

The HEM4 User's Guide

**Instructions for using the Human Exposure Model 4
for Single and Multiple Facility Exposure and Risk Modeling**

Open-Source Version 1.0

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Contents

Disclaimer	ii
Figures.....	vi
Tables	viii
1. Introduction	1
1.1 Organization of the HEM4 User's Guide	1
1.2 Main Features of HEM4	2
1.3 Differences between HEM4 and 2019 Version of HEM-3	4
1.4 Strengths and Limitations of HEM4.....	6
1.5 Requirements for Running HEM4	7
2. Installing HEM4.....	8
2.1 Downloading the HEM4 Program.....	8
2.2 Downloading Chemical Health Effects Data.....	9
2.2.1 Description of Chemical Health Effects Library	9
2.3 Downloading Census Data.....	10
2.3.1 Description of Census Library	11
2.4 Downloading Meteorological Data.....	11
2.4.1 Description of Meteorological Library	12
3. Preparing HEM4 Input Files	15
3.1 Overview and General Rules	15
3.2 Facility List Options File	17
3.2.1 Fields in the Facility List Options File	18
3.2.2 Meteorological Station and Period Options	22
3.2.3 Rural and Urban Dispersion Options.....	23
3.2.4 Modeling Domain Options.....	24
3.2.5 Acute Options	26
3.2.6 Deposition and Depletion Options.....	27
3.2.7 Elevation Option	31
3.2.8 User Receptors Option	31
3.2.9 Building Downwash Option	31
3.2.10 FASTALL Option.....	32
3.2.11 Emissions Variation Option	32
3.3 HAP Emissions File	33
3.3.1 Pollutant Emissions per Source	34
3.3.2 Percent Particulate for Deposition and Depletion	35
3.4 Emissions Location File	35
3.4.1 Source Types and Parameter Requirements	40
3.4.2 Particle Deposition Method	45
3.5 Additional Input Files.....	45
3.5.1 Polygon Vertex Input File for Modeling Polygon Emission Sources.....	46
3.5.2 Buoyant Line Parameter Input File for Modeling Buoyant Line Sources	48
3.5.3 Particle Data Input File for Modeling Particulate Deposition and Depletion	49
3.5.4 Input Files Required for Modeling Vapor Deposition and Depletion.....	51
3.5.5 Building Dimensions Input File for Modeling Building Downwash.....	55
3.5.6 User-Defined Receptors File.....	56
3.5.7 Emissions Variation Input Files	59
3.5.8 Alternate Receptors file.....	62
3.5.9 Census Update file	64
3.5.10 Updating the Chemical Unit Risk Estimates and Health Benchmarks Input Files .	66
4. Step-by-Step Instructions for Running HEM4	67

4.1	Provide Standard Input Files and Indicate Receptors	69
4.2	Provide Additional Input Files	71
4.3	Provide Deposition and Depletion Input Files	72
4.4	Check HEM4 Log	74
4.5	Summarize Risks	76
4.6	Analyze Outputs.....	77
4.7	Revise Census Data Option	81
4.8	Error Messages and Failed Runs	82
5.	HEM4 Modeling Calculations for each Facility.....	85
5.1	Dispersion Modeling	85
5.1.1	Regulatory Default, ALPHA and BETA Options	85
5.1.2	Dilution Factors	86
5.2	Estimating Risks and Hazard Indices	86
5.2.1	Explicit Modeling of Inner Receptors, User Receptors and Polar Receptors	86
5.2.2	Interpolated Modeling of Outer Receptors using the Polar Receptor Network	88
5.2.3	Maximum Individual Risks, Hazard Indices, and Hazard Quotients.....	89
5.2.4	Maximum Offsite Impacts.....	89
5.2.5	Contributions of Different Pollutants and Emission Sources.....	89
5.3	Population Exposures and Incidence	90
5.4	Summarizing Human Health Impacts	92
6.	HEM4 Output Files.....	93
6.1	Facility-Specific Outputs.....	93
6.1.1	Maximum Individual Risk	93
6.1.2	Maximum Offsite Impacts.....	95
6.1.3	Risk Breakdown.....	95
6.1.4	Block Summary Chronic	96
6.1.5	Ring Summary Chronic	97
6.1.6	Source Risk KMZ Image	98
6.1.7	Incidence	99
6.1.8	Cancer Risk Exposure	100
6.1.9	Noncancer Risk Exposure.....	100
6.1.10	All Inner Receptors	101
6.1.11	All Outer Receptors.....	101
6.1.12	All Polar Receptors	102
6.1.13	AERMOD Outputs	103
6.1.14	Input Selection Options	105
6.1.15	Acute Maximum Concentrations (Optional).....	106
6.1.16	Acute Populated Concentrations (Optional)	106
6.1.17	Acute Breakdown (Optional)	108
6.2	Run Group Outputs.....	109
6.2.1	Facility Max Risk and HI	109
6.2.2	Facility Cancer Risk Exposure	110
6.2.3	Facility TOSHI Exposure.....	110
6.2.4	Additional Run Group Outputs	110
7.	Risk Summary Reports	112
7.1	Max Risk Summary	112
7.2	Cancer Drivers Summary	113
7.3	Hazard Index Drivers Summary	113
7.4	Risk Histogram Summary	114
7.5	Hazard Index Histogram Summary	115
7.6	Incidence Drivers Summary	116

