The HEM-3 User's Guide

Instructions for using the Human Exposure Model Version 1.5
(AERMOD version) for Single Facility Modeling

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Note about this Version

This User's Guide dated January 2019 is for an updated Version 1.5 of HEM-3, which was first released in 2017. The primary updates include a newer AERMOD version (v.18081) than available in 2017 and a correction within HEM-3's code for the emission units of buoyant line sources, in accordance with 2018 AERMOD updates by the Environmental Protection Agency.

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1. Introduction

The Human Exposure Model Version 1.5. (HEM-3) is a streamlined, but rigorous tool you can use for estimating ambient concentrations, human exposures and health risks that may result from air pollution emissions from a complex industrial facility, or a cluster of facilities located near one another. HEM-3 is designed for use by the EPA, states, local agencies, industry, and other stakeholders. When modeling a single industrial facility or a cluster of facilities very near one another (where the impact of the cluster as a whole is sought), the single version of HEM-3 (Single HEM-3) is used, as described in this User's Guide. HEM-3 is also available in a Multi-facility version (Multi HEM-3), for modeling multiple facilities spread out from one another in a region or across the entire U.S., as in the Risk & Technology Review (RTR) assessments by EPA of entire source categories or sectors. The foundations of Multi HEM-3 are the same as described in this User's Guide for Single HEM-3. However, the instructions for use are different and different inputs are required, as detailed in the Multi HEM-3 User's Guide (available on EPA's website at http://www.epa.gov/fera/human-exposure-model-hem-3-users-guides). Both models are available for download at http://www.epa.gov/fera/download-human-exposure-model-hem.

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1.1 Organization of the HEM-3 User's Guide

This User's Guide is organized into seven chapters:

Chapter 1	Provides a brief introduction to HEM-3, including the main features and requirements of the model.
Chapter 2	Provides instructions for installing HEM-3, including descriptions of the data libraries provided during installation.
Chapter 3	Provides instructions for preparing the input data files needed by HEM-3 and step-by-step instructions for running the model.
Chapter 4	Describes the calculations performed by HEM-3.
Chapter 5	Describes the outputs produced by HEM-3.
Chapter 6	Provides an instructive list of potential HEM-3 Error Messages.
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1.2 Main Features of HEM-3

HEM-3 performs three main operations: dispersion modeling, estimation of population exposure, and estimation of human health risks. To perform these calculations, HEM-3 draws on three data libraries that are provided with the model. These three libraries are: a Chemical Health Effects Library, a Census Library, and a Meteorological Library. HEM-3 uses the Chemical

Health Effects Library of pollutant unit risk estimates (URE) and reference concentrations (RfCs) 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. More information on how EPA uses these dose-response values in risk assessments, including the source for these values is provided in EPA's Dose-Response Assessment webpage (EPA 2018a) and in Section 2.2.1.

The Census Library of census block internal point ("centroid") locations and populations provides the basis of human exposure calculations. The model includes census data from both the 2000 and 2010 censuses. Thus, you can base a HEM-3 modeling run on either census. The Census Library also includes the elevation of each census block, which you have the option of using in dispersion calculations. The Meteorology Library contains meteorological data used for dispersion calculations from over 800 observation stations across the continental U.S., Alaska, Hawaii, and Puerto Rico.

HEM-3 uses the American Meteorological Society - U.S. EPA Regulatory Model (AERMOD) for dispersion modeling. The EPA's modeling guidance indicates that AERMOD represents the state-of-the-science and EPA recommends AERMOD for most industrial source modeling applications for air toxics applications (EPA 2005). AERMOD was developed under the auspices of the American Meteorological Society - Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC) as summarized on EPA's AERMOD website. (See https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod for all AERMOD model documentation as well as links to AERMOD's preprocessors, AERMET, AERMAP, AERSURFACE and BPIPPRIME.)

This version 1.5 of HEM-3 incorporates AERMOD version 18081, which was released in April 2018 (EPA 2018b). AERMOD can handle a wide range of different source types that may be associated with an industrial source complex, including stack sources, area sources, and volume sources. Additionally, AERMOD is capable of modeling polygon, line and buoyant line source types. 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 the modeled facility, and can (optionally) model both dry and wet deposition with or without plume depletion. HEM-3 will also accept user-supplied dispersion modeling results or monitoring data for the concentrations of HAP and other toxic air pollutants. The model identifies all census block locations within the study domain as defined by the default modeling radius around the facility or a radius that you specify. The Census Library includes locations and populations, elevations, and controlling hill heights for all of the approximately 5.5 million census blocks tabulated in the 2000 Census, and 6.3 million blocks tabulated in the 2010 Census (Census 2000, Census 2010).

HEM-3 estimates cancer risks and noncancer "risks" (hazard indices) due to inhalation exposure at census block locations and at other receptor locations that you may specify. The predicted risk estimates are generally conservative with respect to the modeled emissions because they are not adjusted for attenuating exposure factors (such as indoor/outdoor concentration ratios, daily hours spent away from the residential receptor site, and years of lifetime spent living elsewhere than current residential receptor site). HEM-3 computes cancer risks using the EPA's recommended 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. HEM-3 also computes the chronic

noncancer “risk” or hazard index (HI) by comparing modeled concentrations to RfCs for HAP and other toxic air pollutants.

Optionally, HEM-3 can estimate acute (hourly) concentrations for each chemical and receptor site, including the location of the maximum 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 compute the ratio of the maximum acute concentration to the associated benchmark to determine the maximum acute hazard quotient (HQ) for each pollutant of concern. Section 2.2.1 discusses the terms URE, RfC, HI and HQ.

HEM-3 estimates the predicted lifetime cancer risk, chronic noncancer HIs, and (optionally) acute concentrations at every receptor location and also identifies receptor locations where the impact is highest. For these locations, the model gives the concentrations of different chemicals from various emission sources driving the overall cancer risks, chronic HIs, and acute concentrations. The model also estimates the number of people exposed to various cancer risk levels and HI levels. In addition, HEM-3 estimates the average cancer risks, average HI, and the predicted annual cancer incidence for people living within different distances of the modeled emission sources.

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1.3 Differences between Current and Previous Version of HEM-3

HEM was originally developed as a screening tool for exposure assessment in the 1980s (EPA 1986). The original model was upgraded to run in a Windows™ environment and several versions have been released by the EPA prior to this Version 1.5, including in 2007 and in 2014. The 2014 HEM-3 version included many upgrades and enhanced capabilities compared to the 2007 version, which were detailed in the previous 2014 version of this User’s Guide. This HEM-3 version differs from the 2014 model release in several important ways, as listed below and summarized in Figure 1.

- We updated 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 HEM-3 draws upon has been updated to the most recent data available and processed for HEM-3 use: 2016 met data. The 2014 HEM-3 version was based on 2011 met data.

- We made the met library easy to edit by the user. 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 current met station data.

- We incorporated into 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.

Model Feature	2019 HEM-3 (Version 1.5)	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 concatenated in Excel™
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™
Source Types	Point (vertical, capped, and horizontal), area, volume, polygon, line and buoyant line	Point (vertical), area, volume and polygon
User Receptor Identification	User may name discrete user receptors; name identifies receptor in outputs	Identified as non-descript "User-p"
Target Organ-Specific HIs	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
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
Additional Header Row	Input files allow two (bolded) header rows, enabling better explanation of fields	Input files allowed only one header row
CSV Option for Output files	Output files in .CSV format is optional (in addition to .DBF)	Output files in .DBF format; .CSV format not included
Excel™ Outputs	All Excel™ HEM-3 outputs are .xlsx version files	All Excel™ HEM-3 outputs were .xls version files

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

- We added the line and buoyant line source types, as well as capped and horizontal point source types. HEM-3 now allows you to use line, buoyant line, capped point and horizontal point source types in addition to point (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 HEM-3 now identifies user receptors by their name in the output files and maps. User receptors were identified nondescriptly in the 2014 HEM-3.

- We enhanced 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 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 HEM-3 required integer values.

- 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 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 Emissions Location input file).

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

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1.4 Strengths and Limitations of HEM-3

HEM-3 is designed to perform detailed and rigorous analyses of chronic and acute air pollution risks for populations located near industrial emission sources. The HEM-3 model was previously updated with the goal of simplifying the running of AERMOD without sacrificing any of AERMOD's strengths. In keeping with this goal, you can specify complex emission source configurations, including point sources for stacks, area and volume sources for fugitive emissions, obliquely oriented area sources for roadways, line sources for airport runways, buoyant line sources for roof vents, and polygon sources for a variety of area source shapes including entire census tracts. As noted above, the model identifies all census blocks located near the facility. You can also specify the locations of individual houses, schools, plant boundaries, monitors, or other user-defined receptors to model. HEM-3 can account for impacts of terrain, building downwash effects, pollutant deposition and plume depletion. HEM-3 also analyzes multiple pollutants concurrently, with the capability of including particulate and gaseous pollutants in the same model run.

However, HEM-3's framework has some limitations. First, AERMOD, like all air pollutant dispersion models, is subject to uncertainties. Likewise, pollutant UREs for cancer, RfCs for noncancer HI, and benchmarks for acute health effects are subject to uncertainties. Another limitation of HEM-3 is that the model estimates pollutant concentrations and risks for a census block centroid, as defined by the U.S. Census Bureau. Values calculated for this internal point are not representative of the range of values over the entire block, and may not represent where most people reside within a block. Further, these values do not account for the movement of people from their home census blocks to other census blocks, due to commuting or other daily

activities. In addition, as noted above, HEM-3 calculates outdoor concentrations of air pollutants. These concentrations do not account for indoor sources of pollution, or the reduction of outdoor pollution in indoor air.

HEM-3 performs several tests on user input data—such as emissions data and stack parameters—before using AERMOD to calculate air pollution impacts. However, there are some potential problems users may introduce to their input files that HEM-3 may not detect in these initial tests. The model may sometimes run for an hour or more before detecting a problem with the input data. To avoid this, carefully review the model input guidelines to make sure that the contents and format of your input files meet these guidelines before launching HEM-3.

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1.5 Requirements for Running HEM-3

You can use HEM-3 on any Windows™-based personal computer running Windows 98™ or later. Disk space requirements will depend on the number of census and meteorological files that you use. If using Single HEM-3 to model an individual facility, the model requires, at minimum, 100 megabytes (MB) of disk space for a small facility and 1 to 2 gigabytes (GB) for a large, complex facility. Furthermore, disk space requirements can be 10 to 20 times larger (than 2 GB) for complex facilities located in densely populated urban areas (i.e., with many receptors), depending on the modeling options you choose. The full Census and meteorological libraries that you can download in addition to the model require about 4 GB of space. The HEM-3 model also will need a minimum of 4 MB of RAM. Once installed, you can use HEM-3 to model risks and exposures for any location in the U.S., and for a wide range of emission source configurations.

For each model analysis, you should provide emission rates for all to-be-modeled HAP and emission source locations in the form of Excel™ spreadsheet files. HEM-3 requires separate estimates of emission rates of each pollutant, from each emission source. The model also requires detailed information on each emission source, including location, height, emission velocity, emission temperature, and the configuration of non-point emission sources (e.g., area sources which emit with negligible velocity at ambient temperature). You can also use an optional spreadsheet file to provide the dimensions of buildings near emission sources, for use in computing building downwash effects. When modeling particulate emissions, you can use an optional spreadsheet file to provide particle size information and deposition parameters. If you opt to model deposition of gaseous emissions, you will need to provide additional spreadsheet input files describing the land use and vegetation surrounding the facility. In addition to these required and optional input files, the model will ask you to design the model receptor network and to select other modeling options through a series of user input screens, which are discussed in more detail in Section 3 *Running HEM-3*.

This manual is designed to provide all the information you will need to run Single HEM-3. However, some of the options for running HEM-3 draw on advanced features of AERMOD. If unfamiliar with the AERMOD dispersion model, you may need to refer to the AERMOD documentation (available at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod.) in order to develop some of the inputs needed for HEM-3 (EPA 2018b, EPA 2018c). This is particularly true for some of the more complex modeling options, such as plume deposition and depletion, building downwash, temporal and wind speed variations, and complex source configurations.

2. Installing HEM-3

This section provides instructions for downloading and installing the HEM-3 model and required data libraries from the EPA's HEM Download Page.

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2.1 Downloading the HEM-3 Program

The HEM-3 model is available from EPA's HEM Download webpage at http://www.epa.gov/fera/download-human-exposure-model-hem. This site includes general installation instructions, including hardware and software requirements, as well as links to download and install Single HEM-3, Multi HEM-3 and the RTR Summary Programs. (The RTR Summary Programs are post-modeling programs for use with Multi HEM-3, discussed in the Multi HEM-3 User's Guide and available for download from the above link. They are not used after modeling with Single HEM-3.)

Click on the HEM-3 link under "Software available for download.", then select "run" to begin the installation program for HEM-3. The default location for HEM-3 installation is "C:\HEM3\." **Note**: It may be necessary to run the installer with administrator privileges – right click the icon and select "run as administrator".

To change this location, click on the "Change..." button and indicate 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 "_" in lieu of a period.) The model will place the basic files needed to run HEM-3 in the selected folder, and create several subfolders. A screen stating "Installing HEM3" is displayed while the files are being copied to the destination folder. A program called InstallShield™ is used to install all the necessary files to your computer. When the installation is complete, the window called "InstallShield Wizard Completed" appears.

In addition to user-supplied inputs describing the nature and location of the emissions (discussed in Section 3.1), HEM-3 relies upon several data libraries that supply other required inputs for a modeling run. To complete the installation of HEM-3, download the following data libraries:

- the Chemical Health Effects Library containing the HAP-specific dose response values and benchmark values for affected organs (a.k.a. "Toxicity Value Files"); Note: upon installation, HEM-3's Reference folder will include a Dose Response Library and Target Organ Endpoints table current as of January 2019;
- the Census Library containing nationwide files that provide the population numbers and terrain elevation data surrounding a facility location (both 2000 and 2010 census files are available for download); Note: upon installation, HEM-3's Census_2000 and Census_2010 folders will include the census files needed to run the template/sample files only; and
- the Meteorological Library containing met station files with data that characterize typical weather patterns (including wind speed and direction) in the vicinity of a facility; Note: upon installation, HEM-3's MetData folder will include the meteorological files needed to run the template/sample files only.

You will find links to these data libraries on the HEM Download Page. The following sections provide instructions for downloading these files, along with a brief description of each of these data libraries.

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2.2 Downloading Chemical Health Effects Data

HEM-3 uses a chemical health effects library of pollutant UREs and RfCs to calculate population risks. To download these dose response and benchmark values, click on the "Toxicity Value Files" link on EPA's HEM Download Page (http://www.epa.gov/fera/download-human-exposure-model-hem). Before initiating a modeling run, always check for updated versions of these files on the HEM Download Page. When updated files become available, copy these into the "Reference" folder under the HEM-3 directory that you selected during installation. Be sure to unzip the files and verify they are located in the specified folder when finished. The default folder for chemical health effects data is C:\HEM3\Reference.

2.2.1 Description of Chemical Health Effects Library

For each pollutant that is classified as a HAP, the Chemical Health Effects Library includes the following parameters, where available:

- unit risk estimate (URE) for cancer;
- reference concentration (RfC) for chronic noncancer health effects;
- reference benchmark concentration for acute health effects; and
- target organs affected by the chemical (for chronic noncancer effects).

These parameters are based on the EPA's database of recommended dose response values for HAP (EPA 2018a), which is updated periodically, consistent with continued research on these parameters. The URE represents the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent (HAP) at a concentration of 1 microgram per cubic meter ($\mu g/m^3$) in air (*e.g.*, if the URE is 1.5×10^{-6} per $\mu g/m^3$, then 1.5 excess tumors are expected to develop per 1 million people if all 1 million people were exposed daily for a lifetime to 1 microgram of the chemical in 1 cubic meter of air). UREs are considered plausible upper limits to the true value; the true risk is likely to be less but could be greater (EPA 2018d).

The RfC is a concentration estimate of a continuous inhalation exposure to the human population that is likely to be without an appreciable "risk" of deleterious noncancer health effects during a lifetime (including to sensitive subgroups such as children, asthmatics and the elderly). No adverse effects are expected to result from exposure if the ratio of the potential exposure concentration to the RfC, defined as the hazard quotient (HQ), is less than one (1). Note that the uncertainty of the RfC estimates can span an order of magnitude. (EPA 2018d). Target organs are those organs (*e.g.*, kidney) or organ systems (*e.g.*, respiratory) which may be impacted with chronic noncancer health effects by exposure to the chemical in question. The hazard index (HI) is the sum of hazard quotients for substances that affect the same target organ or organ system, also known as the target organ specific hazard index (TOSHI).

The reference benchmark concentration for acute health effects, similar to the chronic RfC, is the concentration below which no adverse health effects are anticipated when an individual is exposed to the benchmark concentration for 1 hour (or 8 hours, depending on the specific acute

benchmark used and the formulation of that benchmark). A more in-depth discussion of the development and use of these parameters for estimating cancer risk and noncancer hazard may be found in the EPA's Air Toxics Risk Assessment Library (2017a), available for download at http://www.epa.gov/fera/risk-assessment-and-modeling-air-toxics-risk-assessment-reference-library.

You can add pollutants and associated health effect values, as needed, to the two Excel™ spreadsheets comprising HEM-3's Chemical Health Effects Library: the dose response library spreadsheet and the target organ endpoints spreadsheet. These files are located in HEM-3's Reference folder:

- C:\HEM3\Reference\Dose_Response_Library.xlsx; and
- C:\HEM3\Reference\Target_Organ_Endpoints.xlsx.

Note: These two Excel™ spreadsheets, Dose_Response_Library and Target_Organ_ Endpoints, may also be saved as .xls versions in your Reference folder. If both .xls and .xlsx versions are present in your Reference folder, however, HEM-3 will select by default files ending in .xlsx. A warning or error message will be displayed if HEM-3 cannot locate either an .xls or .xlsx file.

The dose response library file includes a listing of HAP and other toxic pollutants and the various URE values, RfC values, and acute benchmark values associated with these pollutants. The target organ endpoint table includes a listing of HAP and other toxic pollutants and the organs or organ systems that may be impacted with chronic noncancer health effects by exposure to these pollutants above the RfC level.

Note that each pollutant you list in your facility-specific input files (discussed in Section 3.1) needs to match exactly (the spelling of) a pollutant name in HEM-3's dose response library, and there can be no extra pollutants listed in your facility-specific input files that aren't also listed in the dose response library. The target organ endpoints table need not contain every pollutant listed in your inputs. You should ensure, however, that every pollutant in your input files that has chronic noncancer health effects associated with it – and that you wish to model as such – has an RfC value in the dose response library and is also listed in the target organ endpoints table, with the appropriate organs and organ systems impacted.

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2.3 Downloading Census Data

You will need census files for the region or regions you wish to model. You can obtain nationwide files on the HEM Download Page (http://www.epa.gov/fera/download-human-exposure-model-hem) of EPA's FERA website, for both the 2000 Census and the 2010 Census. Nationwide files are provided on a state-by-state basis in database format (DBF). HEM-3 will access census files to cover the area within 50 kilometers of each facility you are modeling. Multiple states may be needed to model a particular facility if the facility is located within 50 kilometers of a state boundary.

Download, unzip and copy the nationwide census files into the "Census_2000" and "Census_2010" folders, as appropriate, under the HEM-3 folder you selected during installation.

Once unzipped, check to be sure that these files are now located in the specified folders when finished. The default census folders are:

- C:\HEM3\Census_2000; and
- C:\HEM3\Census_2010.

Take care to place the downloaded 2000 Census files in your Census_2000 folder and the downloaded 2010 Census files in your Census_2010 folder. Do not mix these census data sets. Also, do not delete the Census_key.dbf files (C:\HEM3\Census_2000\census_key.dbf and C:\HEM3\Census_2010\census_key.dbf). These were created when HEM-3 was installed and are required for HEM-3 modeling runs. The North Carolina files for both the 2010 Census and the 2000 Census are also included with the installation package to allow running of the template input files (discussed in Section 3) with or without downloading of all nationwide Census files. **Note that 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**.

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2.3.1 Description of Census Library

The HEM-3 Census Library includes census block identification codes, locations, populations, elevations, and controlling hill heights for the over 5 million census blocks identified in the 2000 Census, and the over 6 million census blocks identified in the 2010 Census. The location coordinates reflect the internal "centroid" of the block, which is a point selected by the census to be roughly in the center of the block. For complex shapes, the internal point may not be in the geographic center of the block. Locations and population data for census blocks in the 50 states and Puerto Rico are extracted from the LandView® database for Census 2000 (Census 2000) and from the U.S. Census Bureau website for Census 2010 (Census 2010). Locations and populations for blocks in the U.S. Virgin Islands are from the U.S. Census Bureau website.

U.S. Geological Survey data was used to estimate the elevation of each census block in the continental U.S. and Hawaii. The data used for the 2000 Census elevations have a resolution of 3 arc seconds, or about 90 meters (USGS 2000). The data used for the 2010 Census elevations have a resolution of 1/3 of an arc second, or about 10 meters (USGS 2015). Using analysis tools (ArcGIS® 9.1 software application for the 2000 Census, and ArcGIS® 10 for the 2010 Census), elevation was estimated for each census block in Alaska and the U.S. Virgin Islands. The point locations of the census blocks in Alaska and the U.S. Virgin Islands were overlaid with a raster layer of North American Digital Elevation Model (DEM) elevations (in meters) (USGS 2000). An elevation value was assigned to each census block point based on the closest point in the ArcGIS elevation raster file. HEM-3 uses these block elevations to estimate the elevation of each nearby polar grid receptor and the elevation of each source, if the user does not provide source elevations, as discussed later in this guide.

An algorithm used in AERMAP, the AERMOD terrain processor (EPA 2018e), is used to determine controlling hill heights. These values are used for flow calculations within AERMOD. To save run time and resources, the HEM-3 census block elevation database is substituted for the DEM data generally used in AERMAP. As noted above, the census block elevations were originally derived from the DEM database. To determine the controlling hill height for each census block, a cone is projected away from the block centroid location, representing a 10%

elevation grade. The controlling hill height is selected based on the highest elevation above that 10% grade (in accordance with the AERMAP methodology). The distance cutoff for this calculation is 100 kilometers. (This corresponds to an elevation difference at a 10% grade of 10,000 meters, which considerably exceeds the maximum elevation difference in North America.)

In addition to census block location, population, elevation and controlling hill height data, the HEM-3 Census Library also includes the locations for over 125,000 schools and 1,000 monitors. School location data is for public and private schools spanning pre-kindergarten through high school, and are from the National Center for Education Statistics (NCES) 2006 data for the Census 2000 dataset (NCES 2006a, NCES 2006b), and from the NCES 2009 data for the Census 2010 dataset (NCES 2009a, NCES 2009b). You can obtain monitoring locations from the Air Toxics Data section of the EPA's Technology Transfer Network Ambient Monitoring Technology Information Center (EPA 2017b). Note that the precision of the latitude/longitude location of these monitors varies and, in some cases, is precise to only two decimal places (roughly ± 600 meters), making comparison with HEM-3 modeling results inexact.

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2.4 Downloading Meteorological Data

You can obtain nationwide meteorological data files from the HEM Download Page (http://www.epa.gov/fera/download-human-exposure-model-hem). Each set of meteorological files contains surface data and upper air data and is named beginning with the state abbreviation for the state in which the station is located. Generally, the closest set of stations will be most representative of the meteorology in the modeling domain. However, there are several situations where a different combination of meteorological stations will be more representative. For instance, if the modeling domain is located on the Gulf of Mexico, a surface station near the Gulf may be more representative than an inland station, even if there is a closer inland station.

Download the nationwide meteorological files into the "MetData" folder under the HEM-3 folder you selected during installation. Unzip the meteorological files. After unzipping, verify they are located in the specified folder. The default meteorological folder is "C:\HEM3\MetData." AERMOD uses two files for each meteorological station and these files have extensions of SFC (surface data) and PFL (upper air data).

Note that when you download the HEM-3 model (as described in Section 2.1), the installation package will place an Excel™ spreadsheet named "metlib_AERMOD.xlsx" in your C:\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 may edit this spreadsheet to include additional met station files, but you must provide the new met station data as both SFC and PFL files in your C:\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 may also edit rows in this spreadsheet, or delete met station entries entirely. This spreadsheet, metlib_AERMOD.xlsx, may also be saved as an .xls version file in your Reference folder. (Note: if both .xlsx and .xls versions exist, HEM-3 will select the .xlsx version. A warning or error message will be displayed if HEM-3 cannot locate either an .xls or .xlsx file in your Reference folder.)

2.4.1 Description of Meteorological Library

AERMOD requires surface and upper air meteorological data that meet specific format requirements. HEM-3 includes a library of meteorological data from National Weather Service (NWS) observation stations. The current HEM-3 AERMOD Meteorological Library includes over 800 nationwide locations, depicted in Figure 2.

USEPA meteorologists obtained calendar year 2016 Integrated Surface Hourly Data (ISHD) for over 800 Automated Surface Observation System (ASOS) (http://www.nws.noaa.gov/asos/) stations spanning the entire US, as well as Puerto Rico and the US Virgin Islands, from the National Climatic Data Center (NCDC). The AERMOD meteorological processor, AERMET (EPA 2018f) and its supporting modeling system (AERSURFACE and AERMINUTE) were used to process the meteorological data.

To estimate the boundary layer parameters required by AERMOD, AERMET requires hourly surface weather observations (which may include hourly values calculated from 1-minute data) and the full (*i.e.*, meteorological variables reported at all levels) twice-daily upper air soundings. The surface and upper air stations are paired to produce the required input data for AERMOD. To support AERMET, ASOS 1-minute data for each surface station were obtained from NCDC in a DSI 6405 format. Further, upper air sounding data for the same time period for over 80 observation sites were obtained from the National Oceanic & Atmospheric Administration (NOAA) Earth System Research Laboratory's (ESRL) online Radiosonde Database (see http://www.esrl.noaa.gov/raobs/General_Information.html). These datasets were produced by ESRL in Forecast Systems Laboratory (FSL) format.

AERMET Processing

Utilizing the AERMET meteorological data pre-processor, and the ASOS surface and FSL upper air stations, surface and profile files for input into AERMOD were generated nationwide. The surface stations were paired with representative upper air stations by taking the upper air station closest to each surface station. The AERSURFACE tool was used to estimate the surface characteristics for input into AERMET utilizing land cover data surrounding the surface station. In addition, the AERMINUTE pre-processor was used to process 1-minute ASOS wind data for input into AERMET. The following provides more detail regarding the pre-processors, AERMET and AERMINUTE, used to generate the AERMOD meteorological data.

- AERMET Options: Version 16216 used to process ASOS site data; surface data in NCDC TD-3505 (ISHD) format; upper air data in FSL (all levels, tenths m/s) format; used the ADJ_U* non-Default BETA option to adjust the surface friction velocity (u* or ustar) for low wind speed stable conditions.

- AERMINUTE Options: Version 15272 used for 1-minute ASOS data in TD-6405 format where available.

The surface files were examined for completeness. If more than 10 percent of the data were missing, the station was not considered suitable for the HEM-3 meteorological database. In all, 824 met station pairs were found suitable and are included in the HEM-3 meteorological library, as depicted in Figure 2.

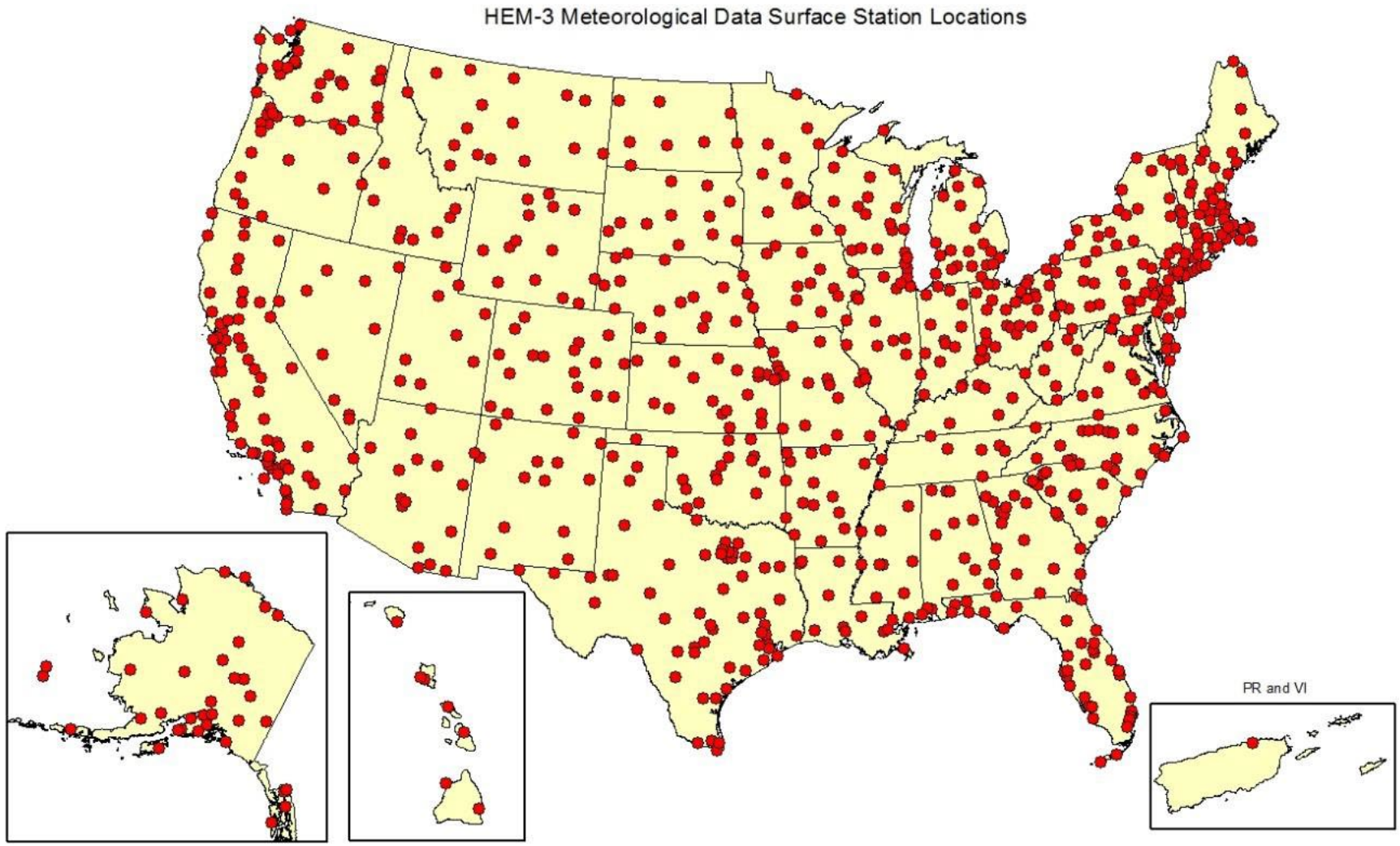

Figure 2. HEM-3 Meteorological Stations

3. Running HEM-3

This section explains how to prepare the required and optional user-supplied input files for HEM-3. It also gives step-by-step instructions for running HEM-3, and provides guidance on the modeling of multiple facilities.

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3.1 Preparing Input Files

HEM-3 requires a series of Excel™ spreadsheet files to specify the emissions and configuration of the facility (or facilities) you are modeling. HEM-3 accepts all Microsoft Excel™ versions (*e.g.*, Excel 2007 and later, and earlier versions including Excel 97-2003 and Excel 5.0/95). However, earlier versions of MS Excel have built-in limitations. For example, Excel 5.0/95 version has a 16,000-row limitation and Excel 97-2003 a 64,000-row limitation, while Excel 2007/2010, 2013 and 2016 have a 1,048,576-row capacity.

To use HEM-3 to calculate ambient pollutant concentrations (using AERMOD), you will need the following two files at minimum:

- an emissions location file, which provides emission source locations and configurations for the facility (or facilities) being modeled; and

- a HAP emissions file, which provides the names and amounts of the pollutants emitted from each emission source at the modeled facility (or facilities).

You may also need the following additional input files, depending on the options you choose to use in your modeling run:

- a polygon vertex file – specifies the location of the polygon and required if the emissions location file contains an area source configured as a polygon (Note: not needed for area sources);

- a buoyant line parameter file – defines the values for a single buoyant line (or the average values for a group of parallel buoyant lines) including building length, building height, building width, line source width, building separation (between the individual lines when multiple lines are averaged) and buoyancy parameter;

- a particle data file – specifies the particle size distribution for various size ranges; required to model particulate deposition;

- the gas parameter file (included) – specifies the parameters needed for modeling dry and/or wet deposition of gaseous pollutants, including diffusion coefficients, cuticular resistance and Henry's Law coefficients; required to model gaseous deposition, whether wet or dry (Note: defaults are provided by the model automatically, but you should provide chemical-specific parameters if available by editing the Gas_param.xlsx file as discussed in Section 3.1.7);

- land use and month-to-season files – describe the land use and vegetative land cover surrounding the facility's emission source(s); required to model dry deposition of gaseous pollutants;

- a building dimensions file – describes building dimensions or other obstructions near emission sources that would produce wake effects; required to model building downwash effects;

- a user-defined receptors file – specifies the locations of additional discrete receptors; required if you want HEM-3 to compute pollutant concentrations and risks at specific locations you specify (e.g., houses, schools, or other sites near the facility); and

- a temporal variations file – provides emission rate factors for individual sources and required to model temporally-varying emissions (e.g., emissions reflecting diurnal, weekly, monthly and seasonal variations or wind speed variations).

