This different facility center location may result in different census blocks being included or excluded in the modeling. The census blocks affected will be ones that are near the maximum radius of the modeling domain (e.g. at a default radius of 50 km, or at the user-specified radius).

To compare the facility-wide results to the source category results using Excel™ spreadsheets, copy and paste the facility-specific MIRs (or HIs), provided in the *Facility_max_risk_and_HI.xlsx* file for both the source category run and facility-wide run, into the same Excel™ spreadsheet. To be certain that each MIR is correctly paired, sort both output files by Facility ID first, to ensure that the rows in the sector/source category file are in precisely the same order as in the facility-wide file. Alternatively, to avoid human error, you may wish to use Access™ to combine the Excel™ outputs by performing a query on facility ID.

Once the source category results and facility-wide results are paired correctly in the spreadsheet, you can make comparisons, including calculating the percentage that the sector/source category MIR (or HI) contributes to the facility-wide MIR (or HI) for every facility modeled. You can display these comparison calculations in a matrix similar to the one shown in Table 3 below.

Table 3. Sample Matrix Comparing Source Category to Facility-Wide MIR Results

Name of Sector/Source Category	Number of Facilities binned by Facility-Wide MIR (in 1 million)				
Sector/Source Category MIR is X% of Facility-Wide MIR	All	MIR < 1	1≤MIR<10	10≤MIR<100	100≤MIR
>90%					
50-90%					
10-50%					
< 10%					
Total					

12. Using Multi HEM-3 for Modeling Numerous Facilities

The ability of Multi HEM-3 to read Microsoft Excel™ 2007/2010, 2013 and 2016 formatted spreadsheets means that large source categories (many facilities) can be processed. Excel™ 2007/2010, 2013 and 2016 spreadsheets are capable of accommodating up to 1,048,576 rows. This large row capacity would allow for the entry of over 1,000 facilities into Multi HEM-3, depending upon the complexity of each facility.

In practice, however, large source category runs are limited by the amount of disk space and memory available to Multi HEM-3, and the amount of time you may be willing to wait for a model run to complete. In addition, FoxPro™ table file sizes are limited to 2 GB. Therefore, Excel™ formatted inputs that are approaching maximum row capacities may cause Multi HEM-3 to attempt to generate FoxPro™ tables that exceed the 2 GB limit. For example, the *all_outer_receptors.dbf* output file may exceed the 2 GB limit (using the default values in the Facility List Options input file). In this case, Multi HEM-3 will automatically generate multiple *all_outer_receptors.dbf* output files to avoid exceeding the 2 GB limit. However, if non-default modeling values are used (e.g., a modeling distance approaching the maximum domain distance), other output files may become large and exceed the 2 GB limit.

To avoid very long run times, you may want to limit the number of facilities in one modeling run to less than 500. If you need to model more than 500 facilities for a sector/source category, you can break up the input files (to <= 500 facilities per run), then combine output files after all modeling runs are complete. However, this is a recommended and approximate guideline, rather than a strict modeling rule.

13. Multi HEM-3 Errors

This section first discusses three common error messages you may encounter while running Multi HEM-3 and explains how to respond to these messages. Following this discussion is a more complete list of error messages provided by Multi HEM-3, including a description of each. See the Single *HEM-3 User's Guide* for a discussion of the general limitations and uncertainties associated with the model (EPA 2019).

1. If running Multi HEM-3 on a computer with a multi-core processor, you may get two types of random error messages. The first type of message is "The file *filename* already exists. Do you want to overwrite it?" You will have the option of choosing either 'Yes' or 'No'. The correct action is to respond 'Yes'; and Multi HEM-3 will continue processing as if the error never occurred. [Note: This Windows™ issue happens only rarely and occurs because the computer mistakenly executes the "Create File" command in the code before the "Erase File" command.]

2. The second type of message is "The file *filename* is read only." You will have the option of choosing 'Cancel', 'Ignore' or 'Help'. The correct action is to respond 'Cancel'; this will end Multi HEM-3. (If you select 'Ignore', another error will occur and the file specified will not contain the correct data.) Once Multi HEM-3 has stopped, restart the model and Multi HEM-3 will begin processing the facility that was being evaluated when the error occurred. [Note: the errors described here are most likely to occur on machines running Windows® XP (32-bit version).]