7.7	Acute Impacts Summary	116
7.8	Multipathway Summary.....	117
7.9	Source Type Risk Histogram Summary	119
8.	Understanding the Risk Results	120
9.	Quality Assurance Remodeling	122
10.	References.....	126
11.	Appendix A: Sample HEM4 Output Files	129

Figures

Figure 1. Summary of Key Improvements for HEM4 versus 2019 HEM-3	6
Figure 2. HEM4 Meteorological Stations	14
Figure 3. Example Orientations of Area Emission Sources for the HEM4 Model.....	44
Figure 4. HEM4 Title Screen	69
Figure 5. Run HEM4 with U.S. Census Receptors	70
Figure 6. Run HEM4 with Alternate Receptors	70
Figure 7. Confirm HEM4 Run Pop-Up Start Box.....	71
Figure 8. Provide Additional Input Files	72
Figure 9. Provide Deposition and Depletion Input Files	73
Figure 10. Log Screen.....	75
Figure 11. Run the Risk Summary Programs	76
Figure 12. View and Analyze Outputs	77
Figure 13. Hazard Index Drivers File Opened via Spreadsheet App.....	78
Figure 14. Select Data to Plot Widget	78
Figure 15. Chronic Risk Map shown in Google Earth™	79
Figure 16. Acute Map View of HTML File	80
Figure 17. Example Graphical Visualization of Incidence by Pollutant and Source Type.....	81
Figure 18. Revise Census Data Screen	82
Figure 19. Sample Google Earth™ Map of Results	99
Figure 20. Sample Max Risk Summary Output.....	112
Figure 21. Sample Cancer Drivers Summary Output.....	113
Figure 22. Sample Hazard Index Drivers Summary Output.....	114
Figure 23. Sample Risk Histogram Summary Output.....	115
Figure 24. Sample Hazard Index Histogram Summary Output (Partial).....	115
Figure 25. Sample Incidence Drivers Summary Output.....	116
Figure 26. Sample Acute Impacts Summary Output (abbreviated)	118
Figure 27. Sample Multipathway Summary Output.....	118
Figure 28. Sample Sourcetype_Histogram_Sorted RTR Summary Output.....	119
Figure 29. Sample Source_risk.kmz HEM4 Output	123
Figure 30. Sample Maximum Individual Risk HEM4 Output (facility-specific)	129
Figure 31. Sample Maximum Offsite Risk HEM4 Output (facility-specific)	129
Figure 32. Sample Risk Breakdown HEM4 Output (facility-specific, abbreviated)	130
Figure 33. Sample Block Summary Chronic HEM4 Output (facility-specific, abbreviated)	131
Figure 34. Sample Ring Summary Chronic HEM4 Output (facility-specific, abbreviated)	132
Figure 35. Sample Source Risk KMZ Google Earth™ Image (facility-specific)	133
Figure 36. Sample Incidence HEM4 Output (facility-specific, abbreviated)	134
Figure 37. Sample Cancer Risk Exposure HEM4 Output (facility-specific)	135
Figure 38. Sample Noncancer Risk Exposure HEM4 Output (facility-specific)	135
Figure 39. Sample All Inner Receptors HEM4 Output (facility-specific, abbreviated)	136
Figure 40. Sample All Outer Receptors HEM4 Output file (facility-specific, abbreviated).....	137
Figure 41. Sample All Polar Receptors HEM4 Output file (facility-specific, abbreviated)	138
Figure 42. Sample AERMOD.inp file (facility-specific, abbreviated).....	139
Figure 43. Sample AERMOD.out file (facility-specific, abbreviated)	140
Figure 44. Sample plotfile.plt output file (facility-specific, abbreviated)	141
Figure 45. Sample maxhour.plt output file (optional facility-specific, abbreviated)	142
Figure 46. Sample Input Selection Options HEM4 Output file (facility-specific, abbreviated) ..	143

Figure 47. Sample Acute Maximum Concentrations HEM4 Output file (optional facility specific, abbreviated).....	143
Figure 48. Sample Acute Populated Concentrations HEM4 Output file (optional facility-specific, abbreviated).....	144
Figure 49. Sample Acute Breakdown HEM4 Output file (optional facility-specific).....	144
Figure 50. Sample Facility Max Risk and HI HEM4 Output file (for run group, abbreviated) ...	145
Figure 51. Sample Facility Cancer Risk Exposure HEM4 Output file (for run group)	145
Figure 52. Sample Facility TOSHI Exposure HEM4 Output file (for run group).....	145
Figure 53. Sample All Facility Source Locations Google Earth™ Image (for run group)	146
Figure 54. Sample HEM4 Log Output file (for run group, abbreviated)	147