In addition to the above list of input files, you can also optionally revise the chemical health effect input files – the dose response values and target organ assumptions – used in the model (as described below in Section 3.1.12).

Finally, as an alternative to running HEM-3 in the standard way – using the emissions location and HAP emissions input files (and optional input files) described above to estimate air concentrations using the AERMOD dispersion model – you can run HEM-3 using previously modeled or monitored pollutant concentrations as inputs. If you choose to run HEM-3 using previously modeled/monitored data, you do not need and will not be able to use the input files described above, since the air concentrations are already determined. However, you will have the option of updating or altering dose response values and target organ assumptions used to estimate risk by HEM-3.

HEM-3 will prompt you to provide the required and optional input file names in a series of input screens. Directly inputting data from spreadsheets avoids having to retype the emission rates and other calculated parameters. However, this method of input has its drawbacks. Notably, HEM-3 will not run successfully unless you have formatted the input files exactly as specified in the format guidelines. Section 3.1.1 describes general rules you should follow to avoid common mistakes. To make formatting easier, specific formatting requirements are exemplified in template input files, which are provided in the default "C:\HEM3\Inputs" folder. **Note**: **If this is your first time running HEM-3, it is highly recommended that you first run the model with the template input files provided, as practice, and to confirm that HEM-3 installed properly on your computer**.

Sections 3.1.2 through 3.1.10 provide detailed guidance on how to prepare the input files when using AERMOD to estimate ambient pollutant concentrations—that is, running HEM-3 in the standard way using a HAP emissions file and an emissions location file (plus optional input files, as desired) to estimate both concentrations and risk. Section 3.1.11 describes how to prepare the input file if providing ambient pollutant concentrations from an external source—that is, if you are going to run HEM-3 using previously modeled or monitored concentration data to estimate risk. Template file names are also provided. Section 3.1.12 explains how to change the dose response values and target organ assumptions in the Chemical Health Effects Library, and how to add pollutants to the Chemical Health Effects Library.

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3.1.1 General Rules for Input Files

- Use a separate Excel™ workbook for each input file. 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).

- Use only one input file worksheet per workbook.

- Match columns with the format specified for the input file. You can use the template input files and substitute actual data for template data. Delete any extra lines of template data.

- Do not insert columns between data columns. HEM-3 will read these, including 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. **You must make the header rows bold-faced**, so that HEM-3 recognizes them as header rows and not data.

- Do not include text in numerical data fields (for instance "<0.001"). 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. 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.). The required units are also indicated in parentheses in the header rows of the template input files which are included with the model.

3.1.2 Emissions Location File

Tables 1 and 2 display the format guidelines for the emissions location file and a sample emissions location input file, respectively. A template input file is provided in the HEM-3 Inputs folder ("C:\HEM3\Inputs\Template_emission_location_file.xlsx"). HEM-3 can model the ambient impacts of multiple emission sources at a single facility or at a cluster of neighboring facilities. The emissions location file should include one record for each individual source (e.g., stack) to be modeled.* This record provides information on the location, size, height, and configuration for each source. (Pollutant data, including the specific chemicals emitted, are provided in the separate HAP emissions file described in Section 3.1.3.)

The "Source ID" is a key parameter in the emissions location file, because HEM-3 uses the Source ID to link the locations to other input files, such as the HAP emissions input file (described below in Section 3.1.3) and other optional input files. Give each Source ID a distinct name. Give different sources unique IDs even if they will be modeled at the same location* The Source ID is currently restricted to eight characters (or fewer) and must contain at least one alphabetic character. Do not use spaces at the beginning or in the middle of the Source ID. Do not include "-" or other typographic characters. In addition, HEM-3 cannot discriminate between upper and lowercase characters. So "ABC" and "abc" would be treated as the same Source ID. If modeling a cluster of facilities, you can use the first few characters of the Source ID to distinguish among the different facilities. For instance, the Source IDs could begin with "F1" for the first facility, "F2" for the second facility, and so on. This will help in the interpretation of model results for the facilities making up the cluster.

You can enter locations as UTM coordinates, or as latitude and longitude. Complete the "coordinate system" field for each source record, and specify which coordinates you are entering. Enter "U" for UTM or "L" for latitude and longitude. If using UTM coordinates, specify the UTM zone (in each emission source record). You must base all coordinates on the NAD83 geographic projection system. Convert any coordinates based on NAD27 to NAD83, before entering them into HEM-3. The National Geodetic Survey (NGS) has developed a computer program called NADCON to convert coordinates between the two NAD systems (NGS 2011). In addition, various commercial computer programs can perform this conversion. The difference between coordinates calculated using the 1927 and 1983 projection systems will vary from location to location, but can be as large as 100 meters.

Use the source type field to indicate whether the emission source is a vertical non-capped point source (P), a capped point source (C), a horizontal point source (H), an area source (A), a volume source (V), a polygon source (I, for upper case "i"), a line source (N), or a buoyant line source (B). A vertical stack is an example of a point (P) source, and requires user-specified exit/release velocity and exit/release temperature for the pollutant plume. Capped and horizontal stacks (C and H, respectively) require the same user-specified parameters as vertical stacks, but are modeled differently than vertical stacks by AERMOD (EPA 2018b, EPA 2018c). Fugitive

* If modeling deposition and/or depletion (described further below in Sections 3.1.6, 3.1.7 and 3.2.3), and pollutant properties are known to vary, we recommend you include a separate record for each pollutant and source—that is, a unique Source ID—for each pollutant being emitted from the same source. This is generally recommended for modeling of gaseous deposition/depletion and for modeling of particulate deposition/depletion if the size or density distributions are known and variable. If you are not modeling deposition/depletion of gaseous phase pollutants, and the same particulate properties are assumed for all pollutants, one record per source in the emissions location input file is sufficient.

emissions are often modeled as rectangular area (A) sources. A conveyor belt, in which release temperature is assumed to be ambient and release velocity zero or negligible, may be simulated as volume (V) sources. A polygon (I) can be used to represent a complex (non-rectangular) area source with many vertices. A polygon (I) may also be used to represent an entire census tract from which a source is modeled as a uniform emission (e.g., for mobile sources). Polygon source types (I) require a Polygon Vertex file as an additional input, as discussed in Section 3.1.4. Line source (N) types can be used to represent roadways and airport runways and may be used instead of similarly shaped area sources.

Unlike Point (P) source types, area (A), volume (V), polygon (I) and line (N) source types in AERMOD all assume ambient pollutant release temperatures and zero or negligible pollutant release/exit velocities. Buoyant line sources (B), on the other hand, are useful in simulating continuous vents along a roofline where the emissions, similar to a stack (point source, P), are released at elevated (non-ambient) temperature and with a non-zero release velocity. However, unlike tall, vertical stack (P) sources where the plume can move in all directions without impediment, buoyant line source types simulate pollutants emitted close to a building's roof where vertical wind shear and building downwash effects become important. Buoyant line (B) source types require a Buoyant Line Parameters file as an additional input, as discussed in Section 3.1.5.

Table 1 provides the format guidelines for each of the required and optional fields in the Emissions Location file. A sample Emissions Location file is provided in Table 2. Note that the sample Emissions Location file (Table 2) indicates the required units in parentheses in the header row, as does the Template Emissions Location file provided with the model (C:\HEM3\Inputs\Template_emission_location_file.xlsx). A more detailed discussion regarding each of the source types follows Tables 1 and 2.

Table 1. Format Guidelines for the Emissions Location Input File

Field	Type	Length, decimal places	Source type(s)*	Description
Source ID**	Character	8,0	all	Source ID is a unique alphanumeric character string up to 8 characters long. It must contain at least one letter, with no spaces or typographical symbols, and must match exactly the Source ID in other input files (*e.g.*, the HAP Emissions file).
Coordinate system	Character	1,0	all	Type of coordinates: L = latitude, longitude; U = UTM.
X-coordinate	Numeric	15,6	all	UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (if System = L) of the center of point or volume sources, or the southwest corner of area sources, or the first vertex of polygon sources, or the starting point of line and buoyant line sources.*** For longitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.
Y-coordinate	Numeric	15,6	all	UTM north coordinate, in meters (if Coordinate System = U) or decimal latitude (if System = L) of the center of point or volume sources, or the southwest corner of area sources, or the first vertex of polygon sources, or the starting point of line and buoyant line sources. *** For latitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.
UTM zone	Numeric	2,0	all	UTM zone where the source is located if Coordinate System = U (blank if coordinate system = L)
Source type	Character	1,0	all	Type of Source*: P = vertical point, C = capped point, H = horizontal point, A = area, V = volume, I = polygon, N = line, B = buoyant line
Length - x	Numeric	7,0	A, N	Length in meters in x-dimension direction for area and line sources. (This is the width for line sources.)
Length - y	Numeric	7,0	A	Length in meters in y-dimension direction for area sources (optional).
Angle	Numeric	5,2	A	Angle of rotation, zero except for area sources. Between 0 and 90 degrees for area sources. (HEM-3 defaults to 0 if left blank).
Lateral	Numeric	9,2	V	Initial lateral/horizontal dimension (in meters) for volume sources.
Vertical	Numeric	9,2	V, A, I, N	Initial vertical dimension (in meters) for volume sources. Optional for area, polygon & line sources.
Release height	Numeric	7,2	V, A, I, N, B	Height of release (in meters) for area, volume, polygon, line and buoyant line sources. Use the top of the source for area and polygon sources and the vertical center for volume sources. (Optional; defaults to 0 if left blank)
Stack height	Numeric	7,3	P, C, H	Release height above ground (in meters) for all point source types.
Diameter	Numeric	7,3	P, C, H	Diameter of stack (in meters) for all point source types.

Table 1. Format Guidelines for the Emissions Location Input File

Field	Type	Length, decimal places	Source type(s)*	Description
Velocity	Numeric	12,7	P, C, H	Velocity at which emissions are released from the stack (in meters/second) for all point source types.
Temperature	Numeric	7,2	P, C, H	Temperature of emissions (in Kelvin) for all point source types.
Elevation	Numeric	6,0	all	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 all source elevations are left blank. Note: if an elevation value is provided by the user for one or more sources, any blanks (i.e., non-entries for other source elevations) will be interpreted by the model as an elevation of 0 meters; therefore, either enter elevations for every source or leave all blank.
X-coordinate2	Numeric	15,6	N, B	Second X coordinate for line and buoyant line source types. UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (if System = L) of the ending point of line and buoyant line sources.*** For longitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.
Y-coordinate2	Numeric	15,6	N, B	Second Y coordinate for line and buoyant line source types. 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.*** For latitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.

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

** If you are modeling deposition and/or depletion, and pollutant properties are known to vary, we recommend a separate record for each pollutant and source. Thus, if modeling gaseous deposition/depletion, use a unique Source ID for each pollutant emitted from a given source (e.g., SAMPLE3A for benzene, SAMPLE3B for 1,3-butadiene). The same is true for particulate deposition/depletion if the particulate properties (size and density distributions) are known and vary for pollutants. If you are not modeling gaseous deposition/depletion and the same properties are assumed for all particulates emitted from a source, one Source ID per emission source is sufficient (e.g., SAMPLE3 for all modeled pollutants from the same source).

*** 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".

Table 2. Sample Input File for Emissions Location

Source ID	Coordinate system (U = UTM, L= latitude, longitude)	Longitude (decimal) or UTM East (m) (X-coord.)	Latitude (decimal) or UTM North (m) (Y-coord.)	UTM zone	Source type (P, C, H = point, A = area V= volume I = polygon N = line B = buoyant line)	Length in x-direction A & N sources (width for N sources) (m)	Length in y-direction A sources (m)	Angle A sources (degrees)	Lateral Dim. V sources (m)	Vertical Dim. V sources or optionally A, I and N sources (m)	Release height A, V, I, N and B sources (m)	*continued*
SAMPLE1	L	-78.884072	35.900550		P [or C or H]							...
SAMPLE2	L	-79.550379	35.336125		A	130	120	45			2	...
SAMPLE3	L	-78.883686	35.900628		V				20	3	10	...
SAMPLE4	L	-78.888792	35.905920		I						30	...
SAMPLE5	L	-78.888430	35.901810		N	20					50	...
SAMPLE6	U	690891	3975044	17	B						40	...

…continued from above (Source type indicated for reference)	Stack height P, C, or H sources (m)	Diameter P, C, or H sources (m)	Velocity P, C, or H sources (m/s)	Temperature P, C, or H sources (°K)	Elevation (m) HEM-3 will calculate if blank for every source	X-coord.2 (decimal) or UTM East N & B sources (m)	Y-coord.2 (decimal) or UTM North N & B sources (m)
…(P, C or H)	50	2.8	21.83	322			
…(A)							
…(V)							
…(I)							
…(N)						-78.886303	35.902183
…(B)						691291	3975044

For point source types, such as a vertical non-capped (P), capped (C) or horizontal (H) stacks, your emissions location file must also include the stack height, diameter, exit velocity, and emission release temperature.

An area source (A) type represents a rectangular area from which emissions are released at ambient temperature and with zero or negligible velocity (*e.g.*, fugitive emissions from a building or tank farm). In AERMOD, area sources can be at ground level, or at a height above ground level. Specifying a release height is optional and defaults to 0. The default orientation for area sources is with one axis in the north-south direction, but you can rotate these sources using the "angle" parameter, which specifies the rotation of the source from north (in the clockwise direction). This feature allows you to simulate emissions from a roadway, using a long, narrow area source (although the line source type may also be used to simulate roadway emissions). The location coordinates (UTM or latitude and longitude) you choose should reflect the southwest corner of the area source. The Length should reflect the length of the source in the easterly direction, or in the southeasterly direction if the source is rotated. The Width should reflect the length in the northerly direction, or the northeasterly direction if the source is rotated.

Unlike AERMOD, where 360-degree rotation is allowed, the angle parameter for HEM-3 area sources must be between 0 and 90 degrees. You can use this angle to represent any possible orientation by switching the length and width (shown in Figure 3). For instance, to model a road segment running from southwest to northeast, use width to specify the road length, and length to specify the road width. To model a road segment running from northwest to southeast, use length to specify road length and width to specify road width.

Volume source (V) types – such as multiple vents and conveyor belts – are specified by a lateral /horizontal dimension, a vertical dimension, and a release height. Emissions from a volume source are assumed to be released at ambient temperature and with zero or negligible velocity. Both the release height and the source location coordinates (UTM or latitude and longitude) should reflect the center of the source.

You can create a polygon source (I) type to represent a polygon with 3 sides or more (≤ 9,999). This source type provides considerable flexibility in specifying the shape of an area source. You can use a polygon source type to reflect census tract boundaries, for example, when modeling mobile source emissions provided at the tract level. An associated polygon vertex input file is required when modeling polygon source types. Section 3.1.4 discusses this in more detail. The shape of the polygon source, as defined in the polygon vertex input file, is determined by a list of X and Y coordinates representing the vertices of the polygon. You can order these X and Y coordinates in either a clockwise or counterclockwise direction. However, the first coordinates entered in the polygon vertex input file must match the coordinates entered in the emissions location file as the location of the first vertex of the polygon. Emissions from polygon source types are assumed to be released at ambient temperature and zero or negligible velocity.

The line source (N) type allows you to specify long, narrow sources, such as roadways or airport runways, based on a start-point and end-point of the line, as well as the width of the line. In this way, the line source can be used as an alternative to a rectangular area source (A). [Note: According to the AERMOD documentation (EPA 2018b), the line source type utilizes the same routines as the area source type and will give identical results, given the same inputs.] Like area, volume and polygon source types, emissions from line source types are assumed to be released at ambient temperature and zero or negligible velocity.

The buoyant line source (B) type was first developed to simulate the transport and diffusion of emissions from aluminum reduction plants in which some emissions from the reduction process escape through continuous (rooftop) ridge ventilators (ERT 1980). In general, the buoyant line source can be used to characterize emissions from a continuous roof vent that spans a portion or the entire building. Emissions from such buoyant line sources result in enhanced plume rise (especially from multiple rows of closely spaced emission lines) and the plume is subject to vertical wind shear and building downwash effects. This source type incorporates an average buoyancy parameter (in meters^4/seconds^3) as well as the average building dimensions (in meters) of the building(s) on which the buoyant line source is located. You must provide HEM-3 with these inputs for your buoyant line source type in a Buoyant Line Parameters Input file, as discussed in Section 3.1.5. For more detailed information regarding the necessary inputs for the buoyant line source type, see the AERMOD documentation (EPA 2018b), as well as documentation for the buoyant line and point source (BLP) dispersion model (ERT 1980).

If considering terrain impacts in your modeling, you can specify the elevation above sea level for each emission source. Enter elevations for every source or for no sources (not a partial list, as blanks/non-entries will be interpreted by the model as a 0 elevation, if a value is entered for one or more other sources). If you do not enter elevation data for each and every emission source (i.e., if you leave the elevation field blank for all sources), then HEM-3 will estimate an elevation for the emission sources based on the elevations of nearby census blocks. This is the case unless you answer "No" to the question on Screen 1 (described in Section 3.2.1) "Do you want to include elevations in the model run?" If you answer "No" to the elevation question on Screen 1, no elevations will be considered in the model run.

It should be noted that HEM-3 will model area, volume, polygon, line, and buoyant line sources as flat surfaces, which can result in strangely located (underground) impacts if the source is located, for example, on a hillside with varying elevations. To avoid this, either model with HEM-3's default elevation option turned off on Screen 1, or break-up the source into smaller pieces with uniform elevations.

It should also be noted that "release height" is different than elevation and indicates the height above the ground elevation where emissions are released (in which the ground is set to an elevation above sea level, or not, as discussed in the preceding paragraphs). For point sources, fill-in the "stack height" field in the Emission Location file to designate the release height. For all other source types (area, volume, polygon, line and buoyant line), you should fill-in the "release height" with the source's height above the ground (in meters). If you leave this field blank, HEM-3 will assume the release height is zero (0), meaning at ground level.

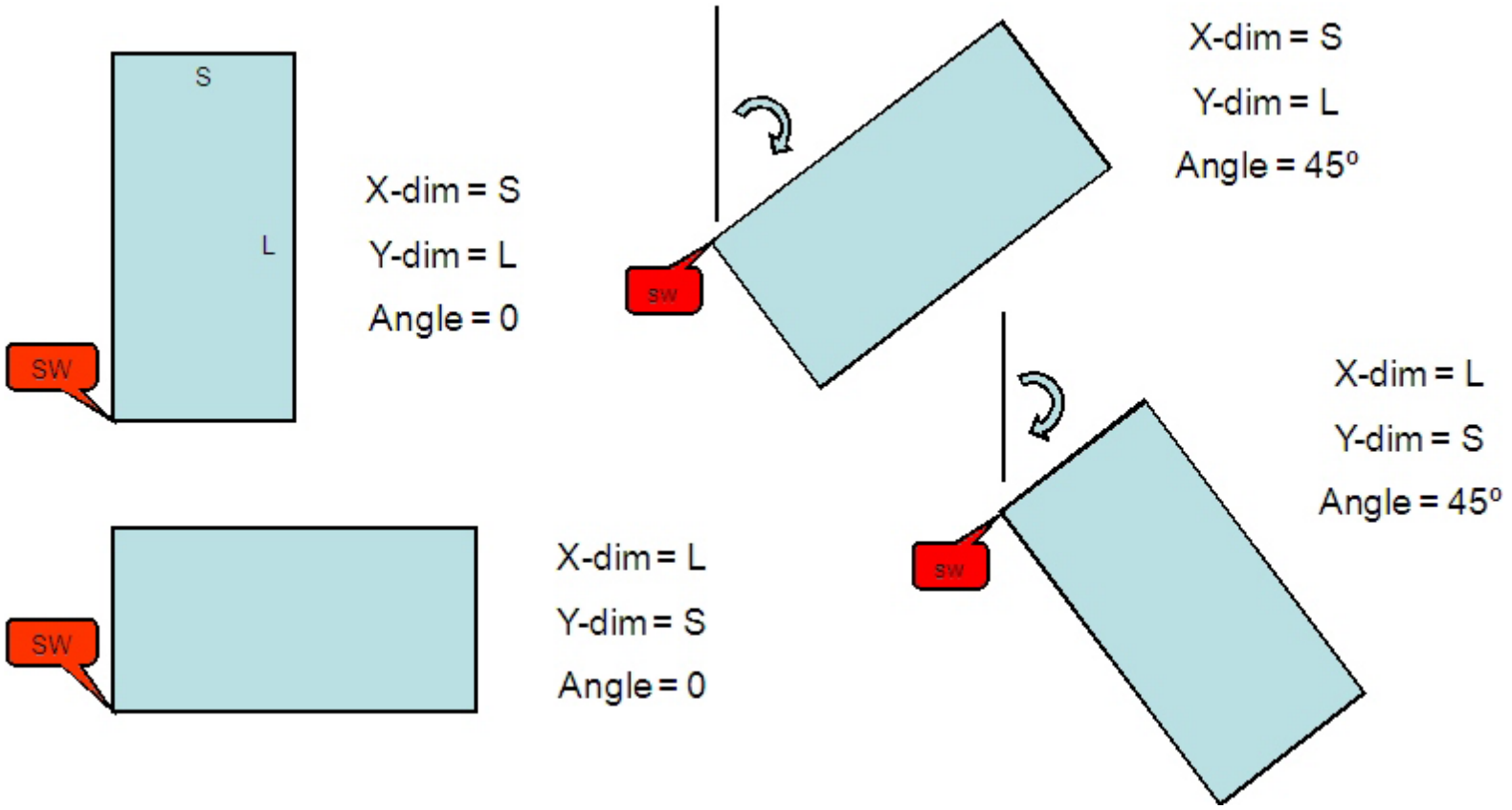

Figure 3. Example Orientations of Area Emission Sources for the HEM-3 Model

3.1.3 HAP Emissions File

Tables 3 and 4 give the format guidelines for the HAP emissions file and a sample HAP emissions input file, respectively. A template input file is provided in the HEM-3 Inputs folder ("C:\HEM3\Inputs\Template_HAP_emission_file.xlsx").

Include one record (row) for each combination of emission source and chemical in your HAP emissions file. Enter each Source ID, taking care to match each named Source ID with a corresponding Source ID in the emissions location file, described in Section 3.1.2.

Each chemical you name in the HAP emissions file must match one of the chemical names listed in the dose response table located in the HEM-3 Reference folder. The dose response values are part of HEM-3's Chemical Health Effects Library, described in Section 2.2. If necessary, you can add pollutants to the two Excel™ spreadsheets comprising HEM-3's Chemical Health Effects Library: the dose response table and the target organ endpoints table. Section 3.1.12 explains how to make changes to the Chemical Health Effects Library.

Table 3. Format Guidelines for the HAP Emissions Input File

Field	Type	Length, decimal places	Description
Source ID	Character	8,0	An alphanumeric character string up to 8 characters in length. It must contain at least one alphabetic character and all Source IDs must match a Source ID used in the emissions location file.
Pollutant	Character	50,0	The pollutant name must correspond to one of the chemical names listed in the dose response library. (see Dose_Response_Library.xlsx in the Reference folder)
Emission Amount	Numeric	20,15	The emitted amount of the pollutant in tons per year.
Percent Particulate	Numeric	7,3	The percent of pollutant emitted as particulate. Required if deposition and/or depletion will be modeled, or if particulate/gaseous percent breakdown is desired in the concentration outputs. If left blank, defaults to 0% particulate when deposition is modeled. If deposition is not modeled, this field is ignored by HEM-3.

Emissions values must be expressed in tons/year. Be sure your input files use the correct units. The smallest value you can model is 1E-15. If modeling deposition, or if you want separate records for particle phase and gaseous phase at each location in the concentration outputs, then you must provide HEM-3 with the breakdown of emissions between gas and particulate matter. This breakdown is expressed as the fraction emitted as particulate for each emission record (each combination of source and chemical). If you are not modeling deposition, then HEM-3 will ignore the field. If you are modeling deposition and have left this field blank, then HEM-3 assumes a default value of 0% particulate.

If modeling deposition with or without depletion, you will need additional input files depending on the type of deposition to be modeled, as described in Section 3.1.6 and Section 3.1.7. If you are not modeling deposition and/or depletion, you will need no additional input file.

Table 4. Sample Input for HAP Emissions

Source ID	Pollutant	Emission Amount (tons/year)	Percent Particulate (%)
SAMPLE1	Antimony compounds	1.2E-01	100.0
SAMPLE1	Chromium (VI) compounds	3.2E-04	100.0
SAMPLE1	Mercury (elemental)	4.2E-02	50.0
SAMPLE1	Dibenzofuran	1.1E-01	90.0
SAMPLE1	Xylenes (mixed)	1.3E+00	0.0
SAMPLE1	Benz(a)anthracene	7.3E-06	11.9
SAMPLE1	Benzo(a)pyrene	2.5E-08	23.9
SAMPLE1	Benzo(b)fluoranthene	2.8E-06	17.8
SAMPLE1	Chrysene	3.2E-05	52.3
SAMPLE1	Dibenz(a,h)anthracene	3.6E-08	99.3
SAMPLE1	Indeno(1,2,3-cd)pyrene	1.1E-07	98.9
SAMPLE2	Chromium (VI) compounds	3.8E-05	100.0
SAMPLE2	Mercury (elemental)	3.6E-04	50.0
SAMPLE2	Nickel compounds	4.8E-03	100.0
SAMPLE2	Selenium compounds	2.1E-04	100.0

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3.1.4 Polygon Vertex Input File for Modeling Polygon Emission Sources

Polygons are useful for complex source configurations at a facility, and for modeling census tracts as sources (*e.g.*, for mobile source emissions modeled uniformly across a tract). If your emissions location file includes one or more polygon sources, you will need to provide HEM-3 with the locations of the polygon vertices in the form of a polygon vertex file.

Include a separate record for each vertex of the polygon in the polygon vertex file. A polygon may have any number of vertices (≥ 3 and ≤ 9,999). Each record must include information for one vertex of the polygon. As noted in Section 3.1.2, you can order the X and Y vertex coordinates in either a clockwise or counterclockwise direction. The first and last vertex must have identical coordinates, and these coordinates must match the coordinates listed as the location of the first vertex of the polygon source in the emissions location file. The first record for each polygon source must also include the number of vertices for the polygon and the total area of the polygon, in meters squared. You can enter coordinates as UTM coordinates, or using latitude and longitude. If using UTM coordinates, you must specify the UTM zone. Base all coordinates on the NAD83 reference system. Convert any coordinates based on NAD27 to NAD83, before entering them into HEM-3 (as explained in Section 3.1.2).

Optionally, you can assign an ID (name) to the polygon. This may be useful, for example, if you are using the polygon to model a Census tract. In this case, you may wish to use the Census tract ID as the polygon ID and enter it in the last column of the Polygon Vertex file.

Tables 5 and 6 give the format guidelines for the polygon vertex file, and a sample polygon vertex input file. A template input file is provided in the HEM-3 Inputs folder ("C:\HEM3\Inputs\Template_poly_vertex_file.xlsx").

Table 5. Format Guidelines for the Polygon Vertex Input File

Field	Type	Length, decimal places	Description
Source ID	Character	8,0	An alphanumeric character string up to 8 characters in length which must begin with an alphabetic character. The Source IDs must be listed as polygon (Type = I) source types in the emissions location input file.
Coordinate system	Character	1,0	Type coordinates: L = latitude, longitude; U = UTM.
X-coordinate	Numeric	15,6	UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (if System = L). For longitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.
Y-coordinate	Numeric	15,6	UTM north coordinate, in meters (if Coordinate System = U) or decimal latitude (if System = L). For latitudes, 5 decimal place accuracy is recommended, corresponding to 1 meter accuracy.
UTM zone	Numeric	2,0	UTM zone where the source is located (if Coordinate System = U).
Num of Vertices	Numeric	4,0	Number of vertices in the polygon. This number must be 3 or greater. The upper limit is 9,999.
Area	Numeric	15,5	Size of area within polygon, in meters squared.
Polygon ID	Character	11,0	Optional. 11-character ID to indicate the name of the polygon (e.g., a Census tract is sometimes modeled as a polygon and the polygon ID may be the Census tract ID).

* For additional information on these variables, please see the AERMOD User's Guide.

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Table 6. Sample Polygon Vertex Input File

Source ID	Coordinate system (U = UTM, L = latitude, longitude)	X-coordinate (decimal) or UTM East (m)	Y-coordinate (decimal) or UTM North (m)	UTM zone	Num of Vertices (≥ 3 and ≤9,999)	Area (m^2)	Polygon ID (optional)
SAMPLE4	L	-95.3586	29.7674		9	402939.4	
SAMPLE4	L	-95.3524	29.7685			0	
SAMPLE4	L	-95.3515	29.7663			0	
SAMPLE4	L	-95.3533	29.7654			0	
SAMPLE4	L	-95.3533	29.7622			0	
SAMPLE4	L	-95.3574	29.7634			0	
SAMPLE4	L	-95.3582	29.7651			0	
SAMPLE4	L	-95.3575	29.7661			0	
SAMPLE4	L	-95.3586	29.7674			0	
SAMPLE5	L	-95.3512	29.7688		11	710176.8	
SAMPLE5	L	-95.3524	29.7685			0	
SAMPLE5	L	-95.3515	29.7663			0	
SAMPLE5	L	-95.3509	29.7653			0	
SAMPLE5	L	-95.3533	29.7654			0	
SAMPLE5	L	-95.3533	29.7622			0	
SAMPLE5	L	-95.3574	29.7634			0	
SAMPLE5	L	-95.3582	29.7651			0	
SAMPLE5	L	-95.3575	29.7661			0	
SAMPLE5	L	-95.3586	29.7674			0	
SAMPLE5	L	-95.3512	29.7688			0	

3.1.5 Buoyant Line Parameter Input File for Modeling Buoyant Line Sources

Buoyant line source types are useful in simulating continuous rooftop vents in which emissions are released at non-ambient (elevated) temperature and non-negligible velocity, as discussed in more detail in Section 3.1.2. If one of the source types in your Emissions Location File is a buoyant line (indicated by a "B"), you must provide HEM-3 with a Buoyant Line Parameter Input File. Because building downwash effects are especially important with buoyant line source types, this additional file must provide HEM-3 with the length, width, and height of the building(s) on which the buoyant line source type (*e.g.*, rooftop vent) sits. In addition, the file must contain the width of the buoyant line source(s), the distance between the buildings (zero for a solitary buoyant line), and the buoyancy parameter for the buoyant line source(s).

Note: The current AERMOD version 18081 allows modeling only a single buoyant line source or cluster per facility, which may be averaged from multiple parallel buoyant line sources at a facility, if present. Multiple model runs may be necessary to adequately model the emissions from multiple non-parallel buoyant line sources at a given facility.

The buoyancy parameter of a line source is calculated from an equation based on the line source length (m) and width (m), the exit/release velocity (m/s), the exit/release temperature (EK), the ambient temperature (EK) and the acceleration due to gravity (9.81 m/s^2), as presented in Equation 2-47 on page 2-37 of the Buoyant Line and Point Source Dispersion

Model User's Guide (ERT 1980).** **These parameters should be average values for the array of buoyant line sources, if multiple parallel buoyant line sources are present** (EPA 2018b). You must provide the following parameters in the Buoyant Line Parameter File:

- Average Building Length (in meters);
- Average Building Height (in meters);
- Average Building Width (in meters);
- Average Line Source Width (in meters);
- Average Separation Distance between Buoyant Lines (in meters); and
- Average Buoyancy Parameter (in meters^4/seconds^3)

Tables 7 and 8 give the format guidelines for the buoyant line parameter input file and a sample buoyant parameter input file. A template input file is provided in the HEM-3 Inputs folder ("C:\HEM3\Inputs\Template_BuoyantLine_parameters.xlsx"). See also the resources shown in footnote ** for helpful guidance in setting up a buoyant line source.

Table 7. Format Guidelines for the Buoyant Line Parameter Input File

Field	Type	Length, decimal places	Description
Average Building Length	Numeric	12, 5	The average length of the building or buildings on which the parallel buoyant line source types are located (in meters)
Average Building Height	Numeric	12, 5	The average height of the building or buildings on which the parallel buoyant line source types are located (in meters)
Average Building Width	Numeric	12, 5	The average width of the building or buildings on which the parallel buoyant line source types are located (in meters)
Average Line Source Width	Numeric	12, 5	The average width of the buoyant line source types (in meters)
Average Separation Distance	Numeric	12, 5	The average separation distance between the parallel buoyant line source types (in meters)
Average Buoyancy Parameter	Numeric	12, 5	The average buoyancy parameter for the buoyant line emission plumes (in meters^4/seconds^3); See BLP Dispersion Model documentation (ERT 1980).

Table 8. Sample Buoyant Line Parameter Input File

Avg Building Length (m)	Avg Building Height (m)	Avg Building Width (m)	Avg Line Source Width (m)	Avg Separation Distance (m)	Avg Buoyancy (m^4/s^3)
454.3	16.76	40	5.73	40.95	3335.49

** In addition, diagrams detailing buoyant line equation parameters and sample calculations are available in: *Source Characterizations: Buoyant Line Sources, Missouri Department of Natural Resources Air Pollution Control Program.* http://dnr.mo.gov/env/apcp/docs/buoyantlinesources10-24-12.pdf on website http://dnr.mo.gov/env/apcp/permitmodeling/sourcecharacterizations.htm. November 12, 2013.