3. Another type of error message may occasionally occur when a facility is located in a sparsely populated region. If no census blocks are found in the modeling domain, Multi HEM-3 will fail with the message "There are no census blocks in the area to be modeled. You may have an error in your source and location input file. Click 'OK' to end Multi HEM-3." As instructed, you should click 'OK' to end Multi HEM-3. Then check the locations of the source IDs for the facility in the *Emissions_location.xlsx* input file. If there is one or more source ID(s) with a location far from the rest of the source IDs, skip that facility until you have determined the correct coordinates of the source(s). To do this, open the *facility_list_options.xlsx* file. Next, cut and paste the row with this facility ID to a separate *facility_list_options.xlsx* file with a different name (e.g., *Rerun_facility_list_options.xlsx*). Then, close both files and restart Multi HEM-3. Be sure to keep all of the current inputs (including any of the rows for facilities already modeled in the *facility_list_options.xlsx* file). Click the 'Next' button on each screen and Multi HEM-3 will begin modeling the next facility in the *facility_list_options.xlsx* file.

   If you need to determine new coordinates for any of these sources, first make a copy of the *Emissions_location.xlsx* input file. Rename the new file as necessary to indicate that you have revised this file (e.g., *Emissions_location_revised.xlsx*). Make any necessary changes to the new file. Do not delete any entries in the new Emissions Location file unless also deleting these entries in the HAP Emissions input file. Remember, any changes you make should be made to a *copy* of the Emissions Location and/or HAP Emissions input files, not the original files. When you are ready to rerun the facilities with the revised input files, start Multi HEM-3. On the first input screen, enter the name of the revised Facility List Options input file and the name(s) of the revised version(s) of the Emissions Location and/or the HAP Emissions input files.

   If all the source ID locations look correct, but you are still encountering an error, it is possible that the facility cannot be modeled (e.g., it is located in an unpopulated area). This has occurred, for example, when facilities are located in unpopulated areas of Alaska and unpopulated islands off the coast of California. Using Google Earth™, look at the area where the facility is located to verify that there are no people living in the modeling domain. If this is the case, make a note of why that facility was not modeled and delete the entry for the facility in the *facility_list_options.xlsx* file. Once you have deleted the facility from the file, restart Multi HEM-3 to begin modeling the next facility in the *facility_list_options.xlsx* file. [Note: Remember that when restarting Multi HEM-3, no rows from the *facility_list_options.xlsx* should be deleted except the facility row in question.]

   Note: In some instances, restarting Multi HEM-3 will cause multiple rows for the same facility to be generated in Multi HEM-3's four outputs (described in Section 6.2). This may occur, for example, if you ended Multi HEM-3 to correct an input for a facility that does not need to be removed from the *facility_list_options.xlsx* file, and then restarted Multi HEM-3. If the values are different for any of these redundant rows, determine which row contains the correct updated (rerun) values. To make this determination, open the respective updated facility subfolder and then delete the Multi HEM-3 rows (e.g., in *Facility_max_risk_and_HI.xlsx*) which have different risk, HI, and population values than those shown in the updated facility subfolder's outputs.

Table 4 lists alphabetically a more complete list of error messages you may encounter when running Multi HEM-3, as well as the meaning and cause of these errors, which will allow you to remedy the error for a successful modeling run.

Table 4. Multi HEM-3 Error Messages

Error Message	Meaning / Cause
Error! No buoyant line source parameters for Facility X.	The buoyant line source parameter file does not contain parameters for Facility ID X
Error! The input Excel file: XYZ does not exist. Please correct. HEM3 will stop.	This error occurs when HEM-3 does not find a user-provided input file (spreadsheet) that the user indicated was in a certain location. HEM-3 displays this error when it attempts to import the spreadsheet into DBF for use by the model.
Error! Too many buoyant line source parameter records for Facility X.	Only one set of buoyant line source parameters can be used per facility (containing average values if multiple buoyant line sources are present). The buoyant line source parameter file must have one row of parameters per facility.
Error! Unknown temporal type: "Temporal Type" in file "VarFile" HEM-3 will end. Please correct this file before rerunning HEM-3.	An invalid temporal type is in the emissions temporal variations file. Valid entries are: SEASON, WSPEED, MONTH, HROFDAY, SEASHR, SHRDOW, or SHRDOW7.
For facility "cFacility" the distance entered for modeling census blocks individual is greater than the maximum modeling distance. This will keep HEM-3 from modeling this facility correctly. HEM-3 will end which will allow you to fix the problem.	The radius in which individual census blocks are used as model receptors cannot be larger than the maximum modeling distance.
No Aermod.out produced.	There was an error when HEM-3 attempted to run AERMOD and no AERMOD output file was produced.
No Census blocks were found in the specified domain. HEM-3 cannot continue with the input and will end when you click 'Ok'.	The modeling domain included in the input file for Voronoi modeling does not overlap any census blocks.
No emissions were input. HEM-3 will end when you click on 'OK'.	No emission sources were input.
Some pollutants are missing for one or more receptors. HEM-3 will end.	The input file used for Voronoi modeling must have the same set of chemicals at each receptor network.
The building downwash filename you entered is not in the location you specified. Click 'Ok' to end HEM-3, then either provide the building downwash file or choose not to model building downwash when you restart HEM-3.	Invalid building downwash filename.
The building downwash filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	An invalid Building Downwash input filename was entered.
The emission location filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	An invalid Emission Locations input filename was entered.