Tables

Table 1. Fields in the Facility List Options Input File (Required)	18
Table 2. Sample Deposition and Depletion Options and Model Results	29
Table 3. Format Guidelines for the HAP Emissions Input File (Required).....	33
Table 4. Sample HAP Emissions Input File	34
Table 5. Fields in the Emissions Location Input File (Required)	35
Table 6. Sample Emissions Location Input File	39
Table 7. Format Guidelines for the Polygon Vertex File	46
Table 8. Sample Polygon Vertex File	47
Table 9. Format Guidelines for the Buoyant Line Parameter Input File	49
Table 10. Sample Buoyant Line Parameter Input File	49
Table 11. Format Guidelines for the Particle Data Input File	50
Table 12. Sample Particle Data Input File	50
Table 13. Format Guidelines for Land Use Input File	53
Table 14. Sample Input File for Land Use	53
Table 15. Format Guidelines for Month-to-Seasons Input File.....	54
Table 16. Sample Month-to-Seasons Input File.....	54
Table 17. Format Guidelines for the Building Dimensions File	55
Table 18. Sample Building Dimensions Input File	56
Table 19. Format Guidelines for the User-Defined Receptors File.....	58
Table 20. Sample Input File for User-Defined Receptors.....	58
Table 21. Format Guidelines for the Emissions Variation Input Files.....	60
Table 22. Sample Emissions Variation File based on Seasons (4 factors)	60
Table 23. Sample Emissions Variation File based on Hour of Day (24 factors)	61
Table 24. Sample Emissions Variation File based on Month (12 factors)	61
Table 25. Sample Emissions Variation File based on Season and Hour of Day (96 factors)	61
Table 26. Sample Emissions Variation File based on Wind Speed (6 factors).....	61
Table 27. Format Guidelines for Alternate Receptors File (CSV)	63
Table 28. Sample Input File for Alternate Receptor Input File	63
Table 29. Format Guidelines for the Census Update File	65
Table 30. Sample Census Update File	65
Table 31. Summary of HEM4 Template Input Files	67
Table 32. Sample List of Error Messages and Causes in HEM4	83
Table 33. Fields Included in the Maximum Individual Risk & Maximum Offsite Impacts Files	94
Table 34. Fields Included in the Risk Breakdown File	96
Table 35. Fields Included in the Block Summary and Ring Summary Chronic Files	98
Table 36. Fields Included in the Incidence File.....	100
Table 37. Fields Included in the All Inner and All Outer Receptor Files	102
Table 38. Fields included in the All Polar Receptors File	103
Table 39. Fields included in the Acute Chem Max and Acute Chem Pop Files.....	107

1. Introduction

The Human Exposure Model 4 (HEM4) Open Source Version 1.0 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 complex industrial facilities. HEM4 can be used to model impacts from a single facility or from multiple facilities located across the entire United States (U.S.) and its territories, as well as anywhere in the world. HEM4 is designed for use by the U.S. Environmental Protection Agency (EPA), states, local agencies, industry and other stakeholders, and is currently used in the Risk & Technology Review (RTR) assessments by EPA of entire source categories. In RTR assessments, HEM4 – like its predecessor, HEM-3 – is used to model emissions and the resulting ambient concentrations from hundreds of facilities, located both near as well as thousands of miles away from each other. The model then predicts the potential exposures and inhalation health risks posed by these emissions, including in zones with combined impacts from multiple nearby facilities. Compared to HEM-3, HEM4 incorporates additional front-end and back-end features and capabilities in the model platform, including additional modeling options, risk summary reports that summarize the cancer risk and noncancer health impacts for your modeled group of facilities, and multiple output viewing and analysis tools. Unlike HEM-3, HEM4 also enables the user to model concentrations, risk and health impacts for their own receptors inside or outside the U.S. HEM4 is available for download at <http://www.epa.gov/fera/download-human-exposure-model-hem>.

1.1 Organization of the HEM4 User's Guide

This User's Guide is organized into 10 sections plus an appendix:

- Section 1 Provides a brief introduction to HEM4, including the main features and requirements of the model and a comparison to HEM-3
- Section 2 Provides instructions for installing HEM4, including descriptions of the data libraries provided during installation
- Section 3 Provides instructions for preparing the input data files needed by HEM4
- Section 4 Provides step-by-step instructions for running HEM4
- Section 5 Describes the calculations performed by HEM4 for each modeled facility
- Section 6 Describes the facility-specific outputs produced by HEM4
- Section 7 Describes the risk summary reports produced for each run group
- Section 8 Explains how to understand the basic risk results
- Section 9 Discusses quality assurance remodeling
- Section 10 References
- Section 11 Appendix A: Sample HEM4 Output Files

1.2 Main Features of HEM4

HEM4 performs three main operations: dispersion modeling, estimation of population exposure, and estimation of human health risks. For dispersion modeling, the American Meteorological Society - U.S. EPA Regulatory Model (AERMOD) is run by HEM4 as a compiled executable program. AERMOD is a state-of-the-science Gaussian plume dispersion model that EPA prefers 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, AERSCREEN, AERSURFACE and BPIPPRIM and post-processor, LEADPOST.)