3.1.6 Particle Data Input File for Modeling Particulate Deposition and Depletion

AERMOD can implement dry and wet deposition of both particulate and gaseous emissions and the resulting plume depletion (EPA 2018b). This section describes the input file needed for modeling particulate deposition with or without depletion.

If you are modeling deposition (with or without depletion) of particulate emissions, you must provide HEM-3 with a separate input file describing the particle size distribution. In this file, include a separate record for each particle size range emitted by each emission source. Each record must include 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 particles in the size range. The mass percentages must total to 100 for each emission source.

You must provide information for each of the sources listed in the emissions location file that emit particulate matter (as specified in the particulate fraction column of the HAP emissions input file). Specify particulate information separately for each source that emits particulate matter; if the particle size and deposition information is the same for all emissions at the facility, then repeat this information for each emission source. Tables 9 and 10 provide format guidelines for the particle data input file and a sample input file, respectively. A template file ("C:\HEM3\Inputs\Template_particle_data.xlsx") is provided in the HEM-3 Inputs folder.

Table 9. Format Guidelines for the Particle Data Input File
(needed only for deposition and/or depletion modeling of particle-phase emissions)

Field	Type	Length, decimal places	Description
Source ID	Character	8,0	The Source ID is a unique alphanumeric character string up to 8 characters in length. It must contain at least one alphabetic character, and must match a Source ID in the emissions location file.
Particle diameter	Numeric	5,2	The average diameter (in μm) for the particle size range covered by this record.
Mass fraction	Numeric	5,1	The percentage (by mass) of particulate matter in this size range. Must add up to 100% for each Source ID.
Particle density	Numeric	5,2	The average density of the particles in this size range (in g/cm^3).

Table 10. Sample Input File for Particle Data

Source ID	Particle diameter (μm)	Mass fraction (%)	Particle density (g/cm^3)
SAMPLE1	0.50	72.0	1.0
SAMPLE1	1.50	8.0	1.0
SAMPLE1	2.50	4.0	1.0
SAMPLE1	4.00	4.0	1.0
SAMPLE1	10.00	12.0	1.0
SAMPLE2	0.50	72.0	1.0
SAMPLE2	1.50	8.0	1.0
SAMPLE2	2.50	4.0	1.0
SAMPLE2	4.00	4.0	1.0
SAMPLE2	10.00	12.0	1.0

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3.1.7 Input Files Required for Modeling Gaseous Deposition and Depletion

Gas Parameter Input File for Modeling Wet and Dry Deposition of Gaseous Pollutants

As mentioned in Section 3.1.6, AERMOD can model dry and wet deposition of both particulate and gaseous emissions and the resulting plume depletion (EPA 2018b). This section describes the inputs required for modeling gaseous deposition with or without depletion. To model deposition of gaseous-phase pollutants, you must provide HEM-3 with the necessary information to evaluate the scavenging of these pollutants in precipitation and deposition on vegetation and other surfaces.

When modeling wet, dry, or both wet and dry deposition of gaseous emissions (with or without plume depletion), HEM-3 accesses a gas parameter file containing pollutant properties related to gaseous deposition, which is included in the model's installation files. The model reads these properties from the "Gas_Param.xlsx" file in HEM-3's Reference folder. (The default file pathway is "C:\HEM3\Reference\Gas_Param".) This file includes the following four parameters for each pollutant:

- diffusion coefficient in air (D_a, in cm^2/sec);
- diffusion coefficient in water (D_w, in cm^2/sec);
- cuticular resistance to uptake by lipids for individual leaves (r_{cl}, in sec/cm); and
- Henry's Law coefficient (H, in Pascal-m^3/mol).

Values for these parameters are provided in the Gas Parameter file for 129 pollutants, based on a study by Argonne National Laboratories (Wesely 2002) and a more recent paper which compiles Henry's Law coefficients from numerous other sources (Sander 2015). When modeling a gaseous pollutant that is not listed in the Gas_Param file, HEM-3 uses the following default parameters:

D_a = 0.07 cm^2/sec, D_w = 0.7 cm^2/sec, r_{cl} = 2,000 sec/cm, H = 5.0 Pascal-m^3/mol.

These defaults are based on the logarithmic average of parameters for the 129 pollutant species currently contained in the Gas Parameter file, using one significant figure accuracy. It

should be emphasized that these defaults are averages taken over ranges sometimes in excess of ten orders of magnitude, and may not be appropriate for the pollutants of interest to you.

You can calculate parameters for additional pollutants and add these to the Gas_Param.xlsx file, or revise the values in the Gas_Param file, as appropriate. For example, you may wish to estimate parameters for pollutants of interest to you by calculating averages based on the values in the Gas Parameter file for smaller groups of pollutants in the same chemical family and of similar molecular weight to your pollutant of interest (*e.g.*, PAHs).

Parameter values for additional pollutant species are available in the literature cited here (Wesely 2002 and Sander 2015), as well as in EPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities Final Report (dated September 2005 and available at https://epa-prgs.ornl.gov/radionuclides/2005_HHRAP.pdf). Wesely 2002 also describes a methodology for estimating cuticular resistance, which is less commonly cited in the literature.

It should be noted that the Gas Parameter Input File is needed only when modeling deposition (wet, dry, or both wet and dry) of gaseous pollutants. It is not required to model deposition (of any type) of particulate emissions.

Land Use and Month-to-Season Input Files for Modeling Dry Deposition of Gaseous Pollutants

To quantify dry deposition of gaseous pollutants to vegetation, AERMOD also requires information on the land use and vegetation surrounding the emission source. You must provide this information in Excel™ spreadsheets. In the land use input file, you will enter a code characterizing the average land use for 36 directions from the emission source, at increments of 10 degrees (compass bearing). Table 11 gives the format guidelines for the land use file, and Table 12 shows a sample land use file. A template land use file is provided ("C:\HEM3\Inputs\Template_landuse.xlsx") in the HEM-3 Inputs folder.

The month-to-season input file provides further information on the typical stage of vegetation in the modeled region during each month of the year. As the format guidelines in Table 13 show, this file associates each month with a season code. Table 14 shows a sample input table for the month-to-season file. A template input file is also provided in the HEM-3 Inputs folder ("C:\HEM3\Inputs\Template_seasons.xlsx").

The land use and month-to-season input files are required only if you choose to model dry deposition of gaseous pollutants with or without the resulting plume depletion. These files are not required for modeling wet deposition of gaseous emissions, nor are they required for modeling (wet or dry) deposition of particulate emissions.

Table 11. Format Guidelines for Land Use Input File

Needed only for dry deposition and depletion modeling of gaseous-phase emissions

Field	Type	Length	Description
Direction Sector 1	Numeric	1	Land use code (value = 1-9) for the modeling domain at a compass bearing of 10 degrees from the emission release point: 1 Urban land, no vegetation 2 Agricultural land 3 Rangeland 4 Forest 5 Suburban areas, grassy 6 Suburban areas, forested 7 Bodies of water 8 Barren land, mostly desert 9 Non-forested wetlands
Direction Sector n (n = 2 thru 35)	Numeric	1	Land use code at a bearing of n × 10
Direction Sector 36	Numeric	1	Land use code at a bearing of 360 degrees

Table 12. Sample Input File for Land Use

D01 (10°)	D02 (20°)	D03 (30°)	D04 (40°)	D05 (50°)	...	D36 (360°)
1	9	5	5	6	...	1

Table 13. Format Guidelines for Month-to-Season Input File

Needed only for dry deposition and depletion modeling of gaseous-phase emissions

Field	Type	Length	Description
January	Numeric	1	Seasonal category (value = 1-5) for month 1 (January): 1 Midsummer with lush vegetation 2 Autumn with unharvested crop land 3 Late autumn after frost and harvest, or with no snow 4 Winter with snow on ground 5 Transitional spring with partial green coverage or short annuals
November	Numeric	1	Seasonal category (value = 1-5) for month 11
December	Numeric	1	Seasonal category (value = 1-5) for month 12

Table 14. Sample Month-to-Season Input File

M01	M02	M03	M04	M05	...	M12
4	4	5	5	1	...	4

3.1.8 Building Dimensions Input File for Modeling Building Downwash

Under AERMOD's regulatory option, the effects of building downwash should be taken into account when a building is close enough to impact dispersion from an emission source. Building downwash will affect dispersion predictions when:

- the stack height is less than either 2.5 times the building height or the sum of the building height and 1.5 times the building width; and
- the distance between the stack and the nearest part of the building is less than or equal to five times the lesser of the height or the projected width of the building (EPA 1995, pg. 1–22 and 1–23).

AERMOD incorporates the Plume Rise Model Enhancements (PRIME) algorithms (Schulman 2000) for estimating enhanced plume growth and restricted plume rise for plumes affected by building wakes (EPA 2018g). A building may impact emissions from multiple sources. To model the impact of building downwash, HEM-3 requires information on the configuration of the building when viewed from different wind directions. You must provide this information in a Building Dimensions input file. The following parameters are required in this file:

- building height (keyword=BUILDHGT);
- projected building width perpendicular to the direction of flow (keyword=BUILDWID);
- building length in the direction of flow (keyword=BUILDLEN);
- distance from the stack to the center of the upwind face of the building parallel to the direction of flow (keyword=XBADJ); and
- distance from the stack to the center of the upwind face of the building perpendicular to the direction of flow (keyword=YBADJ).

You must provide these parameters for 36 wind directions, at increments of 10 degrees (compass bearing). Calculate these parameters using the EPA's Building Profile Input Program (BPIP). You can download the BPIP model code and documentation from the EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website at https://www.epa.gov/scram/air-quality-dispersion-modeling-related-model-support-programs#bpip.

Enter building dimensions using the Building Dimensions input file, which can be either an Excel™ file or a text file. Table 15 gives the format guidelines for the Excel™ Building Dimensions input file, and Table 16 shows a sample Excel™ Building Dimensions file. A template Building Dimensions file ("C:\HEM3\Inputs\Template_bldg_ dimensions.xlsx") is provided in the HEM-3 Inputs folder.

Table 17 provides format guidelines for the Building Dimensions file in a text format, which is modeled on a BPIP output file. The main difference in the file formats is that the spreadsheet uses a single record to list the 36 directional values for each parameter, while the text file uses six records for each parameter, with six directions per record. Table 18 shows a sample building dimensions text file. The text file can be taken from a BPIP output, or extracted from an existing AERMOD input file. If extracting the building input from an AERMOD input file, remove any lines not related to the building parameters.

Table 15. Format Guidelines for the Building Dimensions File – Spreadsheet Option

Field	(notes)	Type	Length, decimal places	Description
Keyword		Character	8,0	Specifies which values are given in this record (row), as follows: BUILDHGT = building height BUILDWID = projected building width perpendicular to the direction of flow BUILDLEN = building length in the direction of flow XBADJ = along-flow distance from the stack to the upwind face of the building YBADJ = across-flow distance from the stack to the upwind face of the building
Source ID		Character	8,0	An alphanumeric character string up to 8 characters long. It must contain at least one letter and it must match one of the Source IDs used in the emissions location file.
Value 1	(n = 1)	Numeric	6,2	Dimension or distance (depending on the Keyword parameter) viewed from a compass bearing of 10 degrees from north (clockwise direction) of the emission release point.
Value 2	(n = 2)	Numeric	6,2	Dimension or distance of the building at a bearing of 20 degrees.
Value n	(n = 3 to 35)	Numeric	6,2	Dimension or distance of the building at a bearing of [n × 10] degrees.
Value 36	(n = 36)	Numeric	6,2	Dimension or distance of the building at a bearing of 360 degrees.

Table 16. Sample Building Dimensions Input File – Spreadsheet Option

Keyword	Source ID	Value 1 (10°)	Value 2 (20°)	Value 3 (30°)	...	Value 36 (360°)
BUILDHGT	SAMPLE1	26.00	26.00	26.00	···	26.00
BUILDWID	SAMPLE1	111.07	107.16	100.00	···	111.60
BUILDLEN	SAMPLE1	128.17	115.85	100.00	···	136.60
XBADJ	SAMPLE1	-93.97	-98.48	-100.00	···	-86.60
YBADJ	SAMPLE1	55.54	53.58	50.00	···	55.80

Table 17. Format Guidelines for the Building Dimensions Input File – Text Option

Field	Type	Length	Description or comment
Pathway	Character	2	"SO" – This represents a source pathway record, which corresponds to the code used in the AERMOD input file and the BPIP output file.
Keyword	Character	8	Specifies which values are given in this record (8 characters maximum), as follows: BUILDHGT = building height BUILDWID = projected width perpendicular to the direction of flow BUILDLEN = length in the direction of flow XBADJ = along-flow distance from the stack to the upwind face of the building YBADJ = across-flow distance from the stack to the upwind face of the building 6 records are needed for each keyword.
Source ID	Character	8	Must match Source IDs used in the emissions location file.
Values, 6 per record	Numeric	any length separated by at least one space	Dimension or distance (depending on the Keyword parameter) for every 10 degrees of compass bearing, beginning at a bearing of 10 degrees from the emission release point. Values for bearings of 10 through 60 degrees are given on the first record, 70 through 120 degrees on the second record, and so on through the 6th record.

Table 18. Sample Building Dimensions Input File – Text Option

Path-way	Keyword	Source ID	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6
SO	BUILDHGT	SAMPLE1	Value at 10°	Value at 20°	Value at 30°	Value at 40°	Value at 50°	Value at 60°
SO	BUILDHGT	SAMPLE1	Value at 70°	Value at 80°	Value at 90°	Value at 100°	Value at 110°	Value at 120°
SO	BUILDHGT	SAMPLE1	Value at 130°	Value at 140°	Value at 150°	Value at 160°	Value at 170°	Value at 180°
SO	BUILDHGT	SAMPLE1	Value at 190°	Value at 200°	Value at 210°	Value at 220°	Value at 230°	Value at 240°
SO	BUILDHGT	SAMPLE1	Value at 250°	Value at 260°	Value at 270°	Value at 280°	Value at 290°	Value at 300°
SO	BUILDHGT	SAMPLE1	Value at 310°	Value at 320°	Value at 330°	Value at 340°	Value at 350°	Value at 360°
SO	BUILDWID	SAMPLE1	Value at 10°	Value at 20°	Value at 30°	Value at 40°	Value at 50°	Value at 60°
5 additional BUILDWID records, up to and including value at 360°								
SO	BUILDLEN	SAMPLE1	Value at 10°	Value at 20°	Value at 30°	Value at 40°	Value at 50°	Value at 60°
5 additional BUILDLEN records, up to and including value at 360°								
SO	XBADJ	SAMPLE1	Value at 10°	Value at 20°	Value at 30°	Value at 40°	Value at 50°	Value at 60°
5 additional XBADJ records, up to and including value at 360°								
SO	YBADJ	SAMPLE1	Value at 10°	Value at 20°	Value at 30°	Value at 40°	Value at 50°	Value at 60°
5 additional YBADJ records, up to and including value at 360°								

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3.1.9 User-Defined Receptors File

HEM-3 will automatically calculate ambient concentrations and resultant cancer risks and noncancer hazard indices for all census blocks within the defined modeling domain. You can also specify additional receptor sites to model, such as schools, ambient monitors, residential areas other than the census block's centroid, or facility boundaries. Specify the locations of these sites in the user-defined receptors input file. Use a separate record to indicate the location of each user-defined receptor.

As noted in Section 3.1.2, you must enter locations of each user-defined receptor using UTM coordinates, or in latitude and longitude. If using UTM coordinates, you must specify the UTM zone. Base all coordinates on the NAD83 reference system. Convert any coordinates based on NAD27 to NAD83, before entering them into HEM-3 (as explained in Section 3.1.2).

If you are including elevations in your model run (i.e., if you answer "yes" to "Do you want to include elevations in model run?" on input screen 1, described in Section 3.2.1), you can enter the elevation above sea level for each user-defined receptor. If you leave this field blank in the user-defined receptors input file (and answer "yes" to the elevation question), then HEM-3 will calculate an elevation for each user-defined receptor based on the surrounding census block elevations. Note: If you include more than one user-defined receptor for your facility, you should enter an elevation for all of the receptors, or leave the elevation field blank for all of the receptors to allow HEM-3 to calculate the elevations. (Otherwise, if you enter an elevation for some but not all user-defined receptors, HEM-3 will assign a 0 value to the receptors you left blank.)

In addition, HEM-3 will calculate the controlling hill height for each receptor you enter in the user-defined receptors file. AERMOD uses the controlling hill height for flow calculations. Controlling hill height is defined as the highest elevation that is above a 10% grade from the receptor. For more information on the use of controlling hill heights, see Section 2.3.1.

You should specify a "receptor type code" indicating the type of receptor. A code of "P" represents populated sites, "B" represents facility boundary sites, and "M" represents ambient monitors. Use "P" for any receptor that is being used to represent a location where people may be impacted. These receptors can include houses, schools, businesses, or other populated locations. You may name your user-defined receptors with up to 10 characters and HEM-3 will display these names in the output files for ease of reference. **Names must be unique**.

Tables 19 and 20 give format guidelines for the user-defined receptors file and a sample user-defined receptors table, respectively. A template input file ("C:\HEM3\Inputs\Template_user _receptors.xlsx") is provided in the HEM-3 Inputs folder.

Table 19. Format Guidelines for the User–Defined Receptors File

Field	Type	Length, decimal places	Description
Coordinate system	Character	1,0	Type of coordinates: L = latitude, longitude, U = UTM.
X-coordinate	Numeric	15,6	UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (if System = L).
Y-coordinate	Numeric	15,6	UTM north coordinate, in meters (if Coordinate System = U) or decimal latitude (if System = L).
UTM zone	Numeric	2,0	UTM zone where the receptor is located, if Coordinate System = U.
Elevation	Numeric	6,0	Height of the receptor, in meters. Optional: HEM-3 will calculate if left blank and you are modeling terrain effects.
Receptor type	Character	1,0	Type of receptor: P = school, house, or other populated site; B = facility boundary; M = monitor.
Receptor ID	Alpha-numeric	10	Name of receptor provided by user, containing letters and numbers, no symbols or spaces. This name will be displayed in the outputs.

Table 20. Sample Input File for User–Defined Receptors

Location type (U – UTM, L = latitude, longitude)	X-coordinate (decimal) or UTM East (m)	Y-coordinate (decimal) or UTM North (m)	UTM zone	Elevation (m)	Receptor type (P = school, house, or other populated site B = facility boundary, M = monitor)	Receptor ID
L	-78.88875	35.90016		100	P	SchoolK12
U	560005	441000	16	244	M	Monitor3

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3.1.10 Temporal and Wind Speed Emission Variation Input Files

AERMOD computes hourly concentration data based on user-supplied emission inputs. AERMOD also gives you the option of specifying variable emission rate factors for individual sources. You can base these source-specific factors on different temporal scales—such as season, month, day of the week, and hour of day—or on wind speed. For HEM-3 to calculate temporal or wind speed emission variations, AERMOD requires information on the type of variation and the factors to use for each variation. You will supply this information in a Temporal Variation Input file in the form of an Excel™ spreadsheet. The types of variations are:

- HROFDY – emission rates vary by hour of the day, number of factors is 24;
- 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;
- 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 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 factors is 864; and
- WSPEED – emission rates vary by wind speed (user-defined or default upper bounds in m/s of 1.54, 3.09, 5.14, 8.23, 10.8 and no upper bound), number of factors is 6.

Table 21 provides the format guidelines for the temporal variation input file. Tables 22, 23, 24, and 25 provide sample temporal variation input files for seasonal emission variations (4 factors), hour of day emission variations (24 factors), monthly emission variations (12 factors), and both season and hour of day emission variations (96 factors), respectively. Template input files are also provided (*e.g.*, “C:\HEM3\Inputs\Template_temporal_month.xlsx”) in the HEM-3 Inputs folder.

Table 26 provides a sample input file for varying source-specific emissions by wind speed. A template input file (“C:\HEM3\Inputs\Template_temporal_wspeed.xlsx”) is provided in the HEM-3 Inputs folder.

See the AERMOD User’s Guide (EPA 2018b) for more detailed information on the temporal and wind speed factors available for varying source-specific emissions.

Table 21. Format Guidelines for the Temporal Variation Input Files

Field	Type	Length	Description
Source ID	Character	8	Source ID is a unique alphanumeric character string up to 8 characters long. It must contain at least one letter and it must match one of the Source IDs used in the emissions location file.
Variation	Character	8	Type of variable emission rates being used (HROFDY, SEASON, MONTH, WSPEED, SEASHR, SHRDOW, SHRDOW7 or MHRDOW). *
Factor 1	Character	8	First factor to be applied to emission rate.
Factor 2	Character	8	Second factor to be applied to emission rate.
Factor 3	Character	8	Third factor to be applied to emission rate.
…	…	..	…
Factor n	Character	8	n^{th} factor to be applied to emission rate.

* Each emission variation type has a set number of "n" factors. The number of factors are as follows: HROFDY=24, SEASON=4, MONTH=12, WSPEED=6, SEASHR=96, SHRDOW=288, SHRDOW7=672, MHRDOW=864. See the Template temporal input files for examples. For additional information on these variables, please see the AERMOD User's Guide.

Table 22. Sample Temporal Input File for Varying Emissions by Season (4 factors)

Source ID	Variation	Winter	Spring	Summer	Fall
SAMPLE1	SEASON	0.50	0.75	1.00	1.00

Table 23. Sample Temporal Input File for Varying Emissions by Hour of Day (24 factors)

Source ID	Variation	Hour factor (1)	Hour factor (2)	Hour factor (3)	Hour factor (4)	Hour factor (5)	Hour factor (6)	…	Hour factor (12)
SAMPLE1	HROFDY	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	…	1.4356
		(13)	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**	**…**	**(24)**
SAMPLE1	HROFDY	1.3959	1.2728	0.1079	1.5255	1.5255	1.5519	…	1.799

Table 24. Sample Temporal Input File for Varying Emissions by Month (12 factors)

Source ID	Variation	JAN	FEB	MAR	APR	MAY	JUN	…	DEC
SAMPLE1	MONTH	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	…	1.4356

Table 25. Sample Temporal Input File for Varying Emissions by Season and Hour of Day (96 factors)

Source ID	Variation	Season-hour Factor	Season-hour Factor	Season-hour Factor	Season-hour Factor	Season-hour Factor	Season-hour Factor	Season-hour Factor	Season-hour Factor
		Winter 1	**Winter 2**	**Winter 3**	**Winter 4**	**Winter 5**	**Winter 6**	**…**	**Winter 12**
SAMPLE1	SEASHR	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	…	1.4356
		Winter 13	**Winter 14**	**Winter 15**	**Winter 16**	**Winter 17**	**Winter 18**	**…**	**Winter 24**
SAMPLE1	SEASHR	1.3959	1.2728	0.1079	1.5255	1.5255	1.5519	…	1.799
		Spring 1	**Spring 2**	**Spring 3**	**Spring 4**	**Spring 5**	**Spring 6**	**…**	**Spring 12**
SAMPLE1	SEASHR	1.9045	1.9475	1.4684	1.0435	0.8305	0.6952	…	0.3979
		Spring 13	**Spring 14**	**Spring 15**	**Spring 16**	**Spring 17**	**Spring 18**	**…**	**Spring 24**
SAMPLE1	SEASHR	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	…	1.4356
		Summer 1	**Summer 2**	**Summer 3**	**Summer 4**	**Summer 5**	**Summer 6**	**…**	**Summer 12**
SAMPLE1	SEASHR	1.3959	1.2728	0.1079	1.5255	1.5255	1.5519	…	1.799
		Summer 13	**Summer 14**	**Summer 15**	**Summer 16**	**Summer 17**	**Summer 18**	**…**	**Summer 24**
SAMPLE1	SEASHR	1.9045	1.9475	1.4684	1.0435	0.8305	0.6952	…	0.3979
		Fall 1	**Fall 2**	**Fall 3**	**Fall 4**	**Fall 5**	**Fall 6**	**…**	**Fall 12**
SAMPLE1	SEASHR	0.2138	0.1433	1.2928	0.098	0.1342	0.3301		1.4356
		Fall 13	**Fall 14**	**Fall 15**	**Fall 16**	**Fall 17**	**Fall 18**	**…**	**Fall 24**
SAMPLE1	SEASHR	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	…	1.4356

Table 26. Sample Input File for Varying Emissions by Wind Speed (6 factors)

Source ID	Variation	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Cat. 6
SAMPLE1	WSPEED	0.2138	0.1433	1.2928	0.098	0.1342	0.3301

3.1.11 User-Supplied Modeled or Monitored Pollutant Concentration Input Files

Most applications of HEM-3 use emission source information to compute ambient pollutant concentration impacts using AERMOD. Alternatively, you can provide pollutant concentrations from an external model (previously run AERMOD or another model). You can also provide pollutant concentrations obtained from monitoring data. HEM-3 can use this external data to compute risk at receptor locations. However, when previously modeled or monitored concentration data is used, HEM-3 cannot compute the contributions of different emission sources (see discussion in Section 5 *Outputs of HEM-3*).

You can provide pollutant concentrations for an array of monitored or modeled locations. HEM-3 uses a Voronoi Neighborhood Averaging approach to interpolate pollutant concentrations and associated risks for all census blocks located within the study domain. Section 4.4 discusses the Voronoi averaging approach in more detail. This approach is intended to be used with monitoring data or gridded modeling data for a large collection of emission sources. It is not intended to be used with modeling data produced with a polar coordinate system for a single facility. In that situation, you should run HEM-3 in the standard way. Forcing polar array data into the Voronoi averaging system will cause a loss of data integrity regarding the spatial relationship between the emission source(s) and the receptors. Furthermore, this approach should only be used when the distance between each user-supplied concentration (e.g., grid node) and nearby HEM-3 receptor is less than the distance between that HEM-3 receptor and a contributing emission source. If a HEM-3 receptor is closer to a contributing emission source than to the user-supplied concentration (from which the HEM-3 receptor concentration will be interpolated), then the concentration and risk at that HEM-3 receptor may be underestimated, because the contribution of the nearby emission source is not sufficiently accounted for in the interpolation. In general, the lower the spatial resolution of the user-supplied concentrations, the more likely that HEM-3 receptor concentrations and risk will be underestimated by this Voronoi approach.

Table 27 gives format guidelines for the user-supplied pollutant concentration file, and Table 28 shows a sample user-supplied pollutant concentration input file, based on a UTM coordinate system. A template input file is provided based on the latitude and longitude coordinate system in the HEM-3 Inputs folder ("C:\ProgramFiles\HEM3\Inputs\Template_User_Conc_ input.xlsx"). You will need one record for each combination of pollutant and location. The first column of the input file specifies the coordinate system used: latitude and longitude (“L”) or UTM (“U”). If you select UTM coordinates, you must specify the UTM zone. Base all coordinates on the NAD83 reference system. Convert any coordinates based on NAD27 to NAD83, before entering them into HEM-3 (as explained in Section 3.1.2). In the second column, you must assign a unique numerical identifier for each separate location for which you are providing concentration data. Next, specify the coordinates of the pollutant concentration locations in columns 3 and 4. Enter the UTM zone in column 5 (if you selected UTM coordinates in column 1, otherwise leave blank). Enter the pollutant name in column 6. This name must match a pollutant name in the dose response library in HEM-3’s Reference folder.

To model multiple pollutants in a single run, you must provide a concentration for all of the modeled pollutants at all of the modeled or monitored locations. When modeling multiple pollutants, use the same location ID in all of the pollutant records for a given location. The final two columns of the input file include the annual average pollutant concentration, and the

optional maximum short-term (generally hourly) concentration. If you are not modeling short-term (acute) impacts, leave the last column blank.

Table 27. Format Guidelines for User-Supplied Pollutant Concentration Data

Field	Type	Length, decimals places	Description
Coordinate system	Character	1,0	Type of coordinates: L = latitude, longitude; U = UTM.
Location ID	Character	8,0	Location ID is a unique number for each modeled location.
X-coordinate	Numeric	15,6	UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (is System = L). If longitude, 5 decimal place accuracy is recommended since it corresponds to 1 meter accuracy.
Y-coordinate	Numeric	15,6	UTM north coordinate, in meters (if Coordinate System = U) or decimal longitude (is System = L). If longitude, 5 decimal place accuracy is recommended since it corresponds to 1 meter accuracy.
UTM zone	Numeric	2,0	UTM zone where the source is located (if Coordinate system = U) otherwise, blank.
Pollutant	Character	50,0	Name of pollutant that must match a pollutant in the dose response library.
Chronic Concentration	Numeric	20, 15	Chronic concentration in μg/m^3.
Acute Concentration	Numeric	20, 15	Acute concentration in μg/m^3, optional

Table 28. Sample Input File for User-Supplied Pollutant Concentration Data

Coordinate System (U = UTM L = latitude, longitude)	Location ID	X-coordinate (decimal) or UTM East (m)	Y-coordinate (decimal) or UTM North (m)	UTM zone	Pollutant	Chronic concentration (μg/m^3)	Acute concentration (μg/m^3)
U	1	688072	3974765	17	Benzene	0.00001	
U	2	688072	3974665	17	Benzene	0.0001	
U	3	688072	3974565	17	Benzene	0.01	
U	4	688072	3974465	17	Benzene	1	
U	5	688222	3974765	17	Benzene	0.0001	
U	1	688072	3974765	17	Benzene	0.00001	
…	…	…	…	…	…	…	…

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3.1.12 Changing the Chemical Unit Risk Estimates and Health Benchmarks Input Files

As discussed in Section 2.2.1, the Chemical Health Effects Library contains chemical health effects data, including dose response toxicity values. You can make changes to the Chemical Health Effects Library by editing the Excel™ spreadsheet files that comprise the library—entitled "Dose_Response_Library.xlsx" and "Target_Organ_Endpoints.xlsx". These files are located in HEM-3's Reference folder. Add new chemicals to these files, as necessary, by checking for updated toxicity values on EPA's Dose Response Assessment webpage (EPA 2018a).

When adding new chemical names to the library, use the same spelling as used in the HAP emissions input file. The Chemical Abstracts Service (CAS) number field in the Chemical Health Effects Library is optional. If you do not specify a cancer URE for a new chemical, then the URE will be assumed to be 0 (zero) and cancer risks will not be evaluated for that chemical. Similarly, if you do not specify a noncancer RfC for a new chemical, HEM-3 will not calculate adverse noncancer health effects. If a noncancer RfC is indicated in the dose response table for a user-added pollutant, enter the pollutant in the target organ endpoints table and indicate what organs or organ systems may be impacted.

Make any changes to the Chemical Health Effects Library prior to running HEM-3 via the user interface screens (described next in Section 3.2).

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3.2 Step-by-Step Instructions for Running HEM-3

After you have prepared the input files for the modeling application, start HEM-3 by double clicking on the HEM-3 icon on your desktop (if you created the icon) or clicking on the *HEM3.exe* file in Windows Explorer™. The HEM-3 title screen will be displayed.

The next screen, entitled ***Dose Response Files***, provides the dates of the dose response and target organ endpoints (toxicity value) files included in the HEM-3 model you downloaded. 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 of your downloaded model, click Exit on this screen. Then download the newer files from EPA's HEM download webpage (from link above), or manually modify the files in your HEM-3's Reference folder based on updated values from EPA's HEM download page or from EPA's Dose Response Assessment webpage (EPA 2018a). Then restart the model.

Following the title screen and the ***Dose Response Files*** screen, the model will display a series of input screens that require you to select modeling options and to provide additional input data, depending on the modeling options you select. These model options and selections are discussed in the following subsections. If necessary, refer to Section 3.1 for descriptions of the requested input files while proceeding through these screens.

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3.2.1 Specify Model Run Information (Screen 1)

On Screen 1 (***1. Specify Model Run Information***), shown below in Figure 4, enter general information about your run, including whether HEM-3 will be computing pollutant concentrations using AERMOD or whether you will provide concentration data and locations (based on previously modeled concentration results or monitoring data). In most applications of HEM-3, ambient pollutant impacts will be computed within the model using AERMOD. Therefore, the instructions in this section describe how to initiate a HEM-3 run using AERMOD to calculate concentrations. Alternatively, to provide external data, click on the box on Screen 1 labeled "Use previously modeled or monitored concentration results" (no other inputs on Screen 1 are necessary for this option), and then skip ahead to Section 3.5 for further instructions.