Error Message	Meaning / Cause
The emission variations filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the folder names.	Invalid emission variations filename.
The facility list filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	Incorrect facility list input filename was entered.
The file containing landuse information cannot be found. Click 'Ok' to end HEM-3, then either provide the landuse file or choose not to model dry vapor deposition when you restart HEM-3.	Invalid landuse filename.
The file containing particle size data cannot be found. Click 'Ok' to end Multi HEM-3, then either provide the particle size file or choose not to model particle deposition when you restart HEM-3.	A particle size filename was not entered.
The file containing seasonal vegetative cover cannot be found. Click 'Ok' to end HEM-3, then either provide the seasons file or choose not to model dry vapor deposition when you restart HEM-3.	Invalid filename for the seasonal vegetative cover file.
The HAP Emissions filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	An invalid HAP Emissions input filename was entered.
The met station "filename" could not be found in the AERMOD met station library. Check your Facility_List_Options input file to change the name.	The meteorological surface filename included in the Facility_List_Options input file cannot be located in the HEM-3 AERMOD meteorological file library. Check that the filename entered is correct.
The number of concentric circles is either less than 3 or greater than 30 for facility "Facility Name". You must end HEM-3 and correct this problem before you can run HEM-3 successfully.	The number of polar receptor rings must be between 3 and 30 inclusive.
The source_id, "XXXXXX", at facility, "FFFFFF ", does not exist in the Emissions Locations input file. HEM-3 will end so you can find and correct the error in your input file. Once the error has been fixed, run HEM-3 again.	There is a source id in the HAP Emissions input file that is not in the Emissions Location input file. Check for consistency between the two files.
The source_id, "XXXXXX", does not exist in the HAP Emissions input file. HEM-3 will end so you can find and correct the error in your input file. Once the error has been fixed, run HEM-3 again.	There is a source id in the Emissions Location input file that is not in the HAP Emissions input file. Check for consistency between the two files.
The source_preface.txt file is not in the working directory	The file SOURCE_PREFACE.TXT is not in the HEM-3 Working folder. This may be caused by HEM-3 not processing any emission sources.
The user receptor filename you entered is not in the location you specified. Click 'Ok' to end Multi HEM-3, then either provide the user receptor file or choose not to model with user receptors when you restart HEM-3.	Invalid user receptor filename.

Error Message	Meaning / Cause
The user receptor filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	An invalid User Receptor input filename was entered.
The weight percentages for "XXXXXX" in your particle size input file do not total 100. HEM-3 needs to end to allow you to update your input file.	For source_id, XXXXXX, the input particle weight percents do not sum to 100.
There are duplicate source ids in your Emissions Locations input file. HEM-3 will end so you can fix the problem and restart HEM-3.	The Emissions Locations input file must contain unique source ids for each facility. A duplicate source id was found.
There are no census blocks in the area to be modeled. You may have an error in your source and location input file. Click 'Ok to end HEM-3 and then check for errors.	No census blocks were selected to use as receptors in the modeling domain. A common cause of this is incorrect emission source locations.
Unable to find AERMOD Building information in specified file.	Use of building downwash was selected for HEM-3, but no building downwash parameters were found in the BPIP input file.
Unable to open user's guide.	HELP cannot open the user guide file "Multi_HEM3_users_ guide.pdf" which is located in the HEM-3 root directory. You may wish to download another copy of the guide from EPA's HEM webpage: https://www.epa.gov/fera/risk-assessment-and-modeling-human-exposure-model-hem.
You must have DOSE_RESPONSE_LIBRARY.XLSX to successfully run HEM-3. The name of the table has changed since the last version of HEM-3. Be sure you have the correct table in the REFERENCE folder. If you do not have the correct table exit HEM-3.	The file DOSE_RESPONSE_LIBRARY.XLSX is not in the HEM-3 Reference folder.
You must have TARGET_ORGAN_ENDPOINTS.XLSX to successfully run HEM-3. The name of the table has changed since the last version of HEM-3. Be sure you have the correct table in the REFERENCE folder. If you do not have the correct table exit HEM-3.	The file TARGET_ORGAN_ENDPOINTS.XLSX is not in the HEM-3 Reference folder.

14. References

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