This version 1.0 of HEM4 incorporates AERMOD version 19191 which was originally made available to the public in August 2019 ([EPA 2019a](#), [EPA 2019b](#)). 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 emissions that vary in time or with wind speed, deposition with or without plume depletion, and other complex plume processes such as building downwash.

HEM4 supplies AERMOD with meteorological data pre-processed by AERMET and required for AERMOD's dispersion calculations. HEM4's Meteorology Library contains meteorological ("met") data from over 800 observation stations across the continental U.S., Alaska, Hawaii, and Puerto Rico. [Section 2.4](#) provides information on how to download the met data used by HEM4, discusses how the met files were processed and the data contained in each, and includes a national map of the locations for all 2019 met stations.

HEM4 runs AERMOD as many times as is necessary to address the gaseous pollutants and particulate matter emitted from each modeled facility. AERMOD outputs annual average ambient concentrations at discretely modeled receptor locations, through the simulation of hour-by-hour dispersions from the emission sources into the surrounding atmosphere.

For U.S. emission sources, after running AERMOD for dispersion modeling, HEM4 estimates population exposure and human health risks by drawing on additional data libraries that are provided with the model, including a U.S. Census Library and a Chemical (Pollutant) Health Effects Library. The Census Library of census block internal point ("centroid") locations and populations provides the basis of human exposure calculations. The model includes location and population data from the 2010 U.S. Census. HEM4 draws upon the Census Library to identify all census block locations within the study domain as defined by the default modeling radius around each facility or a radius that you specify. The Census Library includes locations and populations, elevations, and controlling hill heights for all of the approximately 6.3 million populated blocks tabulated in the 2010 U.S. Census ([Census 2010](#)). [Section 2.3](#) provides information on how to download the census data and discusses the data contained in HEM4's Census Library.

Alternatively, HEM4 can model without the U.S. Census Library by using Alternate Receptors that the user can provide within the U.S. or anywhere in the world.

HEM4 uses the Chemical Health Effects Library of pollutant unit risk estimates (URE) and reference concentrations (RfCs) to calculate population cancer risks and noncancer 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](#).

Using the air concentration results from AERMOD in combination with the data supplied by HEM4's Census and Chemical Health Effects Libraries, HEM4 estimates cancer risks and noncancer "risks" (health hazard indices) due to inhalation exposure at U.S. Census block locations and at other receptor locations that you may specify. As noted above, HEM4 (unlike the previous HEM-3 version of the model) can also be used outside the U.S., without U.S. Census block receptors, to predict concentrations and risk anywhere in the world at receptors specified by the user surrounding emission sources. 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 the current residential receptor site).

HEM4 computes cancer risks using the EPA's UREs for HAP and other toxic air pollutants. The resulting estimates reflect the risk of developing cancer for an individual breathing the ambient air at a given receptor site 24 hours per day over a 70-year lifetime. HEM4 estimates noncancer "risk" (or health hazards) using hazard quotients (HQs) and hazard indices for 14 "target" organs or systems. The HQ for a given pollutant and receptor site is the ratio of the ambient concentration of the pollutant to the RfC at which (and below which) no adverse effects are expected. The chronic hazard index (HI) for a given target organ is the sum of HQs for substances that affect that organ. HEM4 computes target organ-specific hazard indices (TOSHLIs) for the following 14 organ systems: the respiratory system; the liver; the neurological system; developmental effects; the reproductive system; the kidneys; the ocular system; the endocrine system; the hematological system; the immunological system; the skeletal system; the spleen; the thyroid; and whole body effects. Like the cancer risk estimates, noncancer hazard indices are not adjusted for attenuating exposure factors and are therefore considered conservative estimates.

Optionally, HEM4 can estimate acute (short-term, such as hourly) concentrations for each pollutant and receptor site, including the location of the maximum acute concentration for each pollutant emitted from the facility. In addition, the model outputs a listing of the associated acute benchmarks for each pollutant (at or below which certain acute adverse effects are not expected). From these acute concentrations and benchmarks, the ratio of the maximum acute concentration to the associated benchmark is computed to determine the maximum acute HQ for each pollutant of concern. Acute noncancer HQs, like chronic noncancer TOSHLIs and cancer risk are conservative estimates in HEM4. [Section 2.2.1](#) discusses the terms URE, RfC, HQ, HI and TOSHI in more detail.