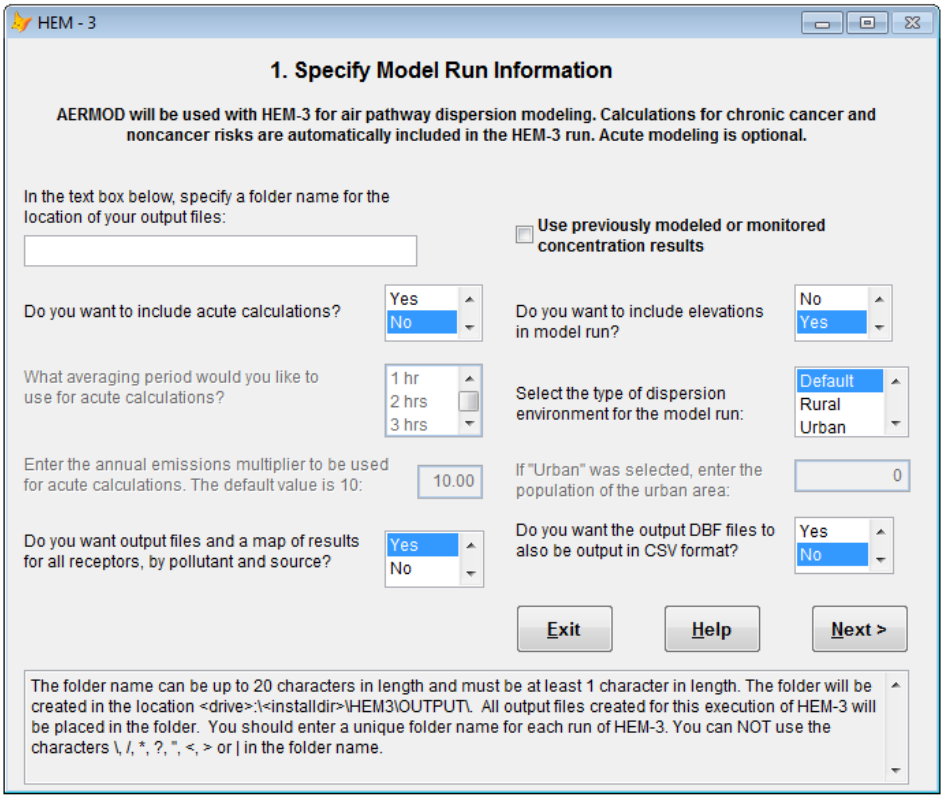

Figure 4. Screen 1 - Specify Model Run Information

First, specify a folder name for your HEM-3 output files. You can use HEM-3 to estimate *chronic* health risks and, optionally, *acute* health risks. Chronic health risks are estimated based on long-term average concentrations, as predicted by AERMOD. The time frame of this average is determined by the number of years covered by the meteorological data file selected for the model run; generally one year when running AERMOD.

Select "Yes" or "No" to indicate whether you want to include acute calculations based on the maximum short term ambient concentrations predicted by AERMOD. If you select "Yes", next select one of eight options for the time frame of the short-term average: 1-hour, 2-hour, 3-hour, 4-hour, 6-hour, 8-hour, 12-hour or 24-hour. Generally, the 1-hour averaging period is used for modeling of acute impacts. Then specify the multiplier for acute calculations, which accounts for

the high end of the short-term variations in emissions. Use the HEM-3 default or provide a multiplier in the appropriate box. The default multiplier is 10, meaning that the maximum hourly emissions could be 10 times the average emission rate you entered in the HAP emissions input file (in tons/year which the model converts to grams/second) – as well as any temporal variation factors applied on Screen 6, as described further in Section 3.2.6). It should be noted that HEM-3 assumes this maximum emission rate can occur at the same time as the worst-case meteorological conditions. Therefore, the acute results produced using an emission multiplier can be viewed as conservative estimates.

If you want HEM-3 to produce detailed output files, in addition to the summary output files that it produces automatically, specify "Yes" to the all receptors question on Screen 1. These detailed output files include concentration, risk and HI results for *all receptors* by pollutant and emission source, as well as a Google Earth™ map of these results. Producing these output files requires additional computer storage space and modeling run time compared to producing the summary output files. The summary output files include risk and HI for each receptor, as well as the contribution of each pollutant and emission source to the receptor experiencing maximum impact. The summary output files, however, do not include concentration, risk and HI results by pollutant and source for all receptors. (See Section 5 for a more detailed discussion of HEM-3's output files.) Note: If you are modeling deposition with depletion (as discussed on Screen 3 below), the summary output files take into account plume depletion as a result of the modeled deposition. These summary files, however, do not include an output file showing the deposition flux (other than in aermod.out). Deposition flux (in $g/m^2/y$) is displayed in the all receptors output file. Therefore, select "Yes" in response to the all receptors question on this screen if you want deposition flux values in the outputs.

Next, select "Yes" or "No" to indicate whether you want to include the impacts of terrain elevations in your modeling run. Elevated terrain around the facility can cause local impacts to increase, though impacts will differ for each set of sources and elevations. Select "Yes" for the elevation option if the height of receptors around the facility may exceed the height of any stacks at the facility. Consult the EPA's *Guideline on Air Quality Models* (also published as Appendix W of 40 CFR Part 51) (EPA 2005) for more explicit directions on when the use of terrain elevations is recommended. A link to this guideline is also provided on EPA's Dispersion Modeling webpage at http://www.epa.gov/scram001/dispersionindex.htm. If you choose to include elevations in the model run, you can provide elevations for each source in the emissions location file. If you do not provide elevations, HEM-3 will calculate source elevations from neighboring census block elevations. Note: Elevations should be provided for every source or for no sources, as noted in Table 1, Format Guidelines for the Emissions Location Input File.

Select "Default", "Rural" or "Urban" to specify whether HEM-3 uses *urban* or *rural* dispersion coefficients for the model run. The EPA provides guidance on whether to select urban or rural dispersion coefficients in its Guideline on Air Quality Models (Appendix W, noted above). In general, use the urban option if (1) the land use is classified as urban for more than 50% of the land within a 3-kilometer radius of the emission source, or (2) the population density within a 3-kilometer radius is greater than 750 people per square kilometer. Of these two criteria, the land use criterion is more definitive. If you choose the urban dispersion environment for the model run, you must specify the population of the urban area surrounding the facility. If you do not know the population of the urban area, or whether the area is rural or urban, select the "Default" option. If you select the default option and also choose the 2010 Census (on the next input Screen 2 discussed below in Section 3.2.2), HEM-3 will find the nearest census block to the facility center and determine whether that census block is in an urban area, as designated by the 2010 Census (FR 77:59). The population of the designated urban area will be used to

specify the population input for AERMOD's urban mode. Note: If you choose to use the 2000 Census (on the next Input Screen 2), the model will default to a rural dispersion environment unless you select “Urban” and supply an urban population.

HEM-3 outputs files in DBF format and others as Excel™ spreadsheets. If you would like the model to output all DBF files in CSV format as well, select “Yes” to the question regarding DBF and CSV files on this screen. Note: if your computer does not have the FoxPro™ programming language software installed, you should choose to output the DBF files in CSV format.

After completing this and every screen, click “Next” to go to the next input screen. [Note: If you selected “use previously modeled or monitored concentration results” on Screen 1 as noted above, an alternate Screen 2 appears after clicking “Next”, rather than the Screen 2 described below in Section 3.2.2. In this case, skip ahead to Section 3.5 which provides instructions for using the alternate Screen 2.]

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3.2.2 Specify Census and Emissions Inputs (Screen 2)

On Screen 2 (***2. Specify Census and Emissions Input Files***), shown below in Figure 5, select “2000” or “2010” to indicate the census year you are using to model the facility or facilities of interest. Use only Census 2000 or only Census 2010 for all census files, including the census key file and any census state files needed for the modeling run (as described in Section 2.3 *Downloading Census Data*). Do not combine Census 2000 and Census 2010 files in the same modeling run. [Note: If you choose the 2000 Census and also chose a default dispersion environment on Screen 1, the model will default to a rural dispersion environment. If you choose the 2010 Census and a default dispersion environment on Screen 1, the model will select an urban or rural environment based on whether or not the nearest census block to the facility is in an urban area.]

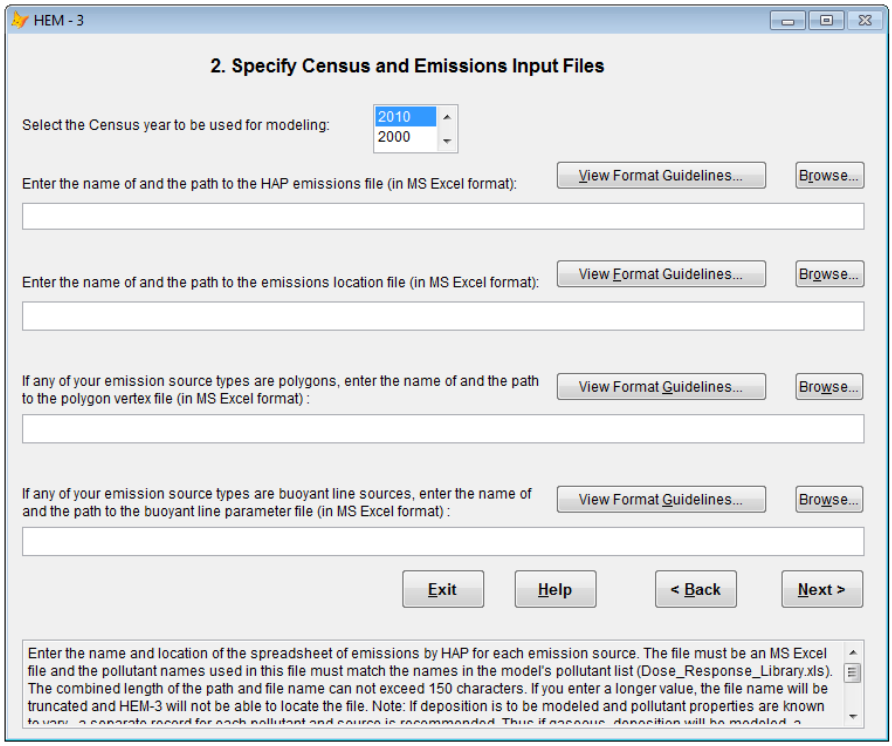

Figure 5. Screen 2 – Specify Census and Emissions Input Files

Next, enter the names and paths for the HAP emissions and emissions location files for the modeling run. Both of these input files are required for a standard HEM-3 run, regardless of the modeling options you choose. If there are polygon sources in your emissions location file, enter the name and path for the polygon vertex file, otherwise leave blank. Likewise, if there are buoyant line sources in your emissions location file, enter the name and path for the buoyant line parameter file, otherwise leave blank.

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3.2.3 Specify Deposition and Depletion (Screen 3)

On Screen 3 (***3. Specify Deposition and Depletion***), shown below in Figure 6, select "Yes" or "No" to choose whether the model will (1) calculate and output a deposition flux and (2) deplete the plume (or not) based on the calculated deposition. Generally speaking, deposition modeled with plume depletion will reduce the ambient impacts from the emission source by removing pollutants from the plume. Air concentrations will be depleted as pollutants are deposited to the ground. The modeled deposition flux may be then used as an input to a separate multipathway model such as the Total Risk Integrated Methodology (TRIM) (EPA 2018h). Alternatively, you may choose to calculate the deposition flux, but not deplete the plume (to allow for higher, more conservative air concentrations).

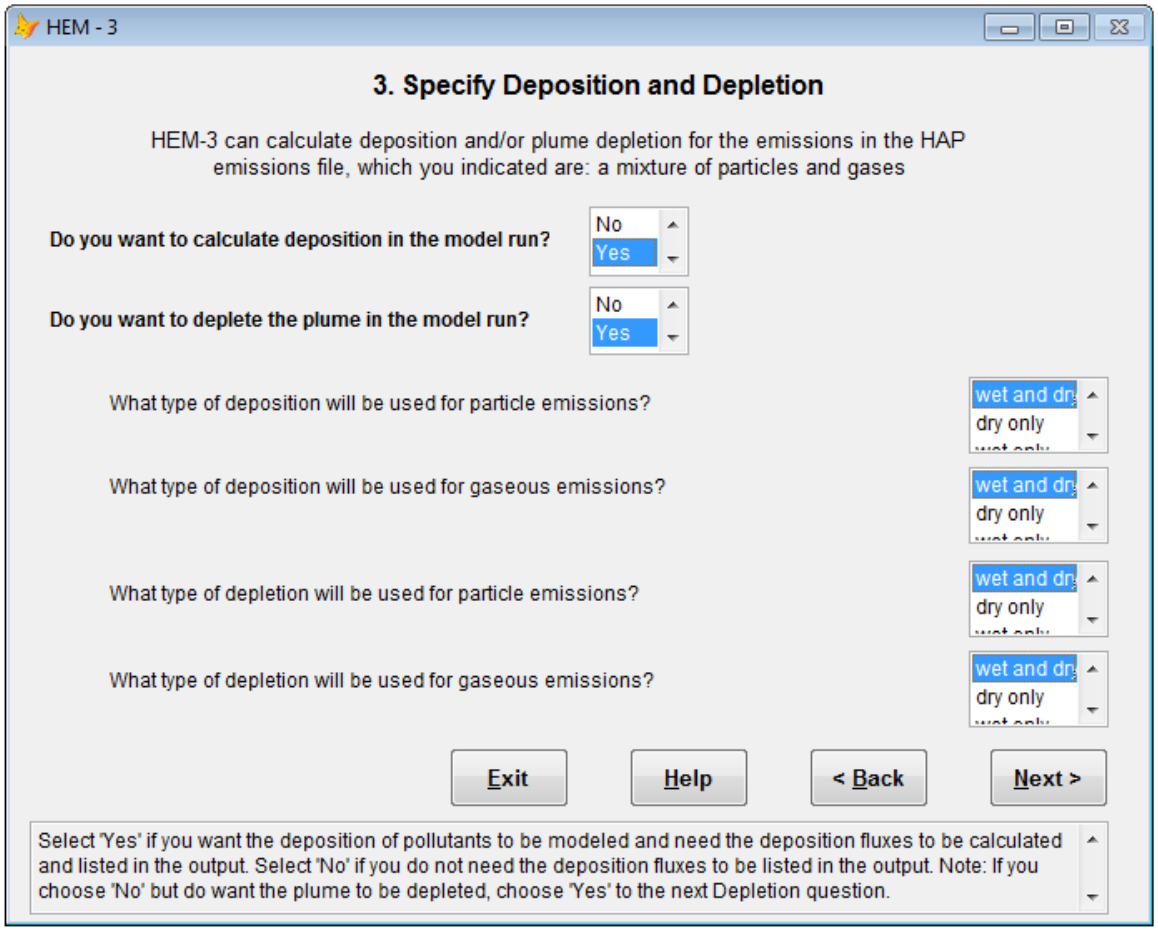

Figure 6. Screen 3 – Specify Deposition and Depletion

HEM-3 uses AERMOD to calculate deposition and depletion effects for particulate matter, gaseous (vapor) pollutants, or both. The make-up of your emissions – that is, the percentage particulate and gas – is dictated to HEM-3 by your HAP Emissions input file. Specifically, the fourth column in the HAP Emission input file ("Percent Particle") indicates to HEM-3 whether your emissions are 100% particle (if the Percent Particle column is populated with 100 for all pollutants), 100% gas (if the Percent Particle column is left blank or populated with 0 for all pollutants), or a mixture of particles and gas. HEM-3 lists the type of emissions indicated by your HAP Emissions file at the top of Screen 3. If your emissions are 100% particles, then only the questions pertaining to particle emissions will be displayed on Screen 3. Conversely, if your emissions are 100% gas, then only the questions pertaining to gaseous emissions will be displayed on Screen 3.

Screen 3 allows you several options for modeling deposition and depletion:

- If you select "Yes" to the deposition question but "No" to the depletion question, then HEM-3 will provide deposition flux columns in the outputs (based on the AERMOD deposition algorithms) which may be used in a multipathway model, but HEM-3 will not deplete the plume.

- If you select "No" to the deposition question but "Yes" to the depletion question, then HEM-3 will deplete the plume (based on the AERMOD deposition algorithms) but will not provide deposition flux columns in the outputs. You might choose this option if you do not need the deposition flux (*e.g.*, for a multipathway model) and wish to conserve computer storage space.*

- If you select "Yes" to both the deposition and depletion questions, then HEM-3 will provide deposition flux columns in the outputs and also deplete the plume.

- If you select "No" to both the deposition and depletion questions, then neither deposition nor depletion will be modeled by HEM-3.

If you select "Yes" to the deposition and/or depletion questions, you must also indicate what type of deposition and/or depletion you wish HEM-3 to model: wet and dry, dry only, wet only, or none. You may mix and match the type of deposition and depletion you tell HEM-3 to model. For example, you may direct HEM-3 to model wet and dry deposition, and then deplete the plume based on those wet and dry deposition processes. Or, you may choose wet and dry deposition, but then only deplete the plume based on the wet deposition process. In addition, the "none" option allows you to model deposition for particles only, for example, even if your HAP Emissions file shows a mixture of particles and gas. To do this, you can indicate what type of deposition to model for your particle emissions (wet and dry, wet only or dry only) and then answer "none" to the question "What type of deposition will be used for gaseous emissions?"

The "none" option is also useful if you do not want deposition or depletion to be modeled, but do want HEM-3 to produce more detailed concentration outputs, showing the breakdown of particles and gas (vapor) at each location. To do so, select "Yes" to the deposition and "No" to the depletion question. Then select "none" for the type of deposition (for particles and gases).

* You should also select this option if your emissions are a mixture of particles and gases, but you wish to deplete the plume for only particles or only gases. Note that in such a case, if you also need the deposition flux in the output files, a second similar run is required (in which deposition but not depletion is modeled). See the HEM-3 Error Messages table at the end of this guide for more detail.

Neither deposition nor depletion will be modeled. However, the outputs will show distinct rows for particles ("P" for particle) and gas ("V" for vapor) at each location, rather than a combined ("C") row. This is helpful only if your HAP Emissions file shows a mixture of particles and gas.

Depending on the type of deposition and/or depletion you chose and the information contained within your HAP emissions input file, HEM-3 will prompt you to specify additional files needed to quantify deposition and/or depletion on Screen 3a (***3a. Specify Files for Deposition and Depletion***), shown below in Figure 7.

If your HAP Emissions file contains particulate pollutants and you want to model deposition and/or depletion of particles, HEM-3 requires a particle size input file. This additional input file contains particle size information, mass fraction and particle size density for each pollutant (HAP). Enter the name and path to the particle size input file in the text box on Screen 3a.

If your HAP Emissions input file contains gaseous pollutants and you want to model dry (or "wet and dry") deposition and/or depletion, HEM-3 requires a land use input file and a month-to-season input file. These additional input files are needed only to quantify dry (or "wet and dry") deposition and/or depletion of gaseous pollutants, as discussed in Section 3.1.7. If you wish to model "wet only" deposition and/or depletion of gaseous pollutants, these additional input files are not needed by HEM-3. (These files are also not needed for 100% particulate emissions.)

You will need to enter the name of and the path to the above input file(s) in the appropriate text box on Screen 3a. Also, you should check to ensure that the gaseous pollutants in your HAP Emissions file are included in the Gas Parameter (Gas_Param) reference file. If these pollutants are not included – or if you wish to include different parameter values than the Gas Parameter file currently uses – you should edit the Gas Parameter file, as discussed in Section 3.1.7. Otherwise, generic default gas parameter values will be used.

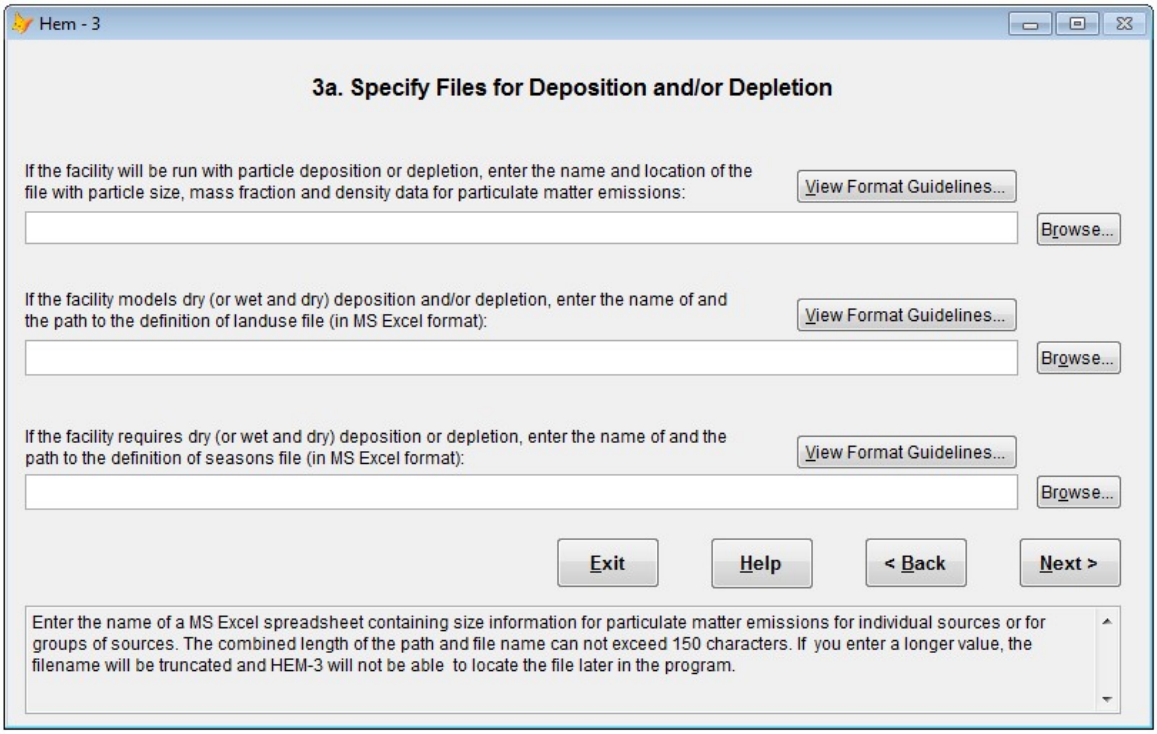

Figure 7. Screen 3a – Specify Files for Deposition and/or Depletion

It should be noted that HEM-3 requires significantly more time to run if you opt to model deposition and/or depletion and you are also modeling acute impacts (*i.e.*, you selected "Yes" to include acute calculations on *Screen 1 Specify Model Run Information*). The exact run time will depend on the particular source configuration and modeling domain, but the combination of acute calculations and deposition/depletion will generally increase run times from a few minutes to over an hour for Single HEM-3 (and even greater than this for Multi HEM-3).

Deposition and plume depletion has more of an effect on ambient concentrations farther from the facility than it does closer to the facility where the maximum impact generally occurs. Therefore, if you select the deposition and/or depletion options for a model run, you may save time by performing two separate runs. For example, you can use the first HEM-3 run to calculate chronic effects and include deposition and plume depletion. You can then use the second run to calculate acute effects without deposition and depletion.

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3.2.4 Specify Additional Modeling Options (Screen 4)

On Screen 4 (**4. *Specify Additional Modeling Options***), shown below in Figure 8, you can select other modeling options for the run that allow for more sophisticated and detailed model predictions.

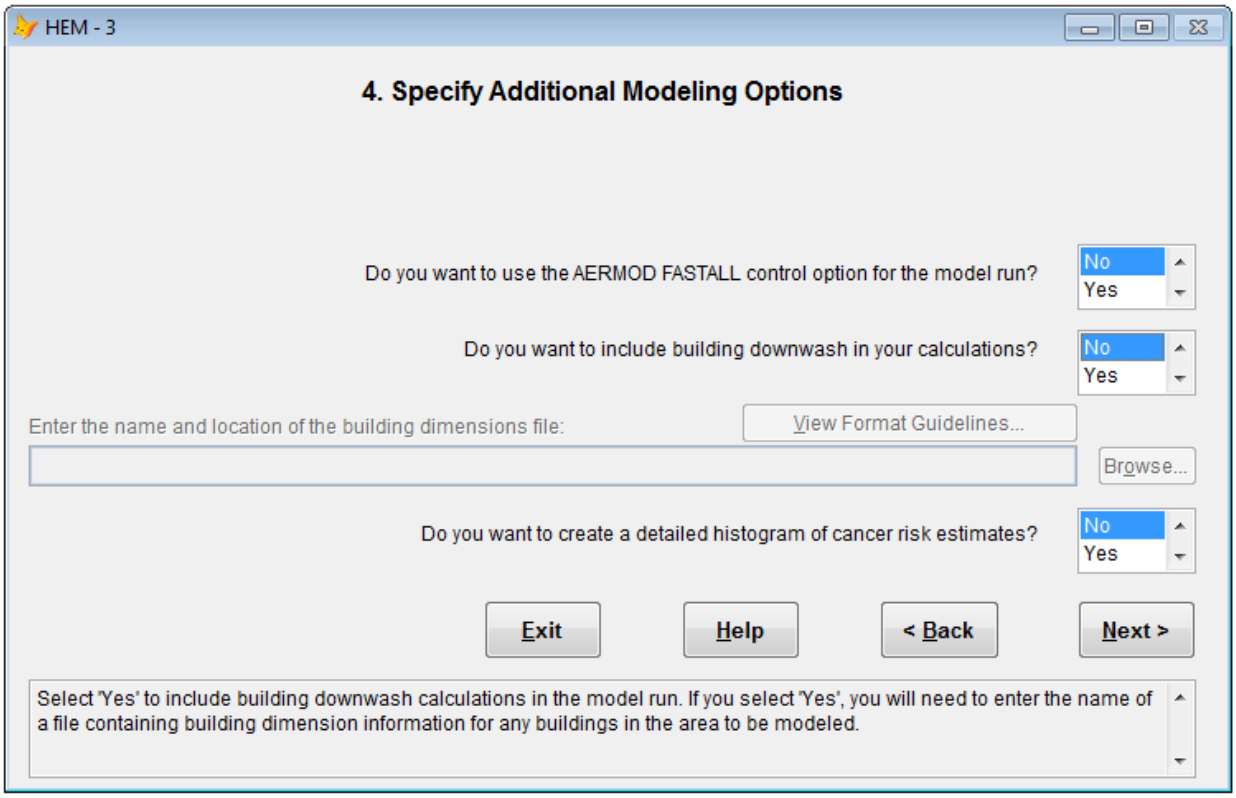

Figure 8. Screen 4 – Specify Additional Modeling Options

Select "Yes" or "No" to indicate whether you want to run HEM-3 with or without AERMOD's FASTALL control option. FASTALL conserves model runtime by simplifying the AERMOD algorithms used to represent meander of the pollutant plume (EPA 2018b). The FASTALL

option eliminates the upwind component of dispersion for point and volume sources, and reduces the requirement for uniformity of emissions over the extent of area sources. HEM-3 defaults to "No" on this option for more rigorous modeling. For faster runs however, you may want to select the FASTALL option which includes these plume and source simplifications. (See AERMOD's model documentation at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod.)

Next, select "Yes" or "No" to indicate whether you want to include the effects of building downwash in your calculations. Section 3.1.8 summarizes situations where we recommend accounting for building downwash. If you select "Yes" to include building downwash calculations, then enter the name and location of the building dimensions input file in the text box on Screen 4.

Finally, select "Yes" or "No" to indicate whether you want to create a detailed histogram of cancer risk estimates. This option directs the model to produce a more detailed histogram of the estimated numbers of people exposed to different levels of maximum individual cancer risk, in addition to the basic risk histogram HEM-3 automatically produces. See Section 5.6.3 for a description of this optional output file ("Cancer_histogram.xls").

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3.2.5 Define the Modeling Domain (Screen 5)

On Screen 5 (***5. Define the Modeling Domain***), shown in Figure 9, select the parameters that will define your modeling domain. The modeling domain is circular and centered on the facility, with a user-specified radius. HEM-3 identifies all of the census block locations in the modeling domain from its census database, and divides the blocks into two groups – inner and outer receptors – based on their distance from the facility. For the inner group of census blocks (closest to the facility), each block location is modeled as a separate receptor in AERMOD.

On this screen, you will specify the cutoff distance for modeling individual census blocks. You can also indicate an "overlap" distance, within which census block centroid coordinates will be classified as on facility property. For census blocks in the outer group, beyond the modeling cutoff distance, emission impacts are interpolated based on modeling results for a polar receptor network, which you will also define on this screen.

Finally, on this screen you can specify the inclusion of user-defined receptors ("user receptors"). This additional input file, described in Section 3.1.9, identifies additional locations to be included as model receptors in AERMOD. These additional discrete receptors may include facility boundary locations, monitoring sites, individual residences, schools, or other locations of interest.

*Enter the maximum radius (in meters) to be modeled. S*pecify the outside maximum radius of the modeling domain. This is the circular study area for which HEM-3 will model ambient impacts (at census block centroid receptors, polar grid receptors, and user receptors, as explained below). This radial distance is usually 30 to 50 kilometers (entered in meters). The center of this area is generally the geographical center of the facility (or facilities) you are modeling, but you can change this center location on a later screen. [Note: The smallest maximum radius allowed is 1,000 meters (1 km). The maximum radius you enter should be ≤ 50,000 meters (50 km) because, as a Gaussian dispersion model, AERMOD is not recommended beyond 50 km.]

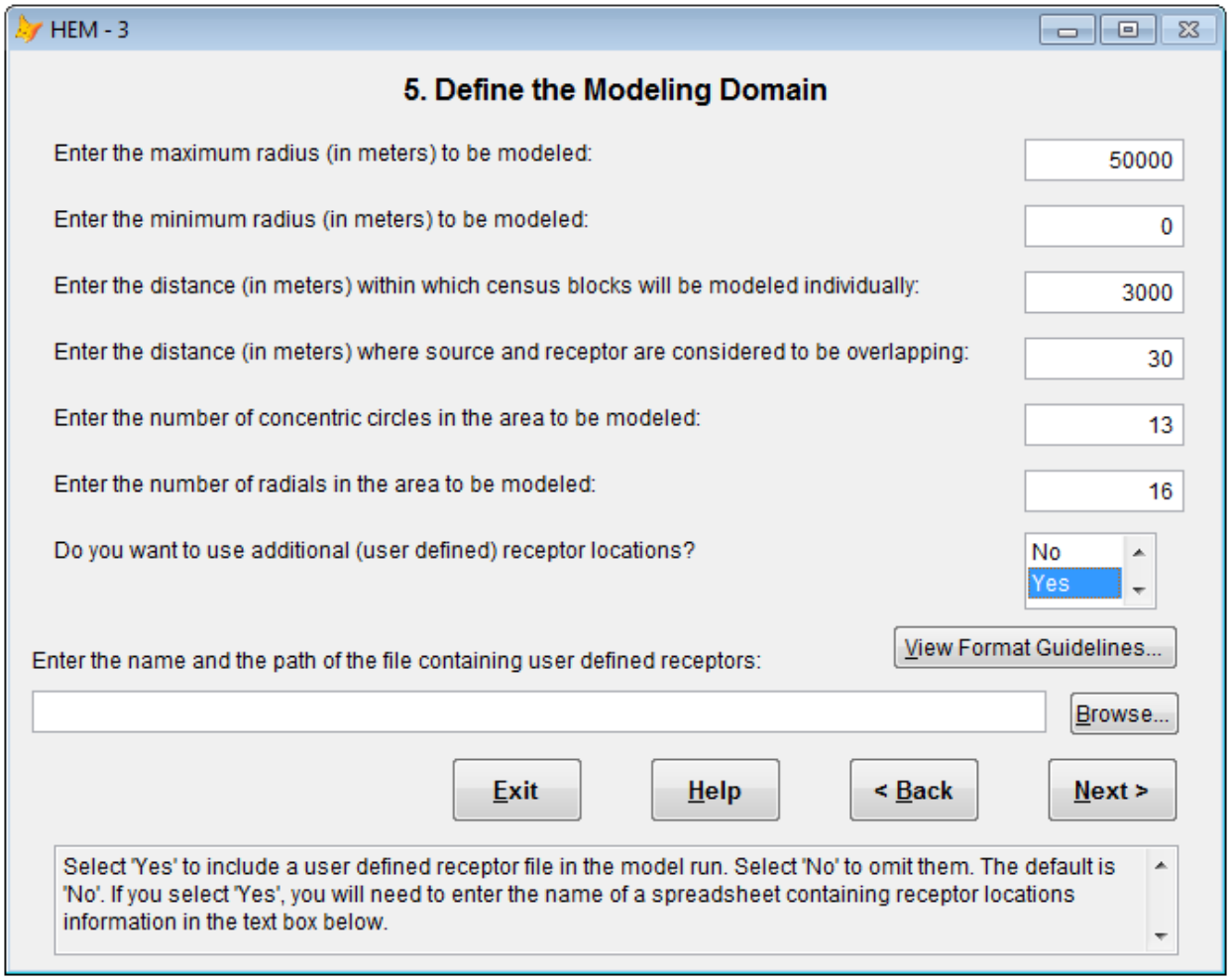

Figure 9. Screen 5 – Define the Modeling Domain

Enter the minimum radius (in meters) to be modeled. You can also specify an inside minimum radius for the modeling domain. Generally, this radius should be set to 0 (zero), although you have the option of entering a value greater than 0. This feature is useful if you want to divide a modeling job into two runs, possibly to make more efficient use of computer resources. For instance, in one run you could model all receptors from 0 to 10,000 meters from a facility. In a second run, you could model receptors located between 10,000 and 50,000 meters from the same facility. In this case, the maximum individual risk (MIR) would be the maximum value for the two runs, and the population exposure to any given risk level would be the sum of population exposures at each risk level for the two runs. (The risk and population exposure outputs are described in more detail in Section 5 below.)

Enter the distance (in meters) within which census blocks will be modeled individually. Enter the cutoff distance for individual modeling of census blocks. Within this radial distance measured from the facility center, AERMOD will model each census block centroid explicitly as a receptor. Outside of this radius, AERMOD will not model the census blocks directly; ambient impacts at the block centroid will instead be interpolated using dispersion modeling results for the polar receptor network, described below.

Larger values for this cutoff distance will require more time to model, because the number of census block receptors requiring explicit AERMOD modeling will be higher. However, set this cutoff value at a large enough distance so that the maximum risk receptor (discussed in Section 4.2.3) will be modeled individually. This distance will vary depending on the configuration of the sources, but is generally between 1,500 and 2,000 meters. A typical modeling cutoff distance for larger facilities is 3,000 meters (or 3 km). When modeling large sources configured as polygons (e.g., census tracts), set this modeling cutoff distance to be greater than the largest distance across the polygon, to ensure discrete modeling of all census blocks within the polygon.

Enter the distance (in meters) where source and receptor are considered to be overlapping. Enter a distance (≤ 500 meters) within which sources and receptors will be considered to be overlapping, as measured from each source at the facility (e.g., stack, edges of area and volume sources). This feature is provided to address situations wherein census blocks are very close to a facility and have complex shapes. In such cases, the centroid of a census block may be much closer to the facility than the nearest actual dwelling. (In fact, if a census block surrounds a portion of the facility, the centroid of the block may be on facility property.) The default value for the overlap distance is 30 meters, or approximately equal to the width of a narrow buffer and a roadway. If a receptor falls within this distance, HEM-3 will not calculate risks based on the location of that receptor, but will instead assume that the risks associated with the receptor are the same as the highest predicted value for any receptor that does not overlap facility property (even if it is not a population receptor). An exception to this occurs when modeling polygon sources. Unlike other sources, when modeling polygons, the overlap function is disabled. This allows the impacts for a census tract modeled as a polygon source (e.g. mobile source emissions modeled uniformly across a census tract) to be calculated within the census tract being modeled.

Enter the number of concentric circles in the area to be modeled. In addition to ambient impacts at census block centroids within the modeling cutoff distance, HEM-3 (using AERMOD) also explicitly models ambient impacts at polar grid receptors within a polar network. This polar network extends beyond the modeling cutoff distance to the maximum (outside) radius. The polar receptor network in HEM-3 serves three functions: (1) it is used to estimate default impacts if one or more census locations are inside the overlap cutoff distance; (2) it is used to evaluate potential acute effects that may occur due to short-term exposures in unpopulated locations outside the facility boundary; and (3) the polar receptor network is used to interpolate long- and short-term impacts at census block locations that are outside the cutoff distance for modeling of individual blocks. Note that, if modeling with terrain effects, the elevation of each polar grid receptor is based on the elevation of nearby discrete (census block and user) receptors. The maximum elevation of nearby discrete receptors is assigned to each polar receptor, to ensure terrain effects on receptor concentrations are conservatively estimated.

Enter the number of radials in the area to be modeled. The polar grid receptor of the polar network are located at the intersection of a polar ring and a radial. HEM-3 will calculate the inner radius of the polar network. This model-calculated first ring distance is based on the location of the emission sources and the facility center. HEM-3 selects the distance that places the first modeling ring just beyond all emission sources, but not less than 100 meters from the facility center. A typical run would include 13 concentric rings and 12 or 16 radial directions. HEM-3 will distribute the radial directions evenly around the facility. For instance, if you select 16 directions, receptors will be modeled at compass bearings of 0, 22.5, 45, 67.5, 90, 112.5, 135, 157.5, 180, 202.5, 225, 247.5, 270, 292.5, 315, and 337.5. You have the option to change HEM-3's calculated ring distances in a later input screen. Section 3.2.10 provides further discussion on the selection of different ring distances.

Do you want to use additional (user-defined) receptor locations? In addition to modeling impacts at census block centroid receptors and polar grid receptors, HEM-3 can model impacts at additional user-defined locations. Select "Yes" or "No" to indicate whether you want to include user receptors. If you answer "Yes", next enter the name and path of the user receptors file (as described in Section 3.1.9) in the text box on Screen 5.

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3.2.6 Specify Optional Temporal Variations (Screen 6)

Use Screen 6 (**6. *Specify Optional Temporal Variations***), shown below in Figure 10, to include temporal and wind variations in the emission inputs AERMOD uses, and/or to show hourly and seasonal resolution in the ambient concentration outputs AERMOD produces.

- You can provide HEM-3 a temporal variations input file that varies the emissions AERMOD uses from specific sources by different user-supplied time scales (*e.g.*, by season, month, hour of day, and/or day of week) or by different wind speeds (6 ranges).

- You can direct 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.

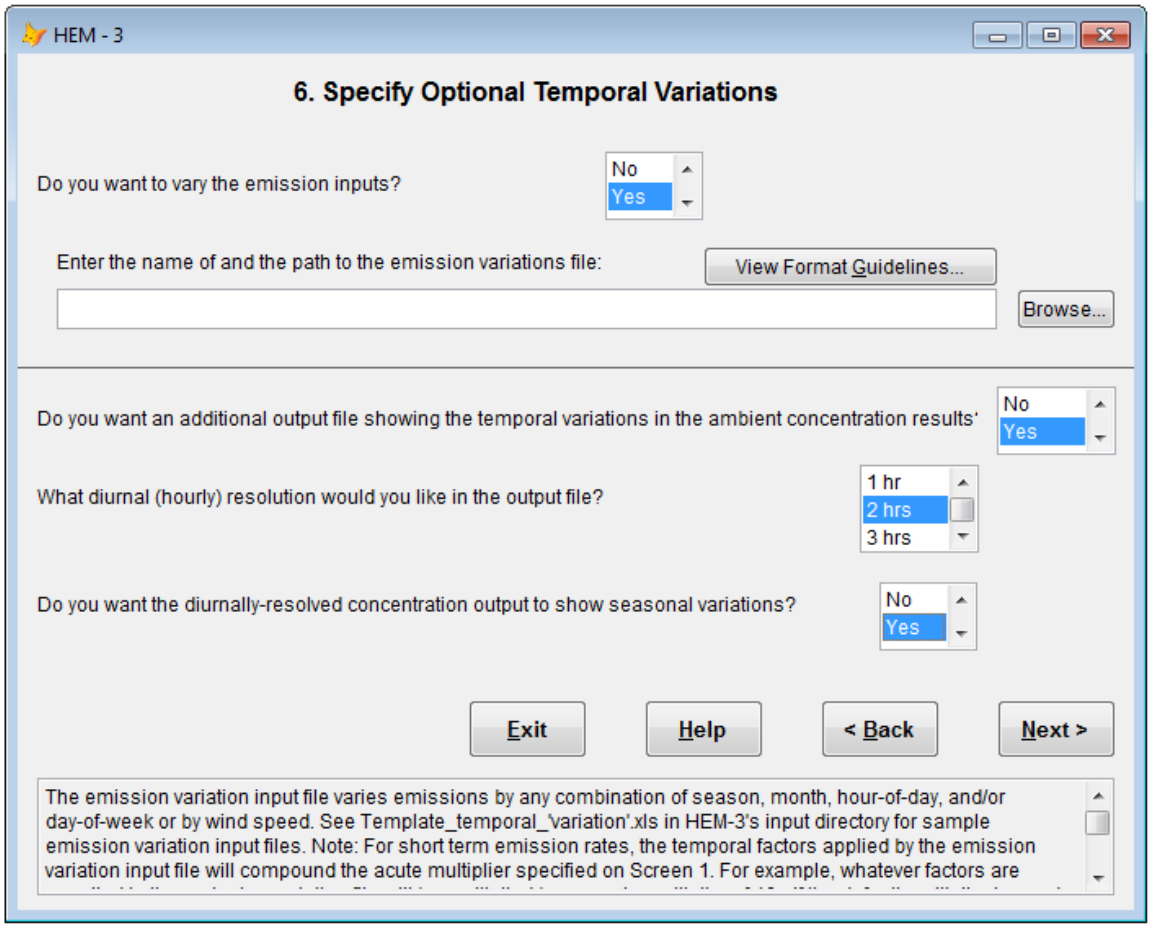

Figure 10. Screen 6 – Specify Optional Temporal Variations

Select “Yes” or “No” on the upper portion of Screen 6 to indicate whether you want to vary the emission inputs. If you select “Yes”, then enter the name and path of the temporal variations input file in the text box on Screen 6. Templates for the various possible temporal variation input files are provided in HEM-3’s Inputs folder (under ‘Template_temporal_’variation’.xlsx). Section 3.1.10 describes these input files in more detail.

Note: Regarding short-term (acute) emission rates, the factors applied by the temporal variation input file will compound the acute multiplier specified on input Screen 1. For example, whatever factors you supply in the temporal variation input file will be multiplied by an acute multiplier of 10 (if the default multiplier is used) to derive the short-term emission rate. Therefore, if applying hour of day temporal factors via Screen 6, you may want to set the acute multiplier to 1 (by clicking on the “Back” button to Screen 1), unless it is reasonable to assume that the short-term rate may still exceed the hour of day factors by an additional multiple.

Select “Yes” on the lower portion of Screen 6 to direct AERMOD to provide finer temporal resolution in the ambient concentration outputs than is otherwise provided by default. AERMOD calculates hourly concentration data based on the emissions inputs, but does not retain this hourly data for the output files (due to its large file size) unless you request it via this option. If you select “Yes” for this option, the ambient concentration outputs will show diurnal or diurnal plus seasonal variation, depending on your selections on the following two sub-questions on the screen.

What diurnal (hourly) resolution would you like 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). Scroll through and click on your selection in the dropdown box.

Do you want the diurnally-resolved concentration output to show seasonal variations? Select “Yes” or “No” to indicate whether you want to show seasonal variations in the diurnally-resolved concentration output. If you select “Yes” for the diurnal question but “No” for the seasonal variation question, a diurnally-resolved concentration output is provided with the indicated resolution, but no seasonal variations will be provided.

You can select the second option alone or in combination with the first option. If you select only the second option—not in combination with a temporal variation input file—then the temporal variations in the ambient concentration outputs will result from the effects of meteorological fluctuations calculated by AERMOD (i.e., based on meteorological parameters provided by the selected met station). If you select the second option in combination with a temporal variations input file you provide, then the temporal variations in the ambient concentration outputs will result from both the effects of meteorological fluctuations and your time or wind speed factors applied to the emissions.

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3.2.7 Modeling Options Selected (Screen 7)

Verify your modeling options on Screen 7 (**7*. Modeling Options Selected***). This screen consists of three pages, with the last of the three pages shown below in Figure 11. Review your selections. If you selected any of the listed modeling options in error, you may use the “Back”

button to go back to the input screen with that option and revise your choice. Note that this is the last user input screen which contains a “Back” button. If all of the indicated selections are as you want them, click “Next” to proceed to Screen 8.

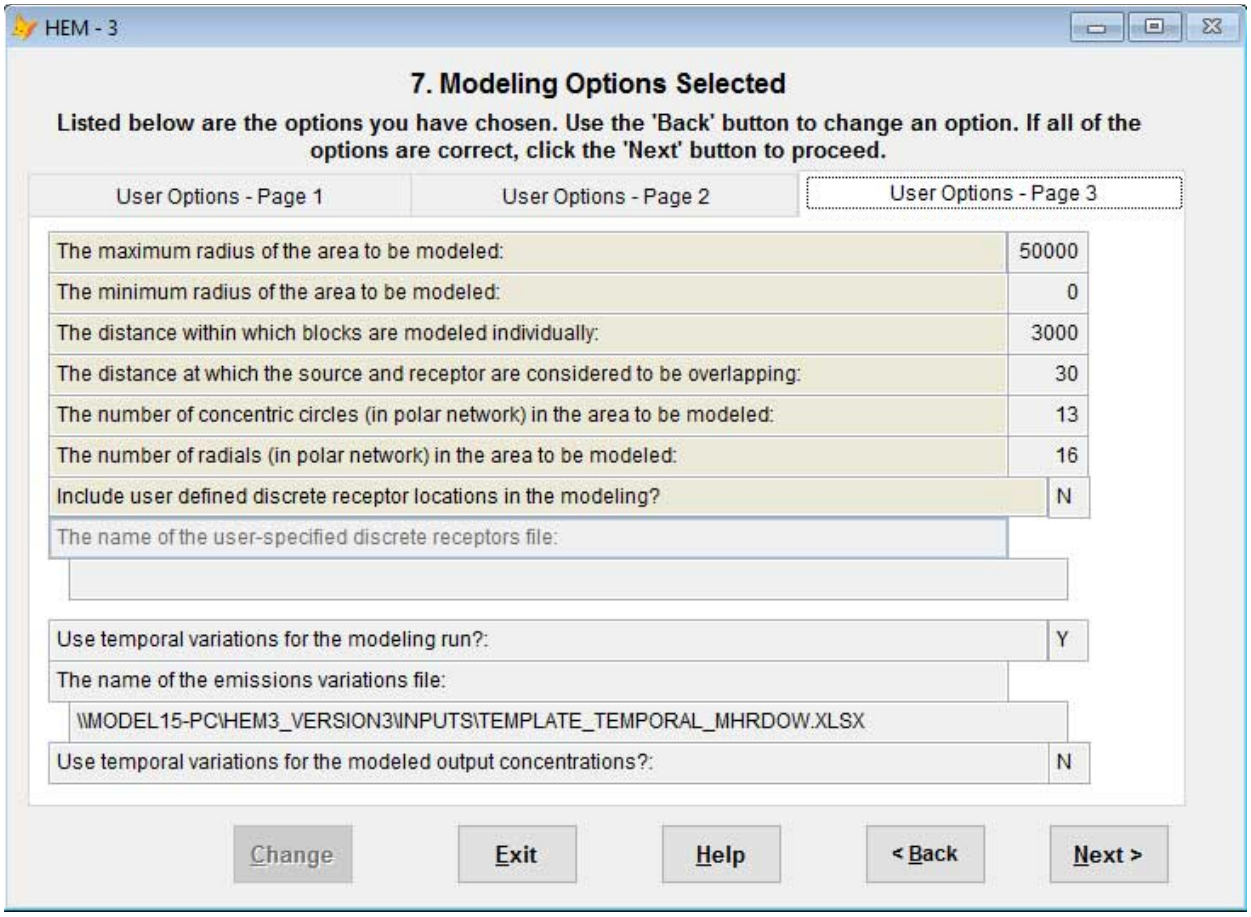

Figure 11. Screen 7 – Modeling Options Selected (page 3 of 3)

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3.2.8 Verify Modeling Domain Center (Screen 8)

Use Screen 8 (**8. *Verify Modeling Domain Center***), shown below in Figure 12, to verify the calculated geographic center of the emission sources as the modeling domain center, or to specify alternate coordinates based on your needs. HEM-3 calculates the geographic center using the combination of all emission source coordinates that you provided in the emissions location file. The modeling domain center will be used in interpolating risks at census blocks outside the modeling cutoff distance, within the polar grid network. In addition, HEM-3 will calculate the total population and average risks within various distances from the modeling domain center.

You may want to change the modeling domain center if the facility includes an outlying emission source, such as a storage tank farm or a ship loading facility. By default, HEM-3 would place the domain center midway between the main process operation and the outlying source. However,

you may want to move the modeling domain center closer to the main process operation, especially if the outlying facility is a small source of emissions.

Review the given modeling domain center. Click within a box to revise the modeling domain center. Note that, if you enter a new center, it must be located within the emission source region defined by the coordinates on this screen. When finished, or if no changes are needed, click "Next" to continue to Screen 9.

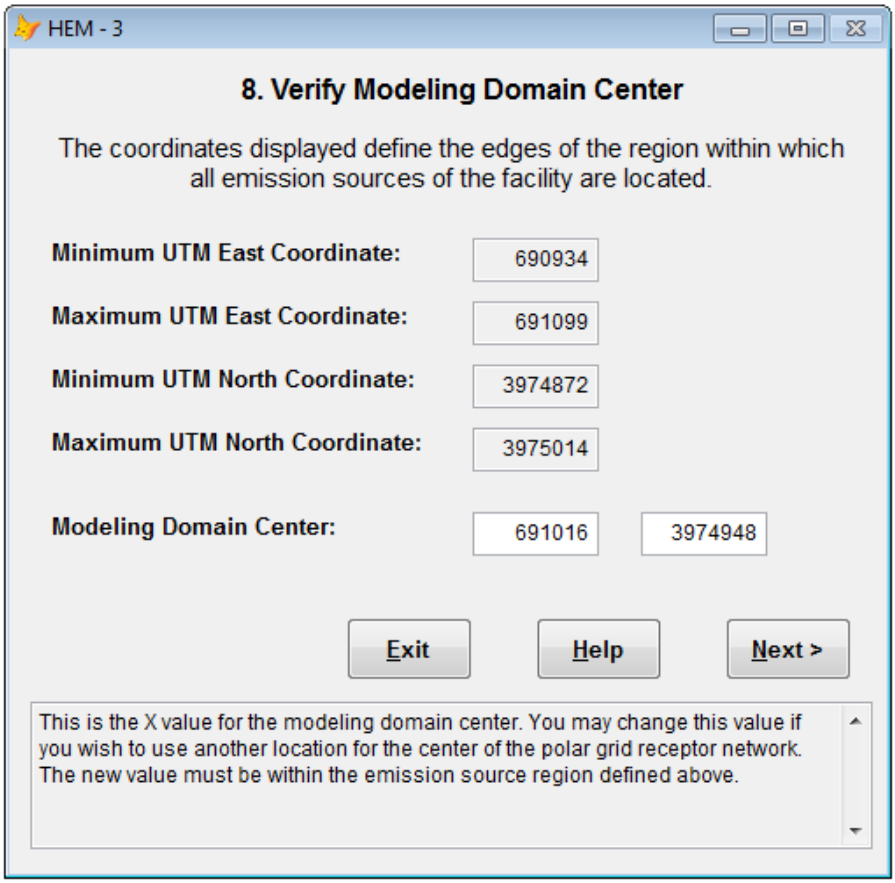

Figure 12. Screen 8 – Verify Modeling Domain Center

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3.2.9 Specify Meteorological Data (Screen 9)

Use Screen 9 (**9. *Specify Meteorological Data***), shown below in Figure 13, to confirm or change the selection of the meteorological (met) input file to be used when modeling the facility (or cluster of facilities). HEM-3 includes a library of processed met data covering over 800 sites used by AERMOD. The met input files include upper air data and surface data, as discussed in Section 2.4.1. HEM-3 calculates the distances from each surface and upper air station to the center of the modeling domain. This input screen then ranks the available met files according to their proximity to the modeling domain.

Generally, the closest set of stations will be most representative of the meteorology in the modeling domain. However, there are a number of situations where a different combination of

met stations will be more representative. For instance, if the modeling domain is located on the Gulf of Mexico, you should select a surface station near the Gulf, even if there is a closer inland station. You can use the top half of this screen to select a different met station (than automatically chosen by HEM-3) in such a case. Alternatively, you can use the bottom half of this screen to provide your own met data file(s) for the specific facility location. **The file(s) must be preprocessed and formatted for AERMOD**—see Section 2.4.1 for more detail—**and placed in your C:\HEM3\Metdata folder**.

If you do not specify a particular set of surface and upper air station files, HEM-3 defaults to the closest available set of stations. These are the stations already indicated with a pointer in the left most column on the top half of this screen. Simply click on "Next" to confirm selection of the default met station chosen by HEM-3.

As noted earlier, when you downloaded the HEM-3 model (as described in Section 2.1), the installation package placed an Excel™ spreadsheet named "metlib_AERMOD.xlsx" in your C:\HEM3\Reference folder. This spreadsheet lists all the SFC and PFL met stations that were provided in the nationwide meteorological data files available on the HEM Download Page (at the time you downloaded the model). **You may edit this spreadsheet to include additional met station files (including ones you may designate on the bottom half of Screen 9), but you must provide the new met station data as both SFC and PFL files in your C:\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 may also edit rows in this spreadsheet, or delete met station entries entirely. This spreadsheet, metlib_AERMOD.xlsx, may also be saved as .xls in your Reference folder.

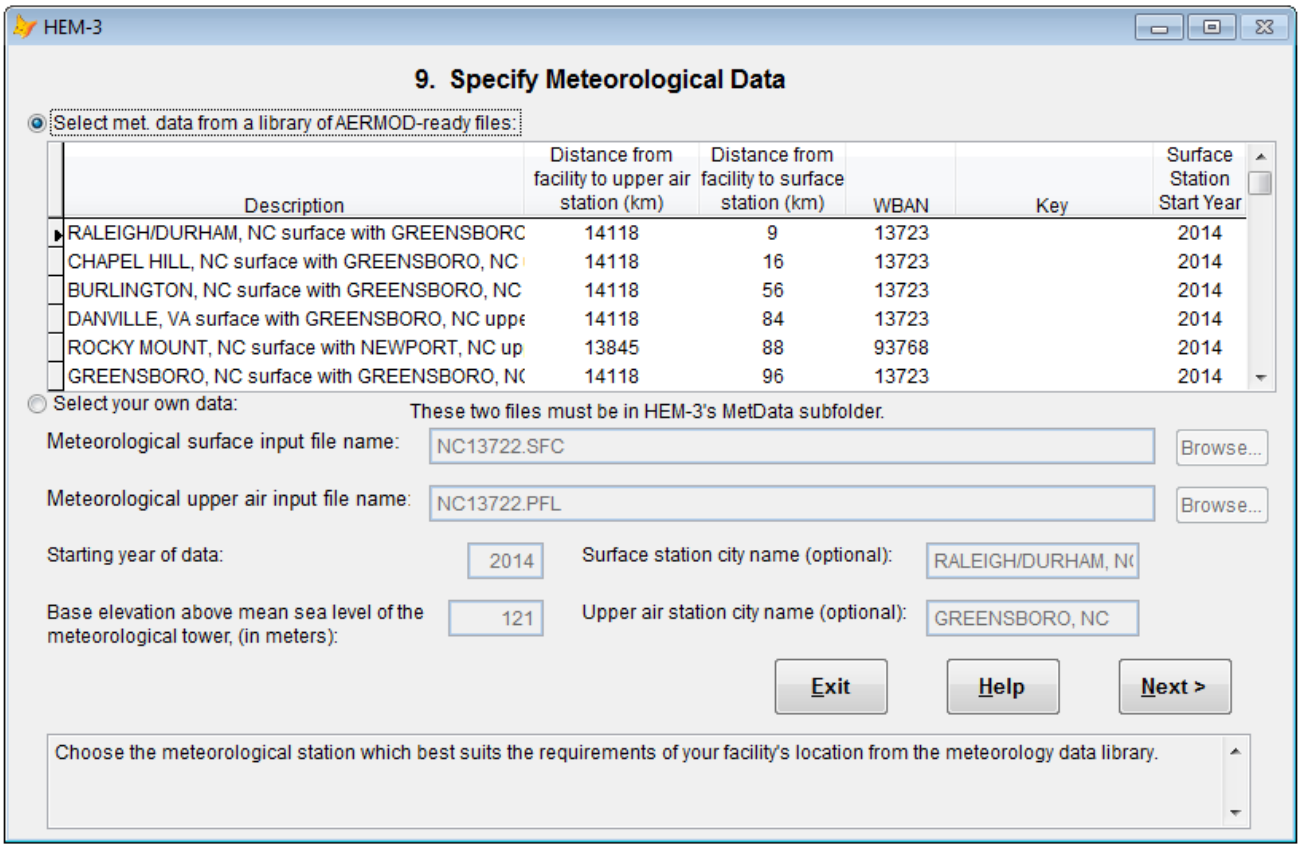

Figure 13. Screen 9 – Specify Meteorological Data

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3.2.10 Verify Polar Ring Distances (Screen 10)

On Screen 10 (**10. *Verify Polar Ring Distances***), shown below in Figure 14, HEM-3 will suggest a list of polar ring (concentric circle) distances based on the number of rings that you specified in the modeling domain input screen, under Section 3.2.5 above. The suggested list will be a logarithmic progression of distances starting at the inner ring distance and ending at the outer radius of the modeling domain. Use this screen to adjust the suggested ring distances to fit the specific size and surroundings of the facility (or facilities) that you are modeling.

As noted in Section 3.2.5, HEM-3 calculates the distance from the facility center for the first ring to be just outside the emission source locations you provided in the emissions location file, but not less than 100 meters from the facility center. Set the first receptor ring to less than 100 meters (or conversely greater than what HEM-3 calculates), if appropriate to the size and shape of the facility property. Place the nearest polar receptor ring as close as possible to the facility boundary— this inner radius of the polar network should be the minimum distance from the facility center that is generally outside of facility property. The first ring distance must be less than the modeling cutoff distance (for explicit modeling of receptors).

For complex or irregularly shaped facilities however, you may find it useful to specify an inner ring that encroaches on facility property in some directions. Furthermore, you may want to specify a set of boundary receptors by employing the user-defined receptors file (as input in the modeling domain input screen, Section 3.2.5).

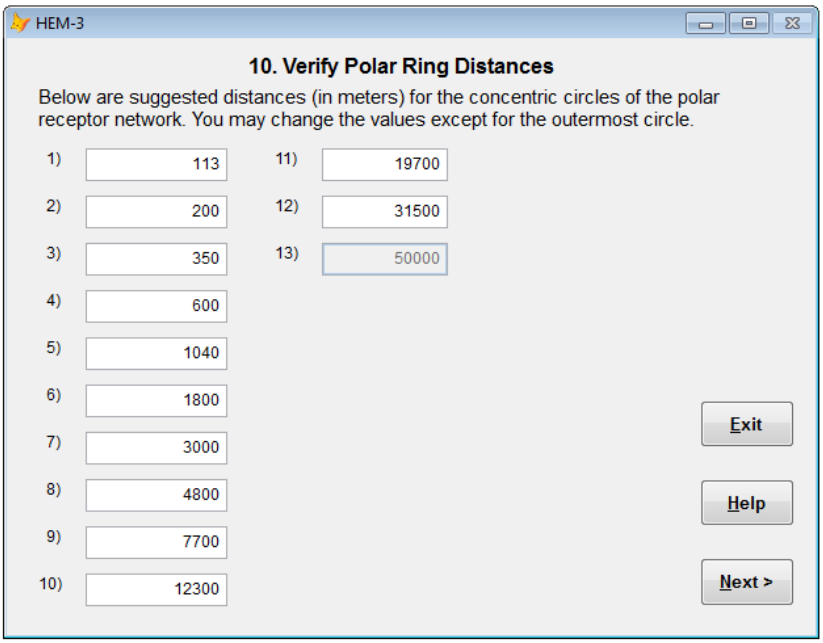

Figure 14. Screen 10 – Verify Polar Ring Distances

Although the polar grid receptors are used primarily for interpolating risks at census blocks outside of the modeling cutoff distance, it is important to include some rings close to the facility. HEM-3 generally estimates maximum individual risks and hazard indices (described below in Section 4) using concentrations calculated at census blocks. However, HEM-3 will default to the next most impacted receptor if a census block is located within the “overlap distance” of any of

the emission sources (as specified in the modeling domain input screen, Section 3.2.5). This next most impacted receptor can be either a census block or a polar grid receptor. The polar receptors are also included in the calculation of maximum offsite impacts (also described in Section 4), which can be used in analyzing the risks of short-term exposure.

Unknown Pollutant(s) Warning Screen:

After you have completed Screen 10, click "Next" to proceed to Screen 11. If, instead of Screen 11, an unnumbered screen appears, this means that some of the pollutants in your HAP emissions input file are not in HEM-3's dose response library. Figure 15 displays a sample warning screen listing unknown pollutants.

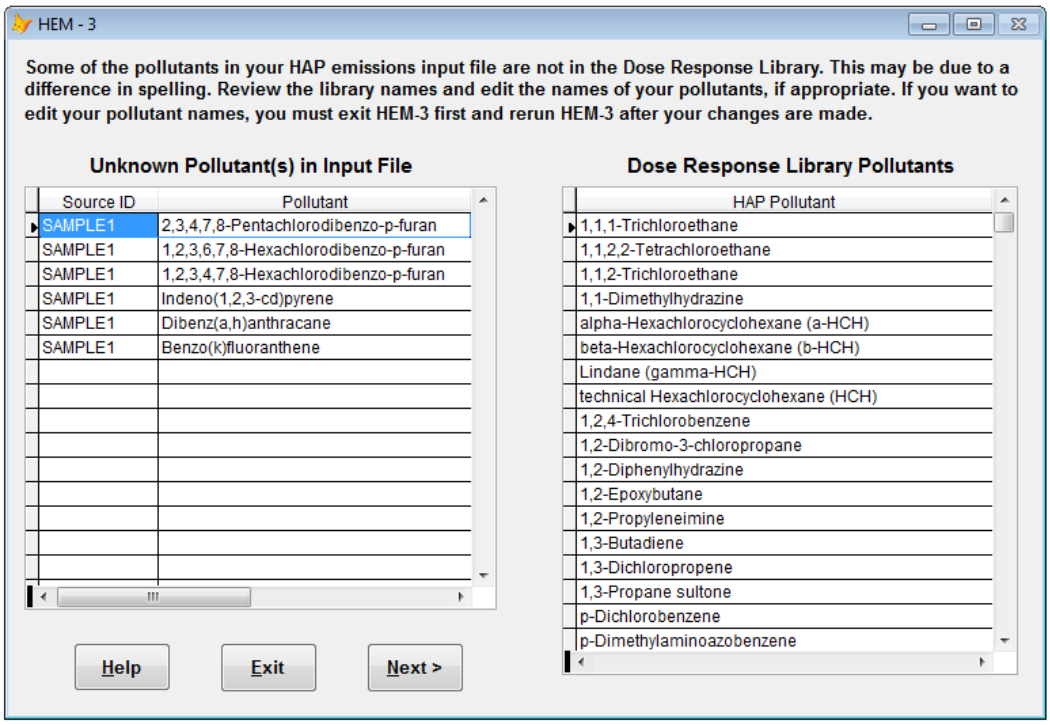

Figure 15. Unknown Pollutant(s) Warning Screen

If you have received this screen, you may want to exit and then re-initiate the model after editing either the HAP emissions input file or the dose response library (located in HEM-3's Reference folder) to ensure that the pollutant spellings between these two files match, and/or that each pollutant that is listed in the HAP emissions input file is listed in the dose response library. However, this is not mandatory. Review the displayed unknown pollutants and decide whether or not any editing or addition of pollutant names and re-initiating of the model is necessary. For example, you may decide that the pollutants that HEM-3 lists on the left side of this screen (as not identified in the dose response library) are not actually toxic pollutants of interest. In this case, click "Next" to continue running the model, and these pollutants will be ignored and excluded from the analysis.

If you decide that editing and/or addition of pollutants is necessary for the analysis, exit the program and make these changes. For example, you can correct misspelled pollutants in the HAP emissions input file using search and replace commands, so that they match the spelling in

the dose response library. You can add a pollutant to the dose response library to reflect a pollutant included in the HAP emissions input file. In this case, include appropriate dose response values (and, if necessary, target organ endpoints for noncancer health effects) for the added pollutant(s), as discussed in Section 3.1.12 *Changing the chemical unit risk estimates and health benchmarks input files*. After making all revisions to the HAP emissions input file and/or the dose response library, re-initiate your model run.

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3.2.11 Review the Emission Locations and Nearby Receptors (Screen 11)

Once you have entered all input data, verified your modeling options, modeling domain, meteorological station and polar ring distances (Screens 1 through 10), HEM-3 identifies the census blocks within the modeling domain. At this point, the model will inform you that the program is looking for census data (this may take a few minutes). Once HEM-3 has retrieved the relevant census data, Screen 11 (shown below in Figure 16) provides you the opportunity to use Google Earth™ to view the location of your emission sources and the receptors close to your facility. Click on the "Google Earth" command button on this screen to view the facility location and the nearest receptors. (If you do not have Google Earth™ installed on your computer, click on the "Install Google Earth" button first.)

If any of the receptors overlap the facility, as defined in Section 3.2.5, HEM-3 will not calculate risks based on the location of that receptor, but will instead assume that the risks associated with the receptor are the same as the highest predicted value for any receptor that does not overlap facility property. Therefore, if there are overlapping receptors, you may wish to enter a series of boundary receptors to make sure that the maximum risks for the overlapping receptors are properly characterized. To do this, click "Exit" to end the current model run. Re-initiate the model run, after entering boundary receptors via Screen 5 in a user-defined receptors file, as described in Section 3.2.5. If the emission source configuration and nearby receptors are sufficient for your analysis—that is, no (or no additional) user-defined boundary receptors are necessary—then click "Next" on Screen 11 to initiate AERMOD's processing within HEM-3.