HEM4 estimates the predicted lifetime cancer risk, chronic noncancer TOSHLIs, annual concentrations, 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 the modeled pollutants (HAP) emitted from each emission source driving the overall cancer risks, chronic TOSHLIs, and acute impacts. The model also estimates the number of people exposed to various cancer risk levels and TOSHI levels.

HEM4 provides these results for each individual modeled facility and also consolidates facility-specific results into output files that provide results for all modeled facilities. HEM4's post-processors, the risk summary programs, produce additional outputs of combined and summarized results that are useful in capturing the risk and health hazards, as well as the pollutant and emission source drivers of these impacts, for a group of modeled facilities as a whole (e.g., an entire source category of facilities modeled under the EPA's RTR program). HEM4 provides a browser-based option of viewing all the summarized results in graphical form, including an interactive map of the facilities modeled, pie and bar charts of overall cancer incidence, population risks, and pollutant and source risk drivers, and an interactive table of the main results for each facility.

1.3 Differences between HEM4 and 2019 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, eventually called HEM-3, and regularly improved and re-released by EPA in several HEM-3 versions over the years, including most recently in 2007, 2014, 2017 and 2019. HEM4 is written in the open-source software language Python™, while HEM-3 is written in the FoxPro® language, last published by Microsoft® in 2007 and now unsupported. In addition, HEM4 includes improved and streamlined user interfaces as well as enhanced graphical output capabilities compared to HEM-3, as listed below, and summarized in Figure 1.

- HEM4 bases model selection options primarily on the data in your input files, rather than on responses to user interface questions, which is less prone to user error.
- HEM4 can model impacts anywhere in the world with user-provided “alternate receptors”, in addition to U.S. Census block receptors.
- HEM4 includes an integrated processor to change the U.S. Census database you use to model by zeroing out block populations, moving blocks, and/or deleting blocks.
- HEM4 will default to using the full year of selected met data, but you may instead model with a specified period of met data by indicating a start and end date and even hour.
- HEM4 allows you to specify the exact location of the facility center or use the center location calculated by the model.
- HEM4 allows you to specify polar ring distances or use the polar ring locations calculated by the model.
- HEM4 allows you to choose Method 1 or Method 2 for particle deposition. Method 2 requires less knowledge of the particle size distribution of your emissions compared to Method 1, which requires a detailed particle size input file.
- HEM4 allows you to choose a different acute high value for each facility (e.g., maximum, 99th percentile, 98th percentile), rather than modeling each facility with the same maximum acute value.

- HEM4 includes the Risk Summary Report programs (previously called the RTR Summary Programs) integrated into the model itself, rather than as an add-on suite of programs.
- HEM4's Risk Summary Reports are enhanced. The HI Histogram output accounts for all 14 TOSHIIs (not just three). The Incidence Drivers output is now sorted in descending order of pollutant-specific incidence and includes the pollutant's percentage contribution to total incidence. The Source Type Risk Histogram output includes the maximum overall risk histogram and incidence for all modeled facilities in your run group, in addition to the histogram and incidence specific to each source type.
- HEM4 performs consistency checks on your input files and includes more specific and instructive error messages, to aid you in rectifying any errors or inconsistencies in your input files before the model run begins.
- In addition to spreadsheet output files, HEM4 includes enhanced capabilities for visualization and analysis of outputs, including browser-based interactive tables, graphs, and mapping options.
- Note: In addition to the enhancements listed above, HEM4 has maintained all the capabilities of the 2019 HEM-3 version, which included numerous enhancements compared to the previous versions.

Model Feature	HEM4	2019 HEM-3
Software language	Written in open-source Python™ language	Written in Microsoft FoxPro® language, now unsupported
Minimal user interface	Model options based primarily on data in input files; less prone to user error	Model options based on input files as well as responses to user interface questions; more prone to user error
Receptor enhancement and flexibility	Modeling can occur anywhere in the world because users can specify alternate populated receptors in lieu of U.S. Census blocks	Only U.S. modeling was possible because U.S. Census receptor data was required for any model run
Census database revisions	Census blocks may be revised or removed using an integrated processor	Census database could not be edited by user
Meteorological Period Options	Period start and end fields allow you to specify exactly what met period HEM4 should instruct AERMOD to use for your modeling run, down to the year, month, day and even hour	HEM-3 always used the default annual period of met data
Facility center	User may specify the location of the facility center	The facility center was always calculated by model based on source locations