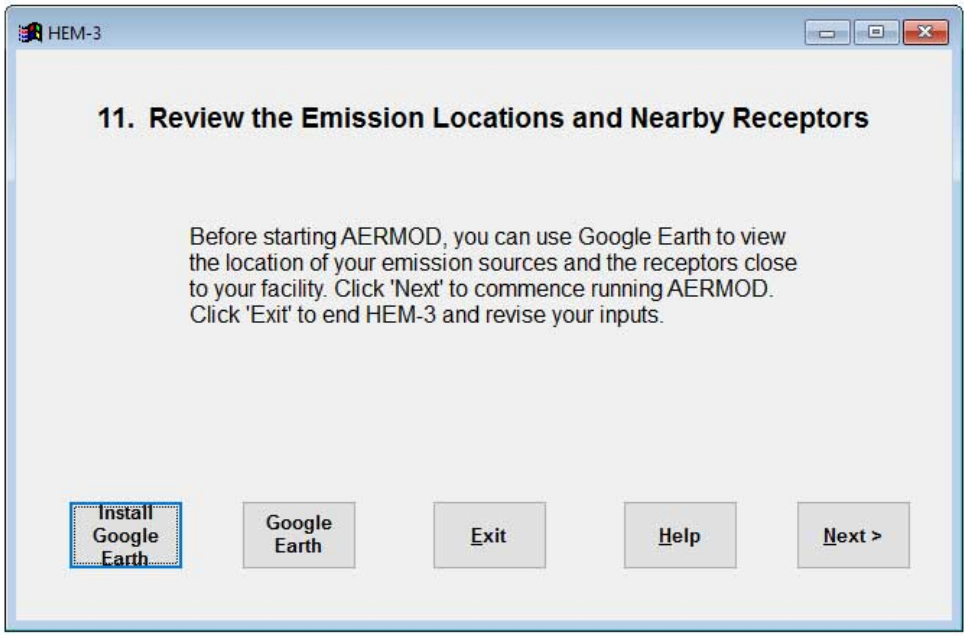

Figure 16. Screen 11 – Review the Emission Locations and Nearby Receptors

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3.3 Commencement and Completion of Modeling Run using AERMOD

After clicking "Next" on Screen 11, a message box appears informing you that AERMOD will begin processing the input data. This may take several minutes to several hours, depending on the complexity of the emission sources and the modeling options you selected. Click "No" on this message box to stop HEM-3 and exit from the program. Click "Yes" to initiate the model run and begin producing the requested outputs.

When AERMOD completes, HEM-3 will display a message box stating "The AERMOD program completed successfully. Output information is being processed prior to display. This may take a few minutes." The next screen to be displayed (Screen 12) is an output screen. Section 4 describes the calculations that HEM-3 performs to produce these outputs. Section 5 lists and describes HEM-3's outputs.

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3.4 Modeling Multiple Facilities

You can use Single HEM-3 to analyze the impacts of a single industrial facility or a cluster of facilities located near one another. As noted in the Introduction, HEM-3 is also available in a Multi-facility version (Multi HEM-3), for modeling multiple facilities spread out from one another in a region or across the entire U.S., as in the RTR assessments by EPA of entire source categories or sectors. The foundations of Multi HEM-3 are the same as described in this User's Guide for Single HEM-3. However, the instructions for use are different and different inputs are required, as detailed in the Multi HEM-3 User's Guide (available on EPA's website at http://www.epa.gov/fera/human-exposure-model-hem-3-users-guides). This section regards modeling multiple facilities located near one another using Single HEM-3, in which the receptors are impacted from the multiple facilities as a grouped whole.

The larger the number of facilities you choose to model at one time, the greater time AERMOD will be required to run; take this into consideration when creating a run. The required runtime will be roughly proportional to the product of the number of emission source locations and the number of receptors modeled. The number of receptors modeled includes all of the census blocks modeled individually, the polar receptor network, and any receptor locations you have defined (as discussed Section 3.2.5).

The cutoff distance for individual modeling of census blocks applies to ***all*** emission source locations, not just to the center of the modeling domain. Thus, HEM!3 ensures that calculated risks and hazard indices are based on actual dispersion model results, rather than interpolation. Due to this feature, the number of individually modeled census blocks will depend on how close the facilities are to one another. For instance, if you have chosen a model cutoff distance of 2 kilometers for a cluster of two facilities located 100 meters apart, the number of individually modeled census blocks will not be much larger than if modeling only one facility. However, the number of individually modeled census blocks will likely double if the facilities are 2 kilometers apart. (The exact numbers will depend on the population density in the modeling domain.)

The interpolations performed in HEM-3 will become less accurate as distances increase between the modeled facilities. This will primarily affect exposure calculations, such as the number of people estimated to be exposed to different risk levels. The accuracy of MIR and maximum HI will generally be unaffected, because these values are not interpolated unless the selected cutoff distance is too small. (HEM-3 will show a warning message when this occurs.)

You can use the HEM-3 output files to distinguish the contributions of different emission sources to the MIR or maximum HI (see Sections 5.1 and 5.2). When modeling a cluster of facilities, use the first few characters of the Source ID to distinguish among different facilities. For instance, "F1" for the first plant, "F2" for the second plant, and so on. This will help you in interpreting model results for the facilities making up the cluster.

The location of the MIR for a cluster of facilities may differ from the location of the MIR for any single facility in the cluster (due to emissions from multiple facilities impacting the same receptors). Therefore, you may wish to model the facilities in the cluster separately as well as together. The Multi HEM-3 model can be used to model the facilities separately, in order to produce facility-specific MIRs and other facility-specific outputs.

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3.5 Instructions for Using Previously Modeled or Monitored Concentration Data

On Screen 1, you have the choice of using AERMOD in the HEM-3 run to compute ambient concentrations, or using previously modeled or monitored concentration data. If you checked the box indicating that you would be using previously modeled or monitored concentration data, an alternate Screen 2 (**2. *User-supplied pollutant concentration inputs***) appears (Figure 17).

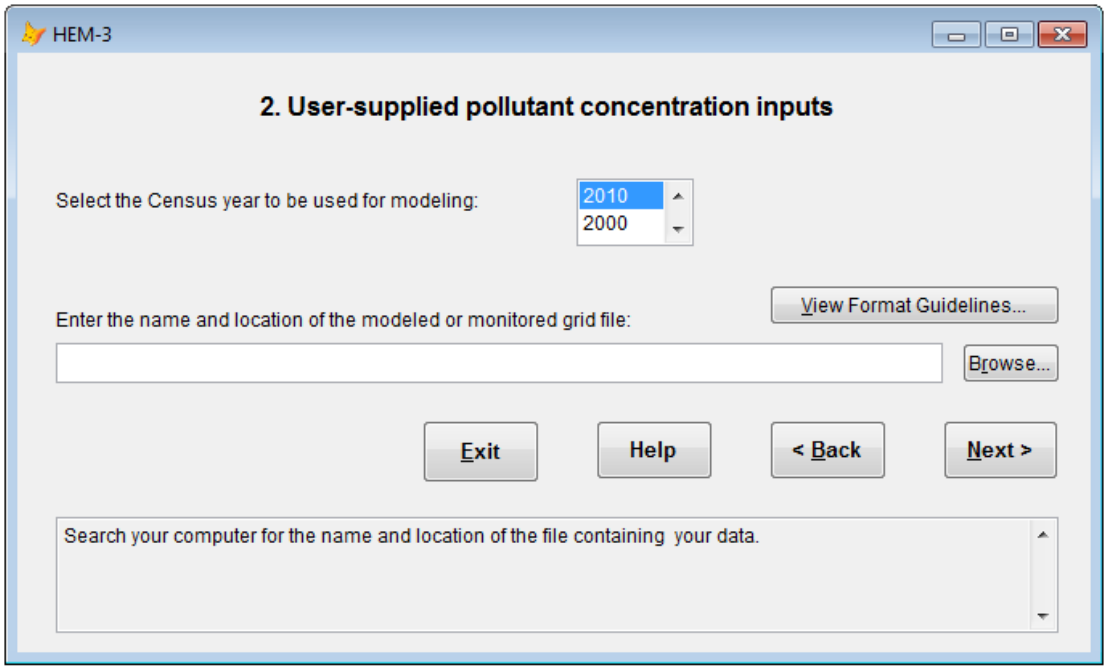

Figure 17. Alternate Screen 2 - User-Supplied Pollutant Concentration Inputs

Select the census year to be used for modeling (2000 or 2010).

Enter the name and location of the input file containing the previously modeled or monitored concentrations. See Section 3.1.11 for a description of this file. When choosing user-supplied concentration results under this option, no modeling by AERMOD will occur. Instead, HEM-3 will interpolate these external concentration results to all census block centroid locations within the study domain using a Voronoi Neighborhood Averaging approach. Section 4.4 describes these Voronoi averaging calculations in more detail. HEM-3 will then compute risk and HI results based on these interpolated values. [Note: This option is not intended to be used with modeled data produced with a polar coordinate system. Furthermore, no polar grid receptors will be created under this option.]

Click “Next” to commence the HEM-3 modeling run. Unlike a HEM-3 run using AERMOD, the screen will not display outputs. Instead, when the run is complete, HEM-3 will notify you that the outputs have been placed in HEM-3’s output folder. See Section 5.7 for a brief discussion of the output files resulting from a HEM-3 run using previously modeled or monitored concentration data.

4. Calculations Performed by HEM-3

This section describes the dispersion modeling calculations that HEM-3 implements automatically, as well as the post-dispersion modeling cancer risk and noncancer hazard calculations HEM-3 performs to generate its outputs.

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4.1 Dispersion Modeling

HEM-3 carries out dispersion modeling by running the AERMOD dispersion model. Section 3 describes a number of options you can specify for running AERMOD—for example, incorporating deposition and depletion, emissions variations, and using urban or rural dispersion parameters. This section discusses the options that HEM-3 implements by default. In addition, this section describes the dilution factor methodology used in HEM-3 for modeling multiple pollutants.

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4.1.1 Regulatory Default Option

HEM-3 uses the regulatory default options when running AERMOD. These options include the following:

- Use stack-tip downwash (except for Schulman-Scire downwash);
- Use buoyancy-induced dispersion (except for Schulman-Scire downwash);
- Do not use gradual plume rise (except for building downwash);
- Use the “calms processing” routines;
- Use upper-bound concentration estimates for sources influenced by building downwash; from super-squat buildings;
- Use default wind profile exponents;
- Use low wind speed threshold;
- Use default vertical potential temperature gradients; and
- Use missing-data processing routines.

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4.1.2 FASTALL Option in AERMOD

If selected, HEM-3 implements AERMOD’s FASTALL. This option conserves model runtime by simplifying the AERMOD algorithms used to represent meander of the pollutant plume. This simplification is achieved by eliminating the upwind component of dispersion for point and volume sources, and by reducing the requirement for uniformity of emissions over the extent of area sources (EPA 2018b). More information on AERMOD’s FASTALL option is available for download at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod in AERMOD’s model documentation. FASTALL is not implemented by default in the current HEM-3 (as noted in Section 3.2.4). AERMOD’s dispersion calculations in HEM-3 are rigorous and do not include FASTALL’s plume and source simplifications.

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4.1.3 Dilution Factors

HEM-3 uses AERMOD to compute a series of dilution factors, specific to each emission source and receptor. This approach more quickly analyzes the impacts of multiple pollutants than if separately modeling each pollutant. The dilution factor for a particular emission source and receptor is defined as the predicted ambient impact from the given source and at the given receptor, divided by the emission rate from the given source.

If you choose not to analyze deposition or depletion, then the dilution factor does not vary from pollutant to pollutant. If you do select deposition or depletion, HEM-3 will compute separate dilution factors for gaseous and particulate pollutants. In addition, you can specify different particle sizes and densities for each particulate matter emission source. To use pollutant-specific parameters for particulates and/or gases, requires a separate Source ID for each pollutant at a given source. You can create multiple Source IDs using the same locations and stack parameters to accommodate different pollutants.

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4.2 Estimating Risks and Hazard Indices

HEM-3 estimates the total cancer risk and noncancer hazard index (HI) for all census block locations in the modeling domain, all user-defined receptors, and all points in the polar receptor network. Section 4.2.1 describes methods used to calculate cancer risks and HI for receptors that AERMOD explicitly models. Section 4.2.2 describes the interpolation approach used to estimate cancer risks and HI at census blocks not explicitly modeled.

Based on the results for census blocks and other receptors, HEM-3 estimates the maximum individual risk (MIR) and maximum HI for populated receptors (Section 4.2.3); as well as the maximum impacts for all offsite receptors, including unpopulated locations (Section 4.2.4). For these locations, the model calculates the contributions of individual chemicals and emission sources to cancer risks and HI (Section 4.2.5).

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4.2.1 Inner Census Blocks and Other Modeled Receptors

HEM-3 calculates cancer risks and target-organ-specific HI for three types of discrete receptors. These are (1) census blocks within the user-defined cutoff distance for modeling of individual blocks, (2) all user-defined receptors, and (3) the user-defined polar receptor network.

As noted in Section 4.1.3, *Dilution Factors*, HEM-3 combines pollutants into two categories—gases and particulates—for the purposes of dispersion modeling. To conserve computer memory, the model retains these categories to calculate cancer risks and noncancer HI. HEM-3 uses the following algorithms:

For cancer risk:

$$CR_T = \Sigma_{i,j}\, CR_{i,j}$$

$$CR_{i,j} = DF_{i,j} \times CF \times \Sigma_k \left[E_{i,k} \times URE_k\right]$$

For noncancer hazard indices:

$$HI_T = \Sigma_{i,j}\, HI_{i,j}$$

$$HI_{i,j} = DF_{i,j} \times CF \times \Sigma_k \left[E_{i,k} / (RfC_k \times 1000\ \mu g/mg)\right]$$

where:

CR_T = total cancer risk at a given receptor (probability for one person)
$\Sigma_{i,j}$ = the sum over all sources i and pollutant types j (particulate or gas)
$CR_{i,j}$ = cancer risk at the given receptor for source i and pollutant type j
$DF_{i,j}$ = dilution factor [($\mu g/m^3$) / (g/sec)] at the given receptor for source i and pollutant type j
CF = conversion factor, 0.02877 [(g/sec) / (tons/year)]
Σ_k = sum over all pollutants k within pollutant group j (particulate or gas)
$E_{i,k}$ = emissions (tons/year) of pollutant k from source I
URE_k = cancer unit risk estimate [1/($\mu g/m^3$)] for pollutant k (cancer risk for an individual exposed to 1 $\mu g/m^3$ over a lifetime)
HI_T = TOSHI at a given receptor and for a given organ
$HI_{i,j}$ = organ-specific hazard index at the given receptor for source i and pollutant type j
RfC_k = noncancer health effect reference concentration (mg/m^3) for pollutant k (concentration at and below which no adverse health effect is expected)

The above equations are equivalent to the following simpler equations:

$$CR_T = \Sigma_{i,k}\, AC_{i,k} \times URE_k$$

$$HI_T = \Sigma_{i,k}\, AC_{i,k} / (RfC_k \times 1000\ \mu g/mg)$$

where:

$AC_{i,k}$ = ambient concentration ($\mu g/m^3$) for pollutant k at the given receptor. This is the same as [$E_{i,k} \times DF_{i,j} \times CF$]

However, use of these simpler equations would require modeling all pollutants individually in AERMOD, and performing separate risk calculations for each pollutant.

If the cancer unit risk estimate (URE) is not available for a given chemical, then that chemical is not included in the calculation of cancer risk. Likewise, if the noncancer reference concentration (RfC) is not available for a given chemical, that chemical is not included in the calculation of HI. Note that separate reference concentrations are used for acute and chronic HI.

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4.2.2 Outer Census Blocks

For census blocks outside of the user-defined cutoff distance for individual block modeling, HEM-3 estimates cancer risks and HI by interpolation from the polar receptor network. HEM-3 estimates impacts at the polar grid receptors using AERMOD modeling results and the algorithms described in Section 4.2.1. If you select the terrain elevation option, then an elevation is estimated for each polar receptor. HEM-3 estimates elevations and controlling hill heights for the polar grid receptors based on values from the census library. HEM-3 divides the modeling domain into sectors based on the polar grid receptor network, with each census block assigned to the sector corresponding to the closest polar grid receptor.

HEM-3 then assigns each polar grid receptor an elevation based on the highest elevation for any census block in its sector. The controlling hill height is also set to the maximum hill height within the sector. If a sector does not contain any blocks, the model defaults to the elevation and controlling hill height of the nearest block outside the sector, or defaults to the elevation of the nearest source (if the polar grid receptor is closer to a source than to a block outside its sector).

HEM-3 interpolates the impacts at each outer census block from the four nearest polar grid receptors. The interpolation is linear in the angular direction, and logarithmic in the radial direction, as summarized in the following equations:

$$I_{a,\,r} = I_{A1,\,r} + (I_{A2,\,r} - I_{A1,\,r}) \times (a - A1) \,/\, (A2 - A1)$$

$$I_{A1,\,r} = \exp\{\ln(I_{A1,R1}) + [\ln(I_{A1,R2}) - \ln(I_{A1,R1})] \times [(\ln r) - \ln(R1)] \,/\, [\ln(R2) - \ln(R1)]\}$$

$$I_{A2,\,r} = \exp\{\ln(I_{A2,R1}) + [\ln(I_{A2,R2}) - \ln(I_{A2,R1})] \times [(\ln r) - \ln(R1)] \,/\, [\ln(R2) - \ln(R1)]\}$$

where:

- $I_{a,r}$ = the impact (cancer risk or hazard index) at an angle, a, from north, and radius, r, from the center of the modeling domain
- a = the angle of the target receptor, from north
- r = the radius of the target receptor, from the center of the modeling domain
- A1 = the angle of the polar network receptors immediately counterclockwise from the target receptor
- A2 = the angle of the polar network receptors immediately clockwise from the target receptor
- R1 = the radius of the polar network receptors immediately inside the target receptor
- R2 = the radius of the polar network receptors immediately outside the target receptor

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4.2.3 Maximum Individual Risks and Hazard Indices

HEM-3 evaluates the predicted impacts for all populated receptors to identify the locations of the MIR and the highest HI for various target organs (maximum TOSHIs). For these calculations, populated receptors include all census block locations and any user-defined receptors designated as type-P (population-oriented). In general, type-P receptors should include houses near the facility boundary, as well as nearby schools, public places, or other populated sites.

The maximum cancer risk may occur at a location other than the maximum HI for a given organ. Likewise, the location of the maximum HI for one organ will not necessarily be the same as the location for a different organ. HEM-3 performs a separate evaluation of the maximum impact location for each health effect.

The model also tests for instances where census blocks or other type-P receptors appear to be located on plant property. To do so, HEM-3 calculates the distance between each receptor and each emission source. These distances are compared with an overlap distance that you can specify. If a population-oriented receptor is located within the overlap distance, then HEM-3 does not use these calculated results for this receptor to estimate the maximum individual cancer risk or maximum HI for populated areas. Instead, the model assumes the impacts at the overlapping receptor to be equal to the maximum impacts for any receptors that do not overlap plant property. This could include both populated and unpopulated receptors, as long as they do not overlap plant property.

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4.2.4 Maximum Offsite Impacts

In addition to evaluating the maximum cancer risks and HI for populated receptors, HEM-3 evaluates maximum offsite impacts for all receptors. All census blocks, all user-defined receptors (populated and unpopulated), and all points on the polar receptor network are included in the evaluation of maximum offsite impacts, except for those receptors that are found to be overlapping emission sources.

4.2.5 Contributions of Different Chemicals and Emission Sources

HEM-3 calculates the contributions of different chemicals and emission sources to cancer risks and HI at the receptors where impacts are highest, both for populated receptors and for all offsite receptors. As noted in Section 4.2.1, HEM-3 conserves computer memory by grouping chemicals together when calculating total risks and HI for the large number of receptors that are typically included in an overall modeling domain. Thus, the model does not compute the contributions of individual chemicals and emission sources for all receptors. However, HEM-3 retains the information needed to determine the contributions of individual chemicals and emission sources at the receptors where impacts are highest. HEM-3 calculates these contributions using the following equations:

$$AC_{i,k,m} = E_{i,k} \times DF_{i,j,m} \times CF$$

$$CR_{i,k,m} = AC_{i,k,m} \times URE_k$$

$$HQ_{i,k,m} = AC_{i,k,m} / (RfC_k \times 1000\ \mu g/mg)$$

where:

$AC_{i,k,m}$ = predicted ambient concentration ($\mu g/m^3$) for pollutant k, from source I, at receptor m

$E_{i,k}$ = emissions (tons/year) of pollutant k from source I

$DF_{i,j,m}$ = the dilution factor [($\mu g/m^3$) / (g/sec)] for source i, receptor m, and pollutant group j, which includes pollutant k

CF = conversion factor, 0.02877 [(g/sec) / (ton/year)]

$CR_{i,k,m}$ = estimated cancer risk from source i, and pollutant k, at receptor m

URE_k = cancer unit risk estimate [1/($\mu g/m^3$)] for pollutant k (cancer risk for an individual exposed to 1 $\mu g/m^3$ over a lifetime)

$HQ_{i,k,m}$ = organ-specific hazard quotient as a result of emissions of pollutant k, from source i, at receptor m

RfC_k = noncancer health effect reference concentration (mg/m^3) for pollutant k (concentration at and below which no adverse health effect is expected)

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4.3 Population Exposures, Average Impacts and Incidence

Using the predicted impacts for census blocks, HEM-3 estimates the populations exposed to various cancer risk levels and HI levels. To do so, the model adds up the populations for receptors that have predicted cancer risks or HI above the given threshold.

The model also calculates the average cancer risks, average HI, and annual cancer incidence for census blocks located within various distances of the emission sources using the following equations:

$$MCR_d = \Sigma_m \left[CR_m \times P_m\right] / \Sigma_m P_m$$

$$MHI_d = \Sigma_m \left[HI_m \times P_m\right] / \Sigma_m P_m$$

$$TCR_d = \Sigma_m \left[CR_m \times P_m\right] / LT$$

where:

MCR_d = the population-weighted average cancer risk for the population located within distance d of the center of the modeling domain

Σ_m = the sum over all census blocks m within distance d

CR_m = the total lifetime cancer risk (from all modeled pollutants and emission sources) at census block m

P_m = the population at census block m

MHI_d = the population-weighted average HI (for a particular organ) for the population located within distance d

HI_m = the total HI for the given organ (from all modeled pollutants and emission sources) at census block m

TCR_d = the estimated annual cancer incidence (cancers/year) of the population living within distance d

LT = the average lifetime used to develop the cancer unit risk estimate, 70 years

HEM-3 also estimates the contributions of different chemicals and emission sources to total annual cancer incidence for the overall modeling domain using the following equations:

$$TCR_{i,j} = \Sigma_m \left[\left(\Sigma_k E_{i,k} \times URE_k\right) \times DF_{i,j,m} \times CF / LT\right]$$

$$TCR_{i,k} = TCR_{i,j} \times E_{i,k} \times URE_k / \left(\Sigma_k E_{i,k} \times URE_k\right)$$

where:

$TCR_{i,j}$ = the estimated total annual cancer incidence (cancers/year) to the population in the modeling domain due to emissions from pollutant type j (1 = particulate, 2 = gas) and emission source i

Σ_m = the sum over all census blocks m in the modeling domain

Σ_k = the sum over all pollutant k, within pollutant type j

$E_{i,k}$ = emissions (tons/year) of pollutant k from source i

URE_k = unit risk estimate [1/($\mu g/m^3$)] for pollutant k (cancer risk for an individual exposed to 1 $\mu g/m^3$ over a lifetime)

$DF_{i,j,m}$ = dilution factor [($\mu g/m^3$) / (g/sec)] at receptor m, for emissions of pollutant type j (which includes pollutant k), from source i

CF = conversion factor, 0.02877 [(g/sec) / (ton/year)]

$TCR_{i,k}$ = the estimated annual cancer incidence (cancers/year) of the population in the modeling domain due to emissions of pollutant k (in pollutant type j) from emission source i

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4.4 Interpolation of Concentrations from User-Supplied Pollutant Concentration Data

You can optionally provide HEM-3 with pollutant concentrations from an external model or monitoring data. If you choose this option, HEM-3 will not run AERMOD. HEM-3 will use the external model or monitoring data to interpolate pollutant concentrations for all census blocks in the study domain. As noted previously: This approach is intended to be used with monitoring data or gridded modeling data for a large collection of emission sources. It is not intended to be used with modeling data produced with a polar coordinate system for a single facility. In that situation, you should run HEM-3 in the standard way. Forcing polar array data into the Voronoi averaging system will cause a loss of data integrity regarding the spatial relationship between the emission source(s) and the receptors. Furthermore, this approach should only be used when the distance between each user-supplied concentration (e.g., grid node) and nearby HEM-3 receptor is less than the distance between that HEM-3 receptor and a contributing emission source. If a HEM-3 receptor is closer to a contributing emission source than to the user-supplied concentration (from which the HEM-3 receptor concentration will be interpolated), then the concentration and risk at that HEM-3 receptor may be underestimated, because the contribution of the nearby emission source is not sufficiently accounted for in the interpolation. In general, the lower the spatial resolution of the user-supplied concentrations, the more likely that HEM-3 receptor concentrations and risk will be underestimated by this Voronoi approach.

You can provide HEM-3 with optional pollutant concentrations using a rectilinear grid, or an arbitrary array of monitored or modeled locations. In either case, HEM-3 analyzes the user-supplied input file to determine the geographic boundaries of the study domain. The model then develops a list of all census blocks with centroids in the study domain.

The model uses a Voronoi Neighborhood Averaging approach to interpolate pollutant concentrations at the census block centroids based on the concentration data you provided. In

the interpolation procedure, HEM-3 handles each census block separately. HEM-3 identifies the available pollutant concentration sites near the census block centroid, then creates a Voronoi diagram for the census block centroid and the nearby concentration sites. Essentially, the creation of this Voronoi diagram involves drawing a polygon around the census block centroid. The sides of the polygon are the perpendicular bisects of the line segments from the centroid to the nearest concentration sites. Any concentration site that shares a polygon boundary with the census block centroid (when taking into account all other neighboring boundaries) is considered a "Voronoi" neighbor. Figure 18 shows an example Voronoi diagram for an array of arbitrarily located concentration sites.

Once all Voronoi neighbors have been identified for a given census block centroid, the model estimates the concentration of each pollutant at the centroid. HEM-3 calculates the average concentration, weighted by the inverse of the distance from the census block centroid to each neighboring location, using the following equation:

$$AC = \exp\left\{\Sigma_k \left[\ln(VC_k) / D_k\right] / \left(\Sigma_k\ 1 / D_k\right)\right\}$$

where:

AC =	estimated ambient pollutant concentration at a given census block centroid ($\mu g/m^3$)
Σ_k =	the sum over all Voronoi neighbors, k, of the given census block
VC_k =	pollutant concentration for site k ($\mu g/m^3$)
D_k =	distance between the census block centroid and site k (m)

HEM-3 calculates the cancer risks and HI from the estimated ambient concentration using the algorithms given in Section 4.2.1.

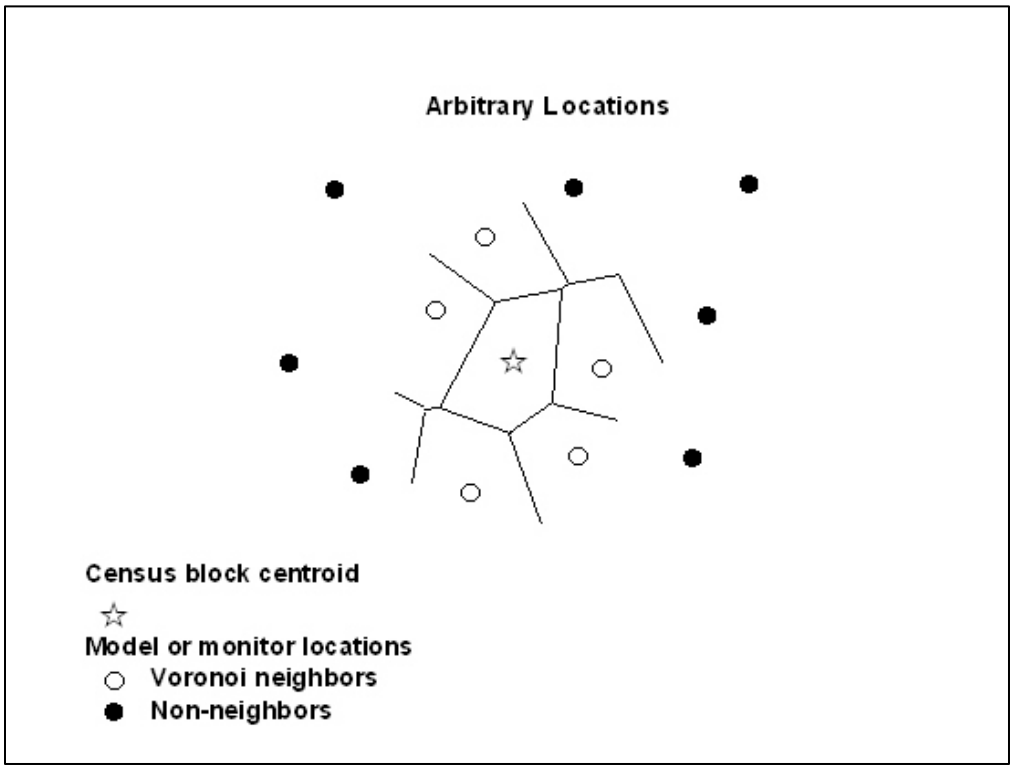

Figure 18. Sample Voronoi Diagram.

5. Outputs of HEM-3

After running the AERMOD dispersion model and completing the necessary risk and exposure calculations, HEM-3 displays a series of output tables on the screen. HEM-3 also copies these screen tables to spreadsheets in Excel™ format in the output folder you specified on Screen 1. Finally, HEM-3 also produces a number of more detailed database format (DBF), CSV (if you so choose on Screen 1), and spreadsheet files that you can use for other related analyses, such as summarizing the demographics of the populations potentially impacted by the modeled emissions, or modeling multipathway impacts based on deposition flux. The following sections describe the output screen tables and files that HEM-3 produces.

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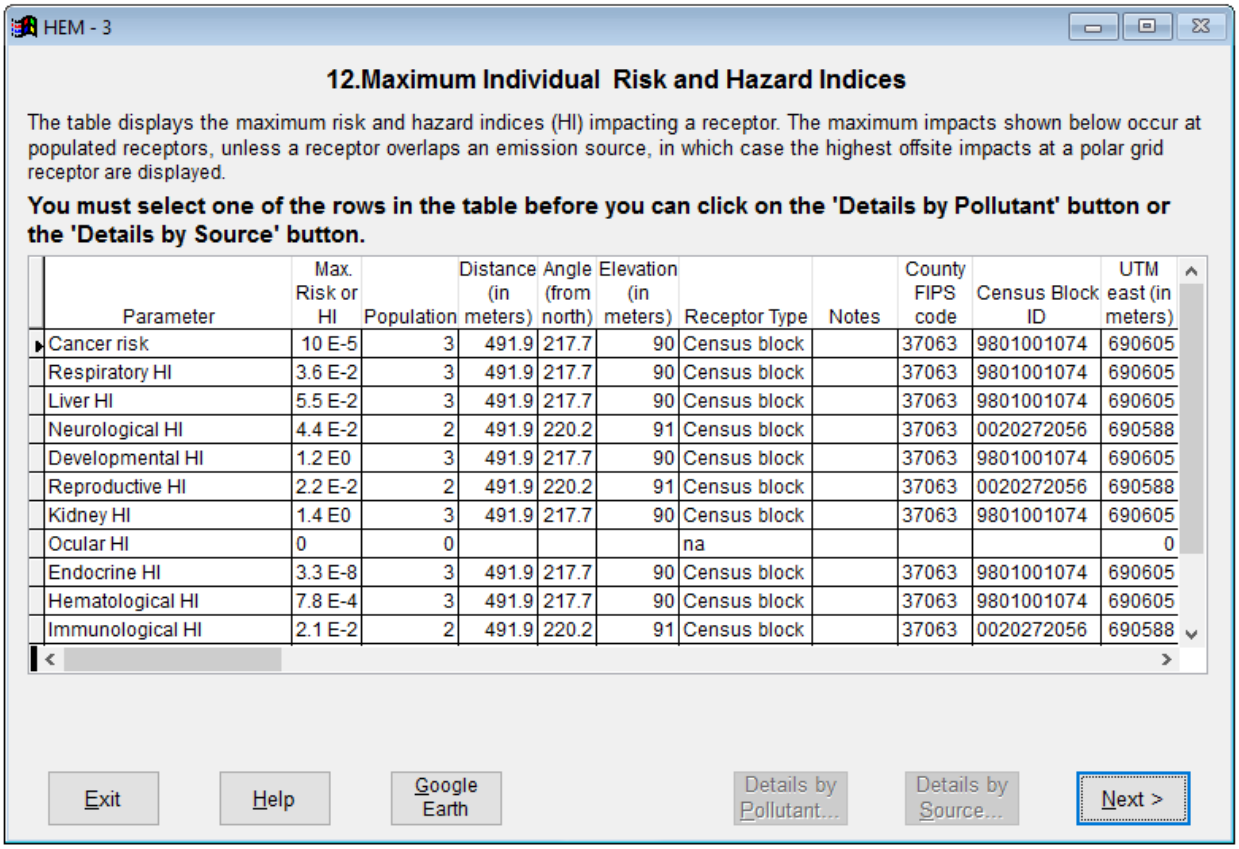
5.1 Maximum Individual Risk and Hazard Indices (Screen 12)

After the modeling run completes, the first output screen displayed by HEM-3 is Screen 12 (**12. *Maximum Individual Risk and Hazard Indices***), shown below in Figure 19. This output screen provides the MIR for cancer and the HI for noncancer chronic health effects, predicted for any populated receptor that does not overlap facility property.



Parameter	Max. Risk or HI	Population	Distance (in meters)	Angle (from north)	Elevation (in meters)	Receptor Type	Notes	County FIPS code	Census Block ID	UTM east (in meters)
Cancer risk	10 E-5	3	491.9	217.7	90	Census block		37063	9801001074	690605
Respiratory HI	3.6 E-2	3	491.9	217.7	90	Census block		37063	9801001074	690605
Liver HI	5.5 E-2	3	491.9	217.7	90	Census block		37063	9801001074	690605
Neurological HI	4.4 E-2	2	491.9	220.2	91	Census block		37063	0020272056	690588
Developmental HI	1.2 E0	3	491.9	217.7	90	Census block		37063	9801001074	690605
Reproductive HI	2.2 E-2	2	491.9	220.2	91	Census block		37063	0020272056	690588
Kidney HI	1.4 E0	3	491.9	217.7	90	Census block		37063	9801001074	690605
Ocular HI	0	0				na				0
Endocrine HI	3.3 E-8	3	491.9	217.7	90	Census block		37063	9801001074	690605
Hematological HI	7.8 E-4	3	491.9	217.7	90	Census block		37063	9801001074	690605
Immunological HI	2.1 E-2	2	491.9	220.2	91	Census block		37063	0020272056	690588

Figure 19. Screen 12 – Maximum Individual Risk and Hazard Indices Output Screen

If any populated receptor is located within the minimum overlap distance, then it is assumed that either the source location or the receptor location is inappropriate. (A block centroid may be inappropriate as a receptor location if the block partially encompasses an emission source, such as at a corner of the facility.) When an overlap condition occurs, the calculated results for the overlapping receptor are not used. Instead, the maximum cancer risk and HI are assumed equal to the maximum impacts for any receptor that does not overlap facility property. This could include both populated (Census, populated user-defined) receptors and unpopulated (polar, unpopulated user-defined such as boundary and monitor) receptors, as long as they do not overlap facility property. When this occurs, a warning message displays. In this situation, check the coordinates in the emissions location input file, and define a set of facility boundary receptors in the user-defined receptors file.

As previously noted, HEM-3 computes cancer risks using the EPA's recommended unit risk estimates (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 over a 70-year lifetime. Noncancer health effects are quantified using hazard quotients (HQ) and hazard indices (HI) for various target organs. The HQ for a given chemical and receptor site is the ratio of the ambient concentration of the chemical to the reference concentration (RfC) level at which no adverse effects are expected. The HI for a given organ is the sum of HQs for substances that affect that organ.

In the example shown in Figure 19, the maximum individual cancer risk or MIR for the modeled facility is 10 E-5 (or 100 in 1 million). That is, an individual's risk of developing cancer at the receptor site of maximum cancer risk impact is approximately 100 in 1 million. This is a conservative estimate, based on a resident being continually exposed to the ambient (outdoor) air over a 70-year lifetime, and is not adjusted with any attenuating exposure factors (such as daily movement out of the maximum receptor site for work and other reasons, indoor versus outdoor concentrations, the fact that people rarely live in one location for 70 years, etc.). None of the maximum target-organ specific hazard indices (TOSHIs) shown in Figure 19 is greater than 1, if using one significant figure precision. The developmental HI and the kidney HI shown in Figure 19 are 1.2 and 1.4, respectively, which both round to 1. Therefore, using a precision of one significant figure, these TOSHIs are below the level at which chronic noncancer adverse effects would be expected, as a result of lifetime exposure to the ambient air at each receptor site. Note that the receptor location of maximum impact for each health effect—cancer, respiratory HI, neurological HI, etc.—may not be the same.

As Figure 19 shows, one health effect is listed per row. These health effects are: cancer risk; and chronic maximum TOSHIs for the respiratory system, liver, neurological system, developmental effects, reproductive system, kidney, ocular system, endocrine system, hematological system, immunological system, skeletal system, spleen, thyroid, and whole body.

To view the contribution of different pollutants to the maximum cancer risk, or to any of the HI, highlight the appropriate line, then click the "Details by Pollutant" button. The pollutant contributions to the maximum cancer risk will be displayed in order of highest impact, as shown below in Figure 20. In the example shown in Figure 20, the arsenic concentration contributed by all emission sources to the receptor location of maximum overall risk (the census block shown in the first output row in Figure 19) is 1.7 E-2 (or 0.017) $\mu g/m^3$. The cancer risk resulting from lifetime exposure to this concentration of arsenic is 7.5 E-5 (or 75 in 1 million). The sum of risk at this receptor location from all modeled pollutants listed in Figure 20 equals the overall cancer risk or MIR listed in the first row on Screen 12 (10 E-5), shown in Figure 19 (when not rounded to two significant figures prior to summation).

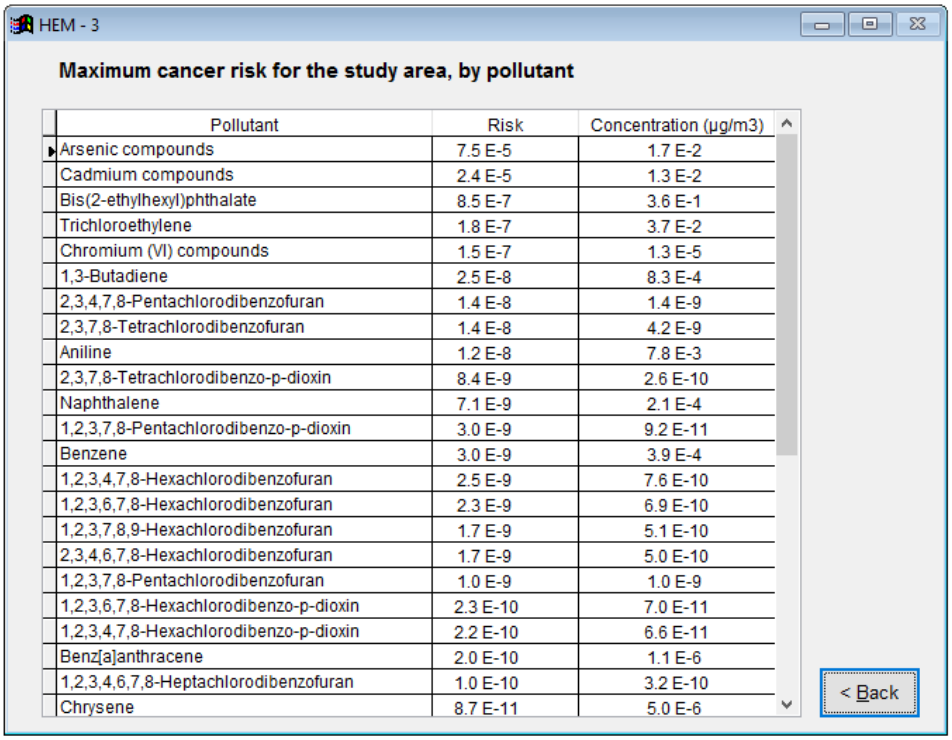


Figure 20. Maximum Cancer Risk for the Study Area, by Pollutant Output Screen

To view the contribution of different emission sources to the maximum risk and maximum HI, highlight the row of interest on Screen 12, then click the “Details by Source” button. The resulting screen is shown below in Figure 21.

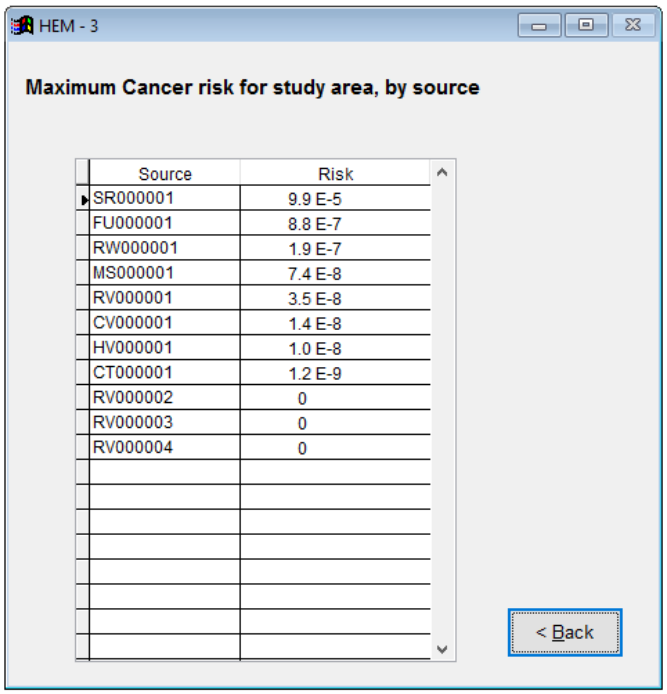


Figure 21. Maximum Cancer Risk for Study Area, by Source Output Screen

In this example, the source identified as “SR000001” contributes 9.9 E-5 (or 99 in 1 million) to the overall risk shown in the first output line of Figure 19. The sum of risk for the 11 sources shown in Figure 21 equals the overall maximum cancer risk or MIR (10 E-5 or 100 in 1 million) listed in the first row of output shown in Figure 19.

If you requested that a map of all receptors be produced (on Screen 1), highlight any of the receptor lines on Screen 12, then click the “Google Earth™” button to view a Google Earth™ map centered on the facility, as shown in Figure 22. (Note that HEM-3 does not produce a Google Earth™ results map if you answered “No” to the Screen 1 question “Do you want output files and a map of results for all receptors, by pollutant and source?”) The map displays the emission sources in the center as red circles for point/stack sources, red rectangles for area sources, red polygons for polygon-shaped sources, and red lines for line and buoyant line sources. The map also displays all receptors within the modeled area, including both census block centroid receptors (displayed as squares) and polar grid receptors (displayed as circles). The MIR receptor is marked with a red “X”.

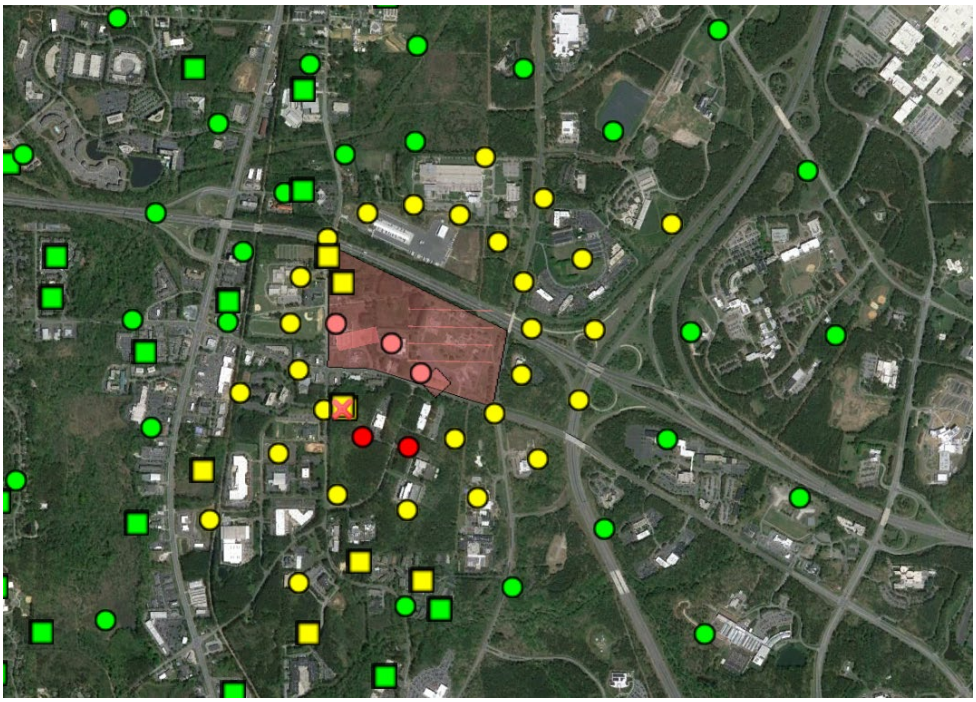


Figure 22. Sample Google Earth™ Map of Results

Click on the square census block receptors to see the total cancer risk and maximum TOSHI for that receptor, the FIPS and block ID of the receptor, as well as a listing of the top pollutants contributing to that block’s total cancer risk and maximum TOSHI. Click on the circular polar receptors to view similar information for each polar receptor. The cancer risk at the census block and polar receptors are color coded on the Google Earth™ map. Red indicates a receptor with a modeled total cancer risk greater than 100 in a million. Yellow indicates a risk level between 20 and 100 in a million. Green indicates a risk less than 20 in 1 million.

Figure 22 shows an example in which only two non-populated polar grid receptors have a risk greater than 100 in a million (shown as dark red circles). All populated census block receptors have modeled risks between 20 and 100 in a million (shown as yellow squares) or less than 20 in a million (shown as green squares).

Table 29 shows the fields displayed in both Screen 12 (**12. *Maximum Individual Risk and Hazard Indices***) and Screen 13 (**13. *Maximum Offsite Impacts and Locations***). See Section 5.2 for a discussion of Screen 13.

Table 29. Fields Included in the Maximum Individual Risk and Hazard Indices Output Screen and Maximum Offsite Impacts and Locations Output Screen

Field	Description
Parameter	Maximum individual cancer risk (MIR), maximum respiratory HI, maximum liver HI, maximum neurological HI, etc.
Max. Risk or HI	MIR value or maximum TOSHI value.
Population	At the location of the MIR or maximum HI, if it is a census block.
Distance	From the center of the modeling domain, in meters.
Angle	From north.
Elevation	In meters above sea level.
Receptor type	Census block receptor, polar grid receptor, user-defined receptor, boundary receptor, monitor location.
Notes	An entry in this field will generally mean that the modeling analysis should be rerun. This field will provide advice on how to change model input files or other specifications.
County FIPS code	Five-digit Federal Information Processing Standard (FIPS) code which uniquely identifies the county of the receptor, if the receptor is a census block.
Census block ID	10-digit census block ID for linking to census demographic data, if the receptor is a census block.
UTM east coordinate	In meters.
UTM north coordinate	In meters.
Latitude	Decimal.
Longitude	Decimal.
Hill Height	Controlling hill height of receptor, in meters above sea level, as described in Section 2.3.1.

As noted above, the information provided on the output screens is also automatically placed in files in HEM-3's Output folder within the subfolder you named on Screen 1. In this subfolder, HEM-3 automatically produces an Excel™ file entitled "maximum_indiv_risks.xlsx" that includes all of the data tabulated on Screen 12 (although not in the identical order as shown above in Table 29). HEM-3 also produces another file, entitled "risk_breakdown.xlsx" that provides the breakdown of risk and HI by pollutant and source, including a listing of pollutant concentration and URE and RfC values.

This file also shows the contributions of gaseous and particulate emissions for any chemicals that are emitted in both forms, if you opted to model deposition, or if on the deposition screen (Screen 3), you elected to show the particulate/gaseous breakdown, as explained in Section 3.2.3. Table 30 shows the fields included in the risk breakdown file. This file includes information about the MIR and HI, as well as the maximum offsite impacts, as discussed in Section 5.2.

Table 30. Fields Included in the Risk Breakdown File

Field	Description
Site type	MIR or maximum offsite impact
Parameter	Cancer risk, respiratory HI, liver HI, neurological HI, etc.
Source ID	Identifying name of source, or "total" for all sources combined
Pollutant	Pollutant name, or "all modeled pollutants" for all pollutants combined
Emission (Pollutant) type	P = particulate, V = vapor (gas), NA = not applicable (for output lines regarding all pollutants)
Value	Cancer risk or noncancer HQ
Value_rnd	Cancer risk or noncancer HQ rounded to two significant figures
Conc_ugm3	Pollutant concentration ($\mu g/m^3$)
Conc_rnd	Pollutant concentration ($\mu g/m^3$) rounded to two significant figures
Emission_tpy	Modeled tons per year (tpy) emitted of pollutant
URE	Unit risk estimate used to compute cancer risks for the pollutant [1 / ($\mu g/m^3$)]
RfC	Reference concentration used to compute HQs for the pollutant (mg/m^3); Note that HEM-3 converts this to $\mu g/m^3$ to compute TOSHIs

Click "Next" on Screen 12 to proceed to Screen 13, entitled *Maximum Offsite Impacts and Locations*.

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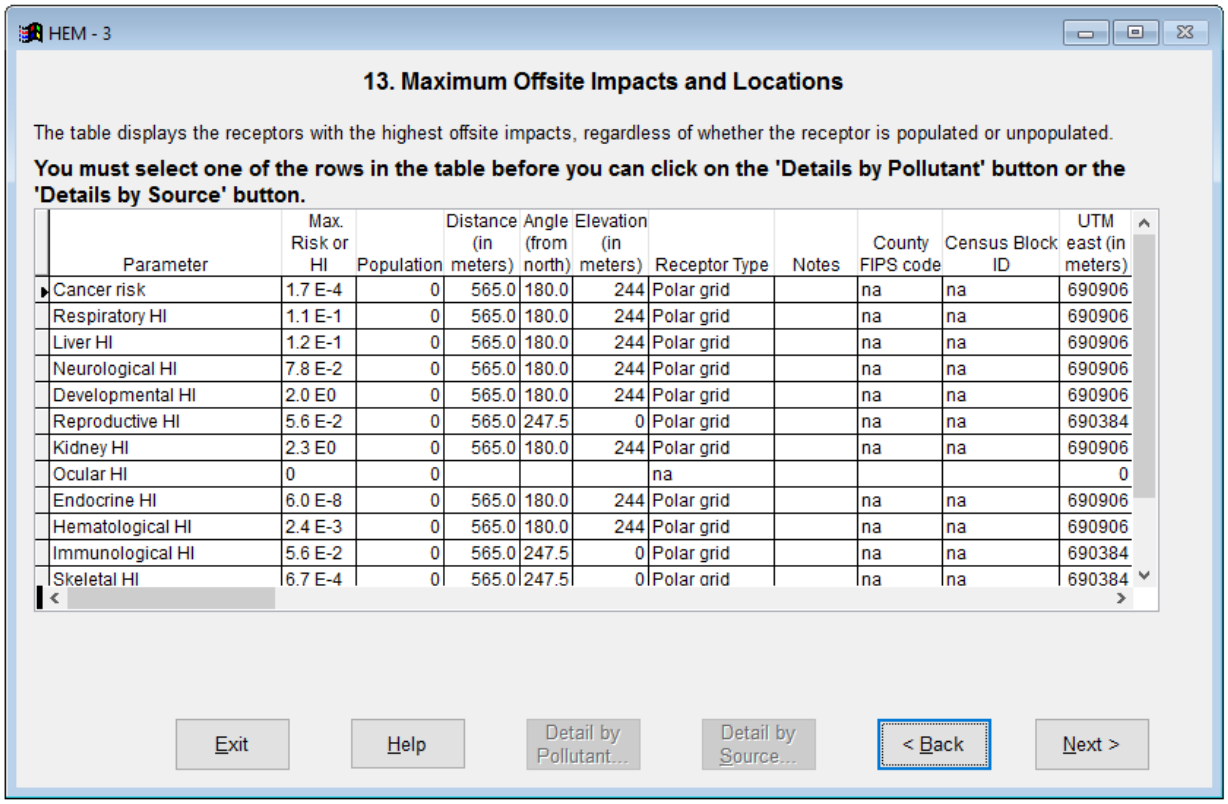
5.2 Maximum Offsite Impacts and Locations (Screen 13)

Screen 13 (**13. *Maximum Offsite Impacts and Locations***), shown in Figure 23, displays a table listing the highest cancer risks and HI predicted at any receptor that does not overlap with the emission sources, whether the receptor is populated or unpopulated. The receptors included in this calculation include all census blocks, all user-defined receptors (including boundary sites and ambient monitor sites), and all points in the polar receptor network, except for those receptors overlapping emission sources. [Note: Polar grid receptors are defined in HEM-3 as unpopulated and, therefore, 0 (zero) population is associated with polar receptor results, as can be seen in Figure 23.]

The format is the same as in Screen 12 (**12. *Maximum Individual Risk and Hazard Indices***). Each row displays one of the following health effects: cancer risk; and maximum chronic TOSHIs including respiratory HI, liver HI, neurological HI, developmental HI, reproductive HI, kidney HI, ocular HI, endocrine HI, hematological HI, immunological HI, skeletal HI, spleen HI, thyroid HI, and whole body HI. Table 29 above explains the fields displayed on Screen 13.



Parameter	Max. Risk or HI	Population	Distance (in meters)	Angle (from north)	Elevation (in meters)	Receptor Type	Notes	County FIPS code	Census Block ID	UTM east (in meters)
Cancer risk	1.7 E-4	0	565.0	180.0	244	Polar grid		na	na	690906
Respiratory HI	1.1 E-1	0	565.0	180.0	244	Polar grid		na	na	690906
Liver HI	1.2 E-1	0	565.0	180.0	244	Polar grid		na	na	690906
Neurological HI	7.8 E-2	0	565.0	180.0	244	Polar grid		na	na	690906
Developmental HI	2.0 E0	0	565.0	180.0	244	Polar grid		na	na	690906
Reproductive HI	5.6 E-2	0	565.0	247.5	0	Polar grid		na	na	690384
Kidney HI	2.3 E0	0	565.0	180.0	244	Polar grid		na	na	690906
Ocular HI	0	0				na				0
Endocrine HI	6.0 E-8	0	565.0	180.0	244	Polar grid		na	na	690906
Hematological HI	2.4 E-3	0	565.0	180.0	244	Polar grid		na	na	690906
Immunological HI	5.6 E-2	0	565.0	247.5	0	Polar grid		na	na	690384
Skeletal HI	6.7 E-4	0	565.0	247.5	0	Polar grid		na	na	690384

Figure 23. Screen 13 – Maximum Offsite Impacts and Locations

Similar to the MIR and HI screen (Screen 12), to view the contribution of different chemicals to the maximum offsite cancer risk, or to any of the offsite HI, highlight the desired output row, then click the “Details by Pollutant” button. Likewise, to view the contribution of different emission sources, highlight the desired row, then click the “Details by Source” button.

As noted previously, the information provided on these output screens is also placed in files in HEM-3’s Output folder within the subfolder you named on Screen 1. HEM-3 automatically produces an Excel™ file entitled “maximum_offsite_impact.xlsx” that includes all of the data tabulated on this screen. In addition, the risk breakdown file (“risk_breakdown.xlsx”) includes the contributions of individual chemicals and emission sources to the maximum offsite impacts. Table 30 above shows the fields included in the risk breakdown file.

Click “Next” button on Screen 13 to proceed to Screen 14, entitled *Estimated Cancer and Noncancer Population Risk*.

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5.3 Estimated Cancer and Noncancer Population Risk (Screen 14)

Screen 14 (**14. *Estimated Cancer and Noncancer Population Risk***), shown below in Figure 24, presents two tables that estimate the populations exposed to different cancer risk levels and to different HIs for noncancer effects. The screen also displays the potential annual cancer incidence. In the example shown in Figure 24, approximately 59,000 people are predicted to have a cancer risk greater than or equal to 1 in 1 million as a result of the facility's modeled emissions. Approximately 1,000 people are predicted to have a cancer risk greater than or equal to 1 in 100,000 (or 10 in 1 million) and approximately 3 people are predicted to have a cancer risk greater than or equal to 1 in 10,000 (or 100 in 1 million). Regarding chronic noncancer HI predictions, shown in the second table of Figure 24, zero (0) people are estimated to experience an HI greater than 1 for the TOSHIs shown, although 5 people are estimated to experience an HI greater than 0.5 (but less than or equal to 1, to one significant figure) for developmental and kidney TOSHIs. This is consistent with the results displayed in Figure 19.

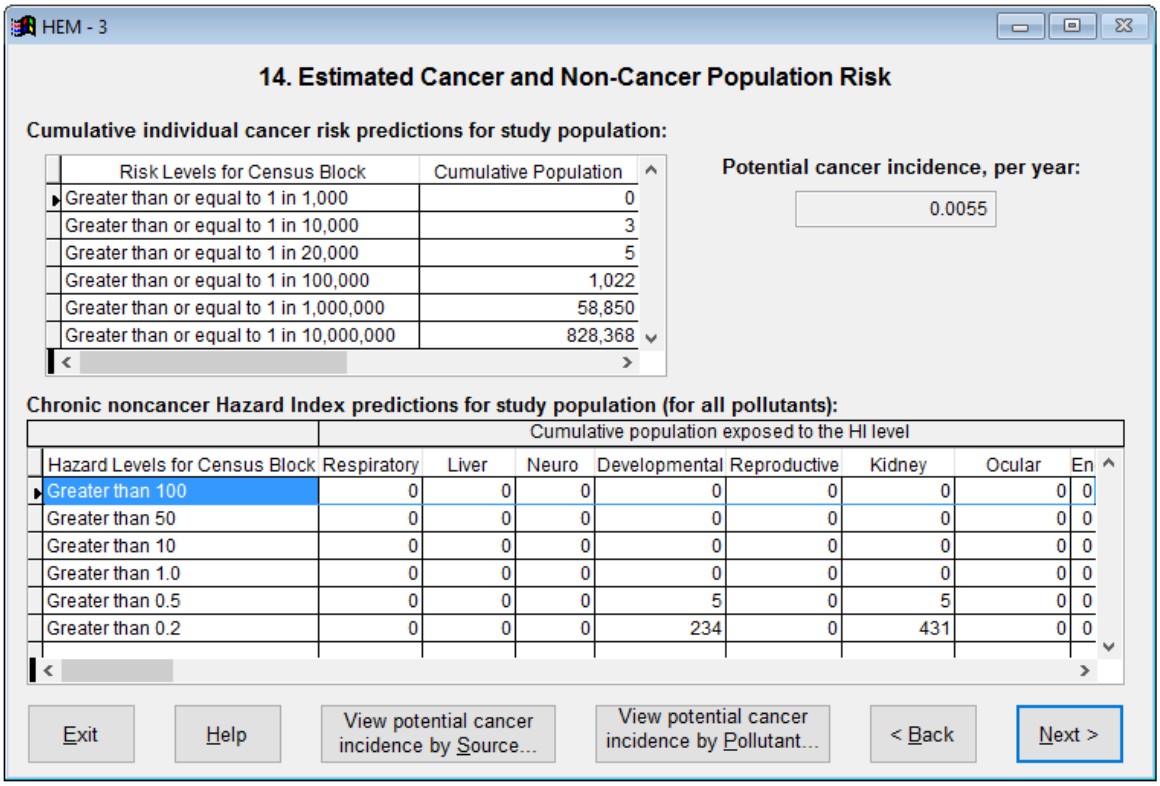

Figure 24. Screen 14 – Estimated Cancer and Noncancer Population Risk

The total cancer incidence (shown in Figure 24) is estimated to be considerably less than 1 excess cancer case per year. That is, 0.0055 excess cancer cases per year are predicted for the study region as a result of the facility's modeled emissions (and assuming continuous inhalation of the outdoor air for 70-year lifetimes, as well as the other conservative assumptions noted above).

Click on the “View potential cancer incidence by Source” button to see the contribution to total incidence made by each individual source (i.e., the source-specific incidence). Click on the “View potential cancer incidence by Pollutant” button to see the contribution to total incidence made by each modeled pollutant (i.e., the pollutant-specific incidence).

HEM-3 also automatically creates three Excel™ files, entitled “Cancer_risk_exposure.xlsx”, “Noncancer_risk_exposure.xlsx”, and “incidence.xlsx” containing the information provided in Figure 24. You can find these in the user-named subfolder of HEM-3’s Output folder.

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5.4 Cancer Risk by Distance (Screen 15)

Screen 15 (**15. *Cancer Risk by Distance***), shown below in Figure 25, displays the average cancer risk and the estimated total potential cancer incidence (or excess cancers per year) for the populations living within each of the ring distances specified for the polar receptor network. This screen also displays the total population for all census blocks with geographic “centroids” inside each ring distance.

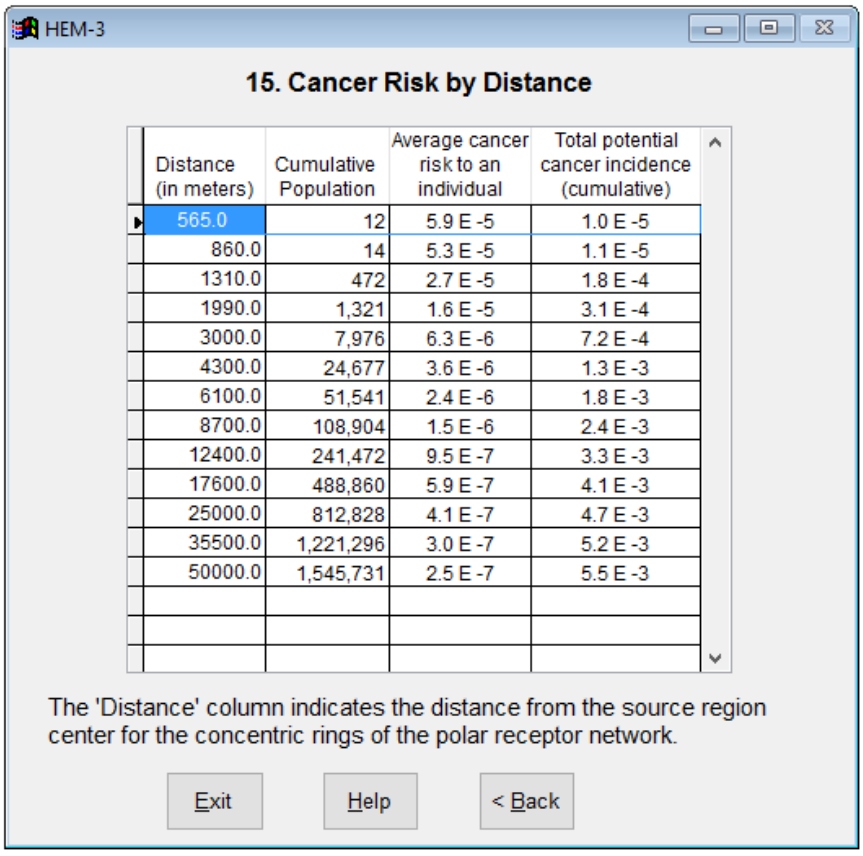

Figure 25. Screen 15 – Cancer Risk by Distance

In the example shown in Figure 25, there are 1,545,731 people living within 50,000 meters (50 km) of the modeled facility. Taking into account this total number of people living within 50 km of the center of the modeled facility, the average cancer risk to an individual in the study area is

2.5 E-7and the total incidence is 5.5 E-3 (consistent with the incidence of 0.0055 reported in Figure 24). Figure 25 also reveals that there are 12 people living within 565 meters from the modeled facility, and that the average risk to someone at this distance is 5.9 E-5 (59 in 1 million). This risk is less than the MIR because the MIR is for the census block of maximum impact, while the population (of 12) shown on Screen 15 (Figure 25) reside in more than that one MIR census block. The incidence at this same distance is only 1.0 E-5, given the small population.

If you did not choose to model acute concentrations and impacts (via the acute option on Screen 1), then Screen 15 will be the last output screen shown for HEM-3. However, if you did choose to model acute concentrations and impacts, then Screen 15 will prompt you to continue. In this case, click the "Next" button on Screen 15 to proceed to Screen 16, entitled *Maximum Offsite Short Term Acute Concentrations Compared with Reference Concentrations for Populated Receptors*.