Model Feature	HEM4	2019 HEM-3
Polar ring distances	User may specify polar ring distances or use defaults	Polar ring distances were set by default only
Particle deposition	User can choose AERMOD's Method 1 or 2 to model particle deposition. Method 2 requires less particle data.	Particle deposition was always modeled via AERMOD Method 1, which requires detailed particle size distribution data
Acute high value	User can specify a different percentile to use as the acute high value for each facility	The same maximum value had to be used for every facility in the modeling run
Risk Summary Programs	Risk Summary Programs are integrated into HEM4	RTR Summary Programs were a separate executable
Risk Summary Report Enhancements	The HI Histogram output accounts for all 14 TOSHLIs. The Incidence Drivers output is sorted in descending order of pollutant-specific incidence and includes the pollutant's percentage contribution to total incidence. The Source Type Risk Histogram output includes the maximum overall histogram for the run group.	HEM-3 accounted for only 3 TOSHLIs in the HI Histogram output. HEM-3's Incidence Drivers output was unsorted and did not include the percentage that each pollutant contributes to the total incidence. HEM-3's Source Type Risk Histogram did not include the maximum overall column for the run.
Error messages	Input file inconsistency checks are automatically made prior to model run with more specific and instructive error messages to aid user in correcting errors pre-run	Error messages were not specific enough and did not capture many input file inconsistencies prior to runs
Graphical outputs	Browser-based interactive tables, graphs, and mapping options for visualization and analysis of outputs, in addition to spreadsheet-based output files	Graphical output options were not available in HEM-3

Figure 1. Summary of Key Improvements for HEM4 versus 2019 HEM-3

1.4 Strengths and Limitations of HEM4

HEM4 is designed to perform detailed and rigorous analyses of chronic and acute air pollution risks for populations located near industrial emission sources. The 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 blocks and tracts. The model identifies all receptors located near each facility, including census blocks (if in the U.S.) and alternate receptors. You can also specify the locations of individual houses, schools, facility boundaries, monitors, or other user-defined receptors to model. HEM4 can account for impacts of terrain, building downwash effects, pollutant deposition and plume depletion, and temporally-varying emissions. HEM4 also analyzes multiple pollutants concurrently, with the capability of including particulate and gaseous pollutants in the same model run.

However, HEM4'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 HEM4 is that, when modeling with census block receptors in the U.S., the model estimates pollutant concentrations and risks for the 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 previously noted, HEM4 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.

HEM4 performs several tests on user input data—including ensuring consistency of input files and some parameters—before using AERMOD to calculate air pollution impacts. However, there are some potential problems users may introduce to their input files that HEM4 may not detect in these initial tests. 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 HEM4.

1.5 Requirements for Running HEM4

You can use HEM4 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. To model an individual facility, the model requires, at minimum, 10 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 3.3 GB of space. The HEM4 model also will need a minimum of 8 GB of random-access memory (RAM). Once installed, you can use HEM4 to model risks and exposures for any location in the U.S. or around the world, and for a wide range of emission source configurations.

For each model analysis, you should provide emission rates for all HAP and emission source locations in the form of Excel™ spreadsheet files. HEM4 requires separate estimates of emission rates of each pollutant, from each emission source, for each facility to be modeled. The model also requires detailed information on each emission source, including location, release height, emission velocity and temperature for point (stack) sources, and the configuration of non-point emission sources (e.g., area sources which emit with negligible velocity at ambient temperature). You will be able to design the model receptor network around each facility to be modeled via an input spreadsheet file. 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. You will be prompted to indicate the location of your input spreadsheet files through user input screens, which are discussed in more detail in Section 4, *Step-by-Step Instructions for Running HEM4*.

This user's guide is designed to provide all the information you will need to run HEM4. However, some of the options for running HEM4 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 HEM4 ([EPA 2019a](#), [EPA 2019b](#)). This is particularly true for some of the more complex modeling options, such as plume deposition and depletion, building downwash, temporal and wind speed emission variations, and complex source configurations.

2. Installing HEM4

This section provides instructions for downloading and installing the HEM4 model and required data libraries from the EPA's HEM Download Page.

2.1 Downloading the HEM4 Program

The HEM4 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 HEM4. Download the HEM4 zip install package under "Software available for download." HEM4 can be installed anywhere on your PC and the root folder is not required to be named HEM4. However, **for the purposes of this User's Guide, it is assumed the root folder will be named "HEM4"**. HEM4 is started by running the executable file ending in ".exe".
Note: The HEM4 source code is available on github.com/USEPA/HEM4.

In addition to user-supplied inputs describing the nature and location of the emissions (discussed in Section 3.1), HEM4 relies upon several data libraries that supply other required inputs for a modeling run. To complete the installation of HEM4, download the following data libraries:

- the Chemical Health Effects Library containing the pollutant (hazardous air pollutant, HAP)-specific dose response values and benchmark values for affected organs, a.k.a. "Toxicity Value Files" (Note: upon installation, HEM4's resources folder will include a Dose Response Library and Target Organ Endpoints table);
- the Census Library containing nationwide files that provide the population numbers and terrain elevation data surrounding a facility location (based on the 2010 Census); Note: upon installation, HEM4's census folder will include the census files needed to run the template/sample files only; and
- the Meteorological Library containing met station files (a surface and profile file for each station) with data for over 800 stations nationwide; Note: upon installation, HEM4's AERMOD 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.

2.2 Downloading Chemical Health Effects Data

HEM4 uses a chemical health effects library of pollutant unit risk estimates (UREs) and reference concentrations (RfCs) to calculate risks. To download these 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 “resources” folder under the HEM4 directory that you selected during installation. Be sure to unzip the files and verify they are located in the specified folder when finished. The folder for chemical health effects data is “HEM4\resources.”

2.2.1 Description of Chemical Health Effects Library

For each pollutant or HAP, the Chemical Health Effects Library includes the following parameters, where available:

- URE for cancer;
- RfC for chronic noncancer health effects;
- reference benchmark concentration for acute health effects; and
- target organs affected by the pollutant (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 ($\mu\text{g}/\text{m}^3$) in air. For example, if the URE is 1.5×10^{-6} per $\mu\text{g}/\text{m}^3$, then 1.5 excess cancer cases are expected per 1 million people, if all 1 million people were exposed daily for a lifetime to 1 microgram of the pollutant 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 2018b](#)).

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 2018b](#)). 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 pollutant 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 concentrations for acute health effects include both “no effects” reference levels for the general public, such as the California Reference Exposure Levels (RELs), and emergency response levels, such as Acute Exposure Guideline Levels (AEGLs) and

Emergency Response Planning Guidelines (ERPGs). A more in-depth discussion of the development and use of the health reference values may be found in the EPA's Air Toxics Risk Assessment Library ([EPA 2017](http://www.epa.gov/fera/risk-assessment-and-modeling-air-toxics-risk-assessment-reference-library)), 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 HEM4's Chemical Health Effects Library: the Dose Response Library file and the Target Organ Endpoints file. These files are located in HEM4's resources folder:

- HEM4\resources\Dose_Response_Library.xlsx; and
- HEM4\resources\Target_Organ_Endpoints.xlsx.

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 Endpoints file 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 HEM4's Dose Response Library file, and there can be no extra pollutants listed in your facility-specific input files that are not also listed in the Dose Response Library file. The Target Organ Endpoints file 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 file and is also listed in the Target Organ Endpoints file, with the impacted organs and organ systems checked. Note: **Only pollutants with RfC values need to be listed in the Target Organ Endpoints file.**

2.3 Downloading Census Data

You will need census files for the region or regions you wish to model. You can obtain nationwide files from the 2010 Census on the HEM Download Page (<http://www.epa.gov/fera/download-human-exposure-model-hem>) of EPA's FERA website.

Nationwide files are provided on a state-by-state basis in JavaScript Object Notation format (.json). HEM4 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 folder under the HEM4 folder you selected during installation. Once unzipped, check to be sure that these files are now located in the specified folders when finished. The census folder is "HEM4\census".

Do not delete the Census_key.json file (HEM4\census\Census_key.json). This file is required for HEM4 modeling runs. Note that the Illinois and North Carolina files for the 2010 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.

2.3.1 Description of Census Library

The HEM4 Census Library includes census block identification codes, locations, populations, elevations, and controlling hill heights for the over 6 million populated census blocks identified in the 2010 Census. The location coordinates reflect an internal point selected by the Census Bureau 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, but they are still referred to as “centroids” in this guide. Locations and population data for census blocks in the 50 states, Puerto Rico, and the Virgin Islands are extracted from the U.S. Census Bureau website for Census 2010 ([Census 2010](#)).

HEM4’s census database includes elevation and controlling hill height data, in addition to the population and location data supplied by the Census Bureau. U.S. Geological Survey data were used to estimate the elevation of each census block in the continental U.S. and Hawaii. The elevation data contained within the 2010 Census files were derived from North American Digital Elevation Model (DEM) data at a resolution of 1/3 of an arc second, or about 10 meters ([USGS 2015](#)). Using the ArcGIS® 10 analysis tool, 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 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. HEM4 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 2018c](#)), is used to determine controlling hill heights. These values are used for flow calculations within AERMOD. To save run time and resources, the HEM4 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 HEM4 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 NCES 2009 data ([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 2018d](#)). 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 \pm 600 meters), making comparison with HEM4 modeling results inexact.

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 in the “aermod” folder under the HEM4 folder you selected during installation. Unzip the meteorological files. After unzipping, verify they are located in the specified folder. The meteorological folder is “HEM4\aermod\MetData.” AERMOD uses two files for each meteorological station and these files have extensions of SFC (surface data) and PFL (profile data).

Note that when you download the HEM4 model (as described in Section 2.1), the installation package will place an Excel™ spreadsheet named “metlib_AERMOD.xlsx” in your “HEM4\resources” 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 “HEM4\aermod\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 resources folder. You may also edit rows in this spreadsheet or delete met station entries entirely. (A Python error message will be displayed if HEM4 cannot locate the metlib_AERMOD.xlsx spreadsheet in your resources folder.)

2.4.1 Description of Meteorological Library

AERMOD requires surface and upper air meteorological data that meet specific format requirements. HEM4 includes a library of meteorological data from National Weather Service (NWS) observation stations. The current HEM4 AERMOD Meteorological Library includes over 800 nationwide locations, depicted in [Figure 2](#).

USEPA meteorologists obtained calendar year 2019 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 Centers for Environmental Information (NCEI) (formerly, the National Climatic Data Center (NCDC)). The AERMOD meteorological processor, AERMET ([EPA 2019c](#)) 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 NCEI 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 19191 used to process ASOS site data; surface data in NCEI 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 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 HEM4 meteorological database. In all, 838 met station pairs were found suitable and are included in the HEM4 meteorological library, as depicted in [Figure 2](#). Of these 838 met stations, 791 stations contain 2019 met data, while the rest are 2016 through 2018.

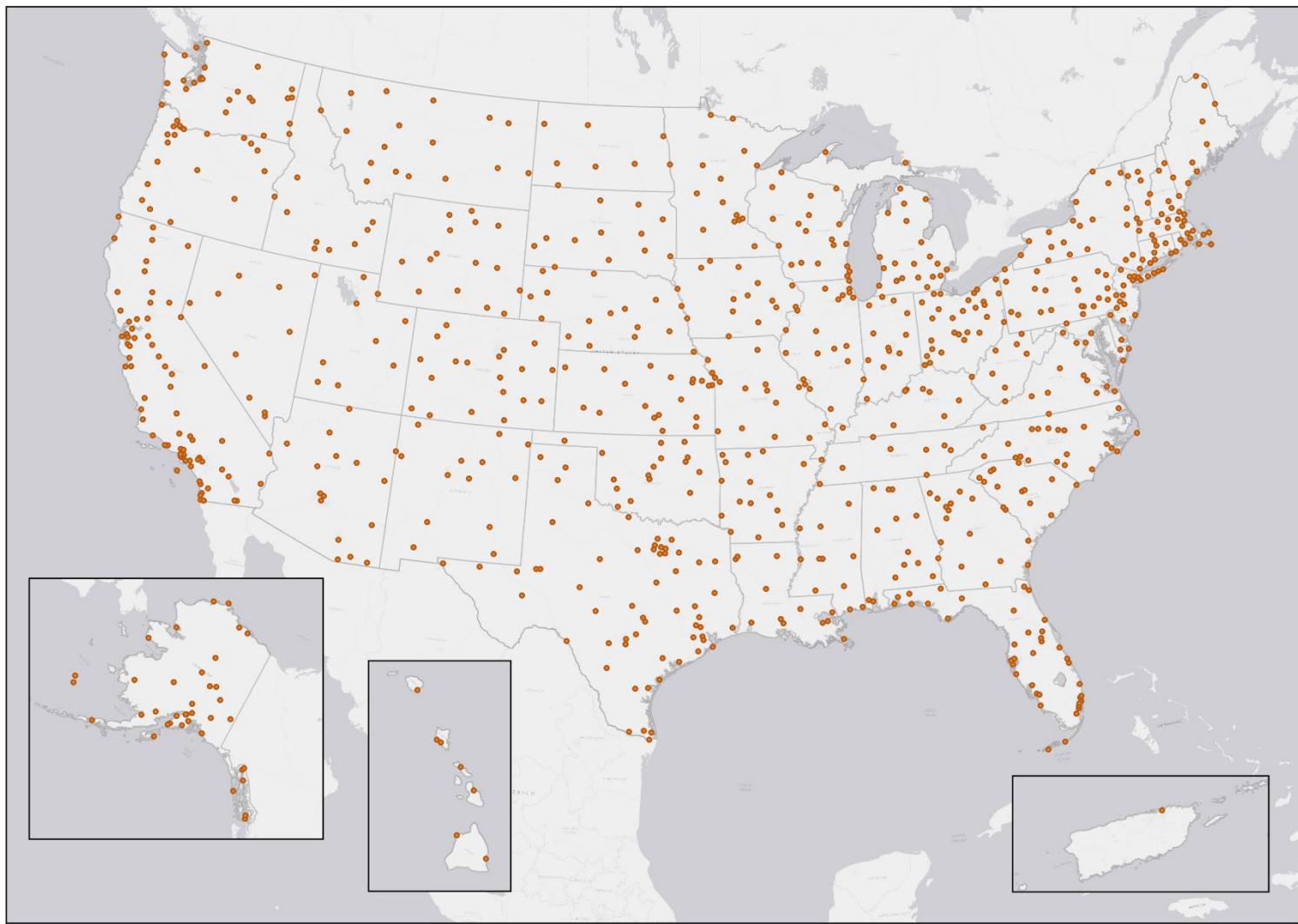


Figure 2. HEM4 Meteorological Stations

3. Preparing HEM4 Input Files

This section explains how to prepare the required and optional user-supplied input files for HEM4. In addition to the instructions provided in this section regarding how to set up your input files, especially for more advanced modeling options