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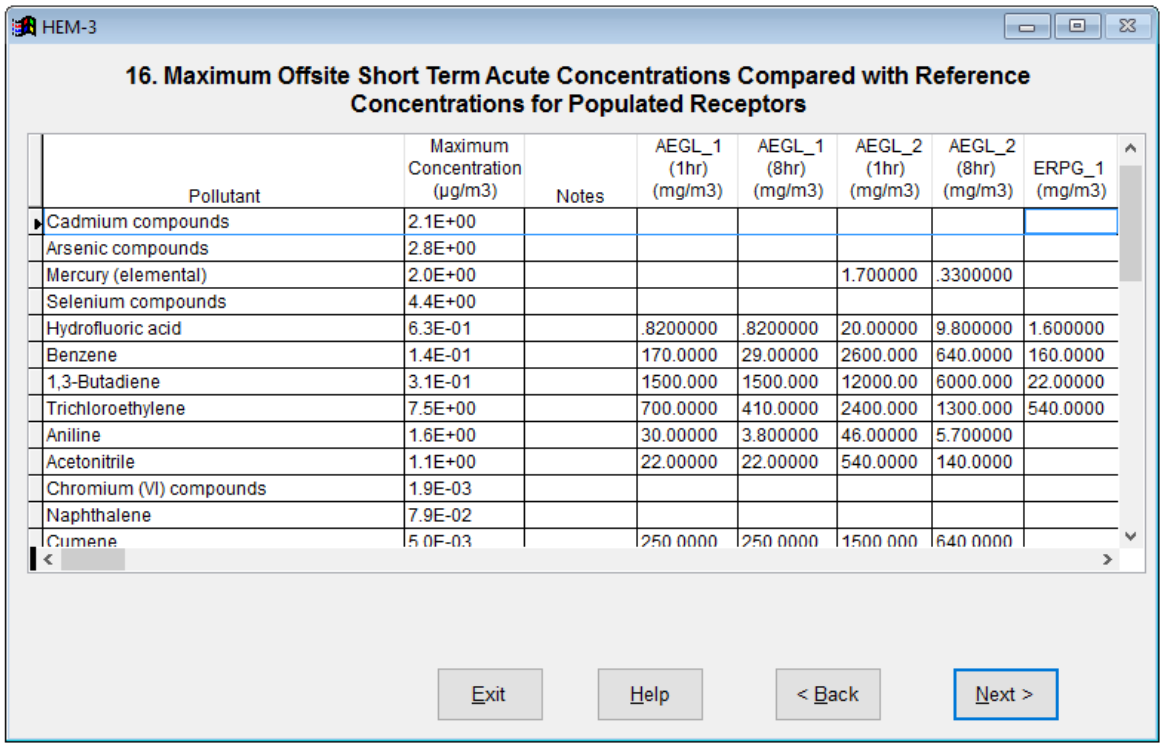
5.5 Optional Maximum Short Term Impacts (Screens 16 and 17)

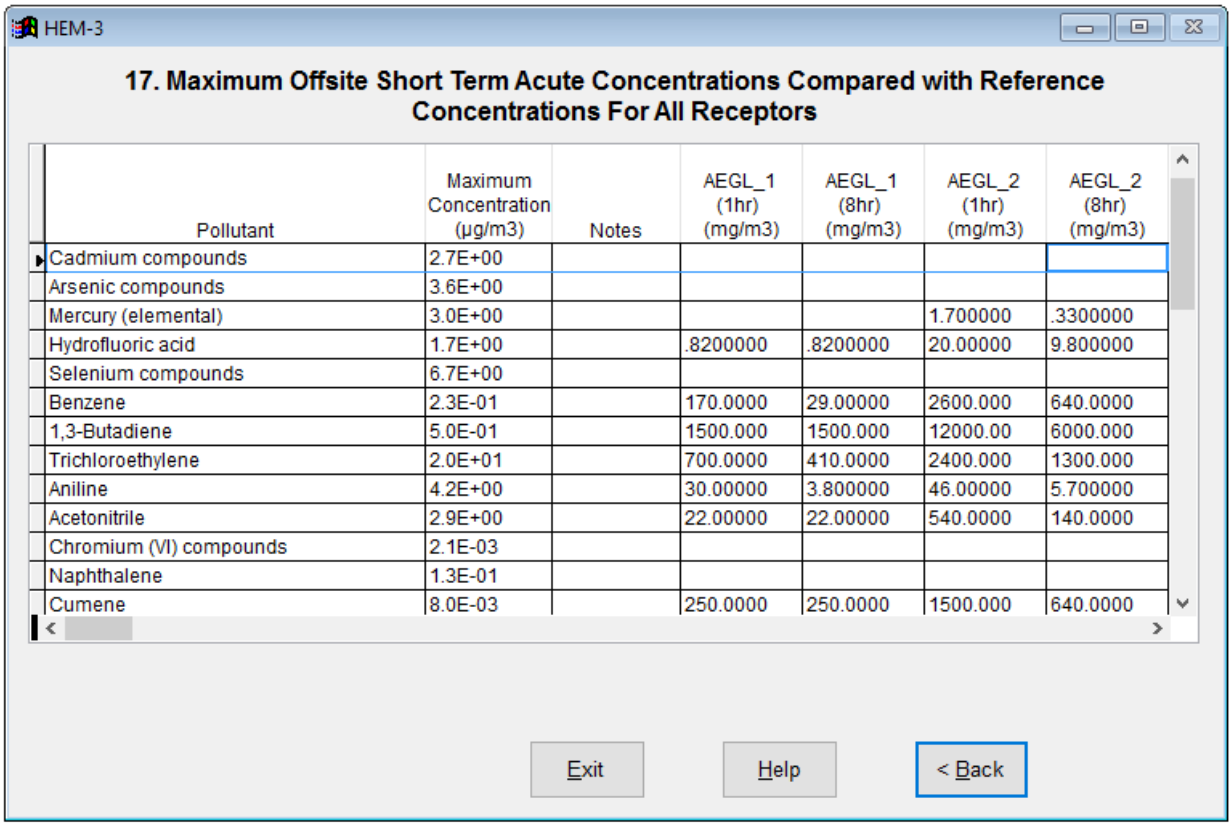
If you selected the "acute option" on Screen 1, the next screen HEM-3 displays is Screen 16 (**16. *Maximum Offsite Short Term Acute Concentrations Compared with Reference Concentrations for Populated Receptors***), shown below in Figure 26. You can use this table to make comparisons of the maximum predicted acute pollutant concentrations with available short-term benchmark levels for populated census block and populated ("P") user-defined receptors. Note that the concentration is reported in μg/m^3 while the acute benchmark values (reference concentrations) are in mg/m^3 and should therefore be multiplied by 1000 to compare.



Pollutant	Maximum Concentration (μg/m3)	Notes	AEGL_1 (1hr) (mg/m3)	AEGL_1 (8hr) (mg/m3)	AEGL_2 (1hr) (mg/m3)	AEGL_2 (8hr) (mg/m3)	ERPG_1 (mg/m3)
Cadmium compounds	2.1E+00						
Arsenic compounds	2.8E+00						
Mercury (elemental)	2.0E+00				1.700000	.3300000	
Selenium compounds	4.4E+00						
Hydrofluoric acid	6.3E-01		.8200000	.8200000	20.00000	9.800000	1.600000
Benzene	1.4E-01		170.0000	29.00000	2600.000	640.0000	160.0000
1,3-Butadiene	3.1E-01		1500.000	1500.000	12000.00	6000.000	22.00000
Trichloroethylene	7.5E+00		700.0000	410.0000	2400.000	1300.000	540.0000
Aniline	1.6E+00		30.00000	3.800000	46.00000	5.700000	
Acetonitrile	1.1E+00		22.00000	22.00000	540.0000	140.0000	
Chromium (VI) compounds	1.9E-03						
Naphthalene	7.9E-02						
Cumene	5.0E-03		250.0000	250.0000	1500.000	640.0000	

Figure 26. Screen 16 – Maximum Offsite Short Term Acute Concentrations Compared with Reference Concentrations for Populated Receptors

Click “Next” to proceed to Screen 17, (**17. *Maximum Offsite Short Term Acute Concentrations Compared with Reference Concentrations for All Receptors***), shown below in Figure 27. This second acute table is for all receptors—populated or unpopulated—including census blocks, polar grid receptors, and user-defined receptors. This table shows the maximum acute concentrations occurring anywhere offsite. If a pollutant’s maximum acute concentration occurs at a populated census block, then the results for that pollutant will be the same in both tables (Screens 16 and 17). If not, the all receptors table (Screen 17) will show the maximum, while the pollutant concentration (Screen 16) will be less than the maximum. Therefore, we recommend that you review Screen 17’s table when looking for the maximum offsite acute concentration. As noted above for Table 16, the concentrations reported in Table 17 are in $\mu g/m^3$, while the acute benchmark values (reference concentrations) are in mg/m^3, and should therefore be multiplied by 1000 for comparison to the modeled concentrations.



Pollutant	Maximum Concentration (µg/m3)	Notes	AEGL_1 (1hr) (mg/m3)	AEGL_1 (8hr) (mg/m3)	AEGL_2 (1hr) (mg/m3)	AEGL_2 (8hr) (mg/m3)
Cadmium compounds	2.7E+00					
Arsenic compounds	3.6E+00					
Mercury (elemental)	3.0E+00				1.700000	.3300000
Hydrofluoric acid	1.7E+00		.8200000	.8200000	20.00000	9.800000
Selenium compounds	6.7E+00					
Benzene	2.3E-01		170.0000	29.00000	2600.000	640.0000
1,3-Butadiene	5.0E-01		1500.000	1500.000	12000.00	6000.000
Trichloroethylene	2.0E+01		700.0000	410.0000	2400.000	1300.000
Aniline	4.2E+00		30.00000	3.800000	46.00000	5.700000
Acetonitrile	2.9E+00		22.00000	22.00000	540.0000	140.0000
Chromium (VI) compounds	2.1E-03					
Naphthalene	1.3E-01					
Cumene	8.0E-03		250.0000	250.0000	1500.000	640.0000

Figure 27. Screen 17 – Maximum Offsite Short Term Acute Concentrations Compared with Reference Concentrations for All Receptors

Table 31 shows the fields included in these tables, with a brief description for each benchmark. The EPA’s Air Toxics Risk Assessment Library (EPA 2017a) provides a more detailed description of these acute benchmarks (available for download at http://www.epa.gov/fera/air-toxics-risk-assessment-reference-library-volumes-1-3). The information listed in Table 31 is also output in two Excel™ files, that HEM-3 places in the Output folder you named, entitled “Acute_chem_pop.xlsx” and “Acute_chem_unpop.xlsx”. The “Acute_chem_pop.xlsx” output file contains the information displayed on Screen 16 (Figure 26); and the “Acute_chem_unpop.xlsx” output file contains the information displayed on Screen 17 (Figure 27). Note that these files specify the receptor where the maximum impact occurs for each pollutant, considering all sources.

HEM-3 also produces a third acute output file entitled “Acute_bkdn.xlsx” which provides the contribution of each emission source to the receptor of maximum impact for each pollutant (i.e., the acute concentration of pollutant at the maximum receptor caused by each source). The acute breakdown file includes columns for: pollutant; Source ID; emission type (P = particle, V = vapor [gas], C = combined); the maximum pollutant concentration ($\mu g/m^3$) at a populated receptor; the maximum pollutant concentration ($\mu g/m^3$) at all receptors (both populated and unpopulated); and flag columns indicating that the pollutant’s maximum concentration was interpolated. [Note: Concentration values are interpolated outside the *Distance for individual modeling of census blocks*—for example, between 3 km and 50 km. A breakdown by individual sources is not available for interpolated concentrations.]

Table 31. Fields Included in the Maximum Offsite Short Term Concentration Output Screens

Field	Description
Pollutant	Chemical name
Maximum concentration	units = μg/m^3
AEGL-1, 1-hour	Acute Exposure Guideline Level 1 (AEGL-1) for a 1-hour exposure: the concentration above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects (mg/m^3).
AEGL-1, 8-hour	See AEGL-1 above, but for an 8-hour exposure.
AEGL-2, 1-hour	Concentration above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape for a 1-hour exposure (mg/m^3).
AEGL-2, 8-hour	See AEGL-2 above, but for an 8-hour exposure.
ERPG-1	Emergency Response Planning Guideline 1 (ERPG-1): concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor (mg/m^3).
ERPG-2	Concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action (mg/m^3).
IDLH/10	Immediately Dangerous to Life or Health: concentration believed likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment, divided by a factor of 10 (mg/m^3).
MRL	Acute Minimal Risk Level: daily human exposure that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure (mg/m^3).
REL	Reference Exposure Level: concentration below which no adverse health effects are anticipated, based on the most sensitive adverse health effect reported (mg/m^3).
TEEL_0	Temporary Emergency Exposure Limit 0 (TEEL) defined by the U.S. Department of Energy: the threshold concentration below which most people will experience no adverse health effects.
TEEL_1	Maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or perceiving a clearly defined objectionable odor.
Block population	If the receptor is a census block
Distance	From the center of the modeling domain (in meters).
Angle	From north.
Elevation	In meters above sea level.
Hill	Controlling hill height in meters above sea level, as described in Section 2.3.1.
County FIPS	If the receptor is a census block.
Census block	For linking to demographic data (if the receptor is a census block).
UTM east coordinate	In meters.
UTM north coordinate	In meters.
Latitude	Decimal.
Longitude	Decimal.
Receptor type	C = census block, P = user-defined population receptor, PG = polar grid receptor point, B = boundary, M = monitor
Notes	An entry in this field will generally mean that the modeling analysis should be rerun. This field will provide advice on how to change model input files or other specifications.

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5.6 Additional Output Files

In addition to the Excel™ output files discussed above, HEM-3 produces other output files that will also be located in your user-named subfolder of HEM-3's Output folder, once the model has completed its run. HEM-3 automatically produces some of these files; others are optional and are produced based on the modeling options you chose. These files are discussed below.

5.6.1 Block and Ring Summary Output Files

HEM-3 automatically produces two Dbase™ formatted (DBF) output files that give total cancer risks and HI for all of the modeled receptors and interpolated receptors in the modeling domain. These files are:

- Block_summary_chronic.dbf
- Ring_summary_chronic.dbf

These files will also be produced in .CSV format, if you elected that option on Screen 1. The "block summary" file gives the total estimated cancer risk at each receptor, as well TOSHI for chronic noncancer effects for the census block locations. The "ring summary" file provides these same results for points in the polar receptor network.

To facilitate detailed GIS analyses of HEM-3 results, each file gives the latitude and longitude, and the UTM coordinates of each receptor, in addition to cancer risk estimates and HI. The "block summary" file also gives the county FIPS code, block identification number, and population of each census block. This information is intended to facilitate studies linking HEM-3 results with census information, such as demographic or economic data.

5.6.2 Quality Assurance Output Files

HEM-3 also automatically provides a set of files designed to facilitate tracking and quality assurance of the model run. These files are described below:

- Input_selection_options.xlsx – lists the options and input file names specified by you in the user input screens.

- Overlapping_source_receptors.xlsx – lists receptors that were identified as located within the user-specified overlap distance of an emission source.

- Aermod.out – the dispersion model log file showing input data, selected options, outputs, and warning or error messages. You should review Aermod.out to confirm that AERMOD completed its modeling without error; any errors internal to the AERMOD portion of HEM-3's run will be noted in this log file. **Note**: Concentration results in Aermod.out and Aermod1.out should not be interpreted as predicted concentrations of any modeled pollutant; rather they reflect concentrations that result from a unit-emission rate (1 kg/s).

- Aermod1.out – a second dispersion model log file produced in cases where both gases and particulate emissions are being modeled separately.

5.6.3 Optional Detailed Output Files

Finally, HEM-3 can produce six optional files providing more detailed results. These files are produced if you chose to produce them via the appropriate input screen (listed in parentheses next to each optional file name) below:

- All_inner_receptors.dbf (Screen 1)
- All_outer_receptors.dbf (Screen 1)
- All_polar_receptors.dbf (Screen 1)
- Allreceptors_risk.kml (Screen 1)
- Cancer_histogram.xlsx (Screen 4)
- Temporal.csv and Temporal.dbf (Screen 6)

Note that the .DBF files listed above will also be produced in .CSV format, if you elected that option on Screen 1. The four "all receptors" files provide detailed model predictions for every receptor in the modeling domain. Select 'Yes' to the all receptors question on Screen 1 ("Do you want output files and a map of results for all receptors, by pollutant and source?") and HEM-3 will produce these files. Each file gives the estimated incremental ambient concentration impact for all emission sources and for all pollutants included in the model analysis.

The "all_inner_receptors" file includes every census block receptor inside the modeling cutoff distance, as well as every user-defined receptor. This file will also contain the deposition flux (in $g/m^2/y$) if you opted to calculate deposition (with or without depletion) on Screen 3. Columns for both wet and dry deposition flux results are provided (Wdp_g_m2_y and Ddp_g_m2_y, respectively) and will be populated with non-zero results depending on the type of deposition modeling (wet, dry or both) you selected on Screen 3. **Note**: If you did not choose to produce the all receptors files (Screen 1), but did choose to model deposition and depletion (Screen 3), then the deposition flux values will be located in the aermod.out output file.

The "all_outer_receptors" file includes every census block receptor that has been interpolated; that is, all receptors located between the modeling cutoff distance (often specified as 3 km) and the outer edge of the modeling domain (often specified as 50 km). The all_polar_receptors file provides detailed concentration estimates for the nodes of the polar receptor grid. The Allreceptors_risk.kml is the Google Earth™ map of results at each receptor. Figure 22 is an example of such a map.

The cancer histogram file gives estimates of the numbers of people exposed to different cancer risk levels, similar to the cancer risk exposure Excel™ file (Figure 25 in Section 5.4). However, the cancer histogram file includes many more risk levels than the default Excel™ file - 10 exposure bins for each factor of 10 change in estimated cancer risk. To produce this more detailed cancer histogram output file, select "Yes" for this option ("Do you want to create a detailed histogram of cancer risks?") on Screen 4.

If you selected "Yes" to output temporal or wind speed variations in emissions on Screen 6, HEM-3 will create two output files named temporal.csv and temporal.dbf in your designated HEM-3 Output folder. The temporal.csv output is a comma delimited text file which may be readily imported and converted into an Excel™ spreadsheet. The Temporal output files contain annual average pollutant concentrations at different times of day for all pollutants and all receptors. This output file provides data suitable for the Hazardous Air Pollutant Exposure Model (HAPEM), which typically divides the day into time blocks ranging from 1-hour to 24-

hours (ICF 2015). However, the number of time blocks available in HEM-3's outputs is variable and depends on what output resolution you selected on Screen 6.

For example, if you chose to vary emissions by the hour of day and output the concentrations diurnally, the temporal.csv and temporal.dbf output files will contain annual average pollutant concentrations at different times of day for all pollutants and all receptors. HEM-3 will compute the hour of day emissions using the resolution you selected (e.g., 1-hour through 24-hour). If you opt for 1-hour resolution and to show seasonal variations in the outputs, the temporal output files will show 96 concentrations for each receptor and pollutant. The first 24 values will represent 24-hour-day winter concentrations, the second 24 values will represent spring concentrations, the third 24 values will represent summer concentrations, and the last 24 concentrations will represent fall. In general, we recommend that you refer to the temporal input file guidelines to help accurately interpret the order of concentration values in the Temporal output files, because the order of output concentrations is consistent with the order of the temporal factors expected by AERMOD in the inputs.

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5.7 Outputs Produced for User-Supplied Pollutant Concentration Data

In HEM-3, you can provide pollutant concentrations from an external model or from monitoring data (on Screen 1), rather than using AERMOD in the HEM-3 run to produce ambient concentrations. When you select this option, HEM-3 will create the following output files:

- User_conc_data_maximum_risk.xlsx – Table of the highest pollutant-specific chronic concentrations, pollutant-specific cancer risks, total cancer risks, pollutant-specific TOSHI, total TOSHI, and (optionally) pollutant-specific acute concentrations predicted for any receptor within the modeling domain. This table also includes the FIPS code, census block ID and block population of the maximum receptor(s).

- User_conc_data_incidence.xlsx – Table of estimated annual cancer incidence as a result of exposure to the pollutants included in the user-supplied concentration file, including both total incidence and pollutant-specific incidence.

- User_conc_data_cancer_histogram.xlsx – Histogram of the numbers of people exposed to different levels of total inhalation cancer risk. This file includes population numbers binned according to risk greater than ("risk_ge") and risk less than ("risk_lt") levels.

- User_conc_data_HI_histogram – Histogram of the numbers of people exposed to different levels of HI for different target organs. This file includes population numbers for each TOSHI (e.g., "No_Resp" for the number of people with a respiratory HI) binned according to TOSHI values greater than ("Toshi_Ge") and TOSHI values less than ("Toshi_Lt") levels.

- User_conc_data_block_summary.dbf – Database of total cancer risk and total TOSHIs for each census block in the modeling domain.

- User_conc_data_detail_output.dbf – Database of concentrations, cancer risk estimates and TOSHIs for specific pollutants at each census block in the modeling domain.

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6. HEM-3 Error Messages

Table 32 lists alphabetically the error messages you may encounter when running 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 32. HEM-3 Error Messages

Error Message	Meaning / Cause
A receptor must be close to the plant to be a candidate for removal from the list of receptors to be modeled. For this configuration, there are no receptors that meet that criteria.	There are no receptors close enough to the plant to be removed.
AERMOD did not complete successfully. If you are using deposition or depletion, make sure the HAP emissions input file has the percent particle column populated for each emission. HEM-3 will end when you click on 'OK'.	Error occurred while running AERMOD. Error message is listed in the AERMOD.OUT file.
Error! No buoyant line source parameters.	The buoyant line source parameter file does not contain any parameters.
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! This combination of deposition and depletion options requires two runs. To deplete the plume for only particles or only gases, select 'No' to the first question on Screen 3 and select 'Yes' to second question (regarding depletion). Then choose the type of depletion. If you also need the deposition flux in the output files, a second run is required. For more information, see the Deposition and Depletion section of the User's Guide.	This error occurs when your emissions include both particles and gases and you attempt to model deposition and depletion but deplete the plume based only on particle deposition or based only on gaseous deposition (i.e., you selected “None” for the type of depletion but not the corresponding type of deposition). To accomplish this different treatment of particles and gases, you can select “No” to deposition and “Yes” to depletion and then indicate the different types of depletion. To obtain the deposition flux in the outputs, perform a second similar modeling run in which deposition but not depletion is modeled.

Error Message	Meaning / Cause
Error! Too many buoyant line source parameter records.	The buoyant line source parameter file must have one row of parameters for the given 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.
Error! Your choices are not consistent. If you wish to model depletion type 'none' for all of your emissions, choose 'No' for the second question on Screen 3. For more information see the Deposition and Depletion section of the User's Guide.	This error occurs when you select “Yes” to model both deposition and depletion but then select “none” as the type of depletion for particles and gases. For this kind of run, you should select “Yes” to the deposition question but “No” to the depletion question.
For an urban environment, the population of the area must be at least 50,000.	Urban dispersion was chosen, but too small of an urban population was entered. It must be at least 50,000.
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.
Google Earth is not installed on your computer. To install, go to http://pack.google.com/intl/en/integrated_eula.html?hl=en&ciint=ci_earth&ci_earth=on&utm_source=en-cdr-earth4&utm_medium=cdr&utm_campaign=e	Google Earth is required to view the map of modeling results.
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.
Recheck the value you selected in the listbox for Particle and Vapor emissions.	On the deposition and depletion entry screen, the only valid options for particle and gaseous (vapor) emissions are Particle, Vapor, or Both.
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 approximate ratio value cannot be zero. The smallest number possible for this value is 1.	
The definition of landuse filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	Invalid landuse filename.

Error Message	Meaning / Cause
The definition of seasons filename you entered is not in the location you specified. Click 'Ok' to re-enter the filename or change the directory.	Invalid seasons filename.
The emissions 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.
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 filename you entered for the building downwash data 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 folder name you have specified already exists. Do you want to overwrite the files in this folder? Select 'Yes' to overwrite the folder or select 'No' to enter a different name for the folder.	The specified output folder name already exists.
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 magnitude of the maximum individual risk is too small to compute the input for Crystal Ball. No output file will be created by HEM-3.	The maximum cancer risk value is too small to generate risk level intervals.
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 location 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.

Error Message	Meaning / Cause
The UTM east value you entered for the source region center is outside the source region. Please enter a value that is within the source region boundaries.	The modeling domain center easting coordinate that was entered is outside the emission source box.
The UTM north value you entered for the source region center is outside the source region. Please enter a value that is within the source region boundaries.	The modeling domain center northing coordinate that was entered is outside the emission source box.
The UTM zone that you entered for one of your user receptors is too far from the source region center. HEM-3 cannot run correctly with this specification. Click 'Ok' to end HEM-3 to enable you to correct the user specified discrete receptor(s) file.	The UTM zones for user receptors must be within one zone of the source region.
The value you entered for the distance where source and receptor are considered to overlap is greater than 500. Change the value to a number less than or equal to 500.	Invalid entry for the distance where source and receptor are considered to overlap.
The value you entered for the distance where source and receptor are considered to overlap is greater than 500. Change the value to a number less than or equal to 500.	Invalid entry for the distance where source and receptor are considered to overlap.
The weight percentages for "XXXXXX" in your particle data 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 location input file. HEM-3 will end so you can fix the problem and restart HEM-3.	The emissions location 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.
There was a problem with running AERMOD. Make sure you are able to open a DOS window on your computer and double-check your input files to make sure they are correct. HEM-3 will end when you click on 'OK'.	There was an error when HEM-3 attempted to run AERMOD and no AERMOD output file was produced.
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 "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.

Error Message	Meaning / Cause
You have not specified a polar receptor network for interpolation. Make the value for the distance within which blocks are modeled the same as the maximum radius or, make the number of concentric circles or the number of radials a value other than 0.	A polar receptor network has not been defined.
You must enter a name and location of an existing file with size and deposition information for particulate matter for HEM-3 to run correctly.	A particle data filename was not entered.
You must enter a name and location of an existing file with size and deposition information for particulate matter for HEM-3 to run correctly.	A particle data filename was not entered.
You must enter a name of a pollutant in the pollutant field.	This error occurs when adding a pollutant to the HAP library file and the pollutant name was not entered.
You must enter a numeric value in the acute concentration field. If you do not have an Acute concentration value for the pollutant, enter zero (0).	This error occurs when adding a pollutant to the HAP library file and an acute concentration was not entered.
You must enter a numeric value in the RFC field. If you do not have an RFC value for the pollutant, enter zero (0).	This error occurs when adding a pollutant to the HAP library file and an RFC value was not entered.
You must enter a numeric value in the URE field. If you do not have an URE value for the pollutant, enter zero (0).	This error occurs when adding a pollutant to the HAP library file and a URE value was not entered.
You must enter a value for the distance within which blocks are modeled individually that is greater than 0.	Invalid entry for the distance in which census blocks are used as receptors.
You must enter a value for the distance within which blocks are modeled individually that is greater than 0.	A modeling distance must be entered.
You must enter a value for the maximum radius that is greater than 0.	The maximum radius of the polar receptors must be larger than 0.
You must enter a value for the maximum radius that is no greater than 50,000 meters.	The maximum radius of the polar receptors must be less than 50,000 meters.
You must enter a value for the number of concentric circles that is at least 4 and not greater than 30.	Invalid entry for the number of polar rings to use.
You must enter a value for the number of concentric circles that is at least 4 and not greater than 30.	Invalid number of polar receptor rings entered.

Error Message	Meaning / Cause
You must have DOSE_RESPONSE_LIBRARY.XLSX or DOSE_RESPONSE_LIBRARY.XLS 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 or TARGET_ORGAN_ENDPOINTS.XLS 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.

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7. References

Census, 2000. *LandView® 5 on DVD*. U.S. Census Bureau, Washington, DC.

Census, 2010. Census Summary File 1 – United States: http://www2.census.gov/census_2010/04-Summary_File_1/ prepared by the U.S. Census Bureau, Washington, DC, 2011. See also Technical Documentation for the 2010 Census Summary File 1. (Website last accessed January 2019.)

EPA, 1986. User's Manual for the Human Exposure Model (HEM). EPA-450/5-86-001, U.S. Environmental Protection Agency, Research Triangle Park, NC.

EPA, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models (revised) Volume II – Description of Model Algorithms. EPA-454/B-95-003b, U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/scram001/userg/regmod/isc3v2.pdf (Website last accessed January 2019.)

EPA, 2005. Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions. Appendix W of 40 CFR Part 51. http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf (Website last accessed January 2019.)

EPA, 2017a. Risk Assessment and Modeling - Air Toxics Risk Assessment Reference Library, U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/fera/risk-assessment-and-modeling-air-toxics-risk-assessment-reference-library. Website updated January 17, 2017. (Website last accessed January 2019.)

EPA, 2017b. Air Toxics Data - Ambient Monitoring Archive, U.S. Environmental Protection Agency. Research Triangle Park, NC. http://www.epa.gov/ttn/amtic/toxdat.html#data. See also Technical Memorandum dated February 14, 2017 at https://www3.epa.gov/ttn/amtic/files/toxdata/techmemo2017.pdf. (Website last accessed January 2019.)

EPA, 2018a. *Dose-Response Assessment for Assessing Health Risks Associated With Exposure to Hazardous Air Pollutants*. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/fera/dose-response-assessment-assessing-health-risks-associated-exposure-hazardous-air-pollutants. See also "Toxicity Value Files" available for download on the HEM Download webpage at https://www.epa.gov/fera/download-human-exposure-model-hem. (Website last accessed January 2019.)

EPA, 2018b. User's Guide for the AMS/EPA Regulatory Model (AERMOD). EPA-454/B-18-001, U.S. Environmental Protection Agency, Research Triangle Park, NC. April 2018. https://www3.epa.gov/ttn/scram/models/aermod/aermod_userguide.pdf. (Website last accessed January 2019.)

EPA, 2018c. AERMOD Implementation Guide. EPA-454/B-18-003, U.S. Environmental Protection Agency, Research Triangle Park, NC. April 2018.

https://www3.epa.gov/ttn/scram/models/aermod/aermod_implementation_guide.pdf. (Website last accessed January 2019.)

EPA, 2018d. NATA Glossary of Key Terms. 2014 National Air Toxics Assessment. U.S. Environmental Protection Agency. http://www.epa.gov/national-air-toxics-assessment/nata-glossary-terms. Website updated August 17, 2018. (Website last accessed January 2019.)

EPA, 2018e. User's Guide for the AERMOD Terrain Preprocessor (AERMAP). EPA-454/B-18-004. U.S. Environmental Protection Agency, Research Triangle Park, NC. April 2018. https://www3.epa.gov/ttn/scram/models/aermod/aermap/aermap_userguide_v18081.pdf (Website last accessed January 2019.)

EPA, 2018f. User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-18-002, U.S. Environmental Protection Agency, Research Triangle Park, NC. April 2018. https://www3.epa.gov/ttn/scram/7thconf/aermod/aermet_userguide.pdf. (Website last accessed January 2019.)

EPA, 2018g. AERMOD Model Formulation and Evaluation. EPA-454/ R-18-003, U.S. Environmental Protection Agency, Research Triangle Park, NC. April 2018. https://www3.epa.gov/ttn/scram/models/aermod/aermod_mfed.pdf. (Website last accessed January 2019.)

EPA, 2018h. Total Risk Integrated Methodology (TRIM) – Overview. EPA's Fate, Exposure, and Risk Analysis (FERA) webpage. U.S. Environmental Protection Agency. https://www.epa.gov/fera/total-risk-integrated-methodology-trim-overview. (Website last accessed January 2019.)

ERT, 1980. Buoyant line and point source (BLP) dispersion model user's guide. Prepared by Environmental Research & Technology (ERT) for The Aluminum Association, Inc. Document P-7304B, July 1980.

Federal Register, 2012. Qualifying Urban Areas for the 2010 Census. FR 77:59 (27 March 2012). p.18652. http://www.gpo.gov/fdsys/pkg/FR-2012-03-27/pdf/2012-6903.pdf (Website last accessed January 2019.)

ICF International, 2015. The HAPEM User's Guide, Hazardous Air Pollutant Exposure Model, Version 7. Prepared for the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. July 2015. http://www.epa.gov/sites/production/files/2015-12/documents/hapem7usersguide.pdf. Additional HAPEM documentation available at http://www.epa.gov/fera/human-exposure-modeling-hazardous-air-pollutant-exposure-model-hapem (Website last accessed January 2019.)

Jindal, M. and D. Heinold, 1991. Development of particulate scavenging coefficients to model wet deposition from industrial combustion sources. Paper 91-59.7, *84th Annual Meeting - Exhibition of AWMA*, Vancouver, BC, June 16-21, 1991.

NCES, 2006a. *CCD Public School Data 2006-2007 school year*, Institute of Education Sciences, National Center for Education Statistics (NCES) of the U.S. Department of Education, Alexandria, VA. http://nces.ed.gov/ccd/schoolsearch/ based on February 2009 access.

NCES, 2006b. *PSS Private School Universe Survey data for the 2006-2007 school year*, Institute of Education Sciences, National Center for Education Statistics (NCES) of the U.S. Department of Education, Alexandria, VA. http://nces.ed.gov/surveys/pss/privateschoolsearch/ based on February 2009 access.

NCES, 2009a. *CCD Public School data 2009-2010 school year*, Institute of Education Sciences, National Center for Education Statistics (NCES) of the U.S. Department of Education, Alexandria, VA. http://nces.ed.gov/ccd/schoolsearch/ based on February 2012 access.

NCES, 2009b. *PSS Private School Universe Survey data for the 2009-2010 school year*, Institute of Education Sciences, National Center for Education Statistics (NCES) of the U.S. Department of Education, Alexandria, VA. http://nces.ed.gov/surveys/pss/privateschoolsearch/ based on February 2012 access.

NGS, 2011. NADCON - Version 4.2. National Geodetic Survey, National Oceanic and Atmospheric Administration. http://www.ngs.noaa.gov/PC_PROD/NADCON/ (Website last accessed January 2019.)

Sander, R., 2015: Compilation of Henry's law constants (version 4.0) for water as solvent, Atmos. Chem. Phys., 15, 4399-4981, doi:10.5194/acp-15-4399-2015, 2015. http://www.atmos-chem-phys.net/15/4399/2015/ (Website last accessed January 2019)

Schulman, L.L., D.G. Strimaitis, and J.S. Scire, 2000. Development and Evaluation of the PRIME Plume Rise and Building Downwash Model. *Journal of the Air & Waste Management Association*, Vol. 50, pp. 378-390.

Scire, J.S., D.G. Strimaitis and R.J. Yamartino, 1990. *Model formulation and user's guide for the CALPUFF dispersion model*. Sigma Research Corp., Concord, MA.

USGS, 2000. *US GeoData Digital Elevation Models – Fact Sheet 040-00 (April 2000)*. U.S. Department of the Interior - U.S. Geological Survey, Washington, DC. https://pubs.usgs.gov/fs/2000/0040/report.pdf (Website last accessed January 2019.)

USGS, 2015. USGS Seamless Data Warehouse. U.S. Department of the Interior - U.S. Geological Survey, Washington, DC. http://nationalmap.gov/viewer.html (Website last accessed January 2019.)

Wesely, M.L, P.V. Doskey, and J.D. Shannon, 2002. *Deposition Parameterizations for the Industrial Source Complex (ISC3) Model*. ANL/ER/TR–01/003, Argonne National Laboratory, June 2002. Work sponsored by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Environmental Sciences Division and partially by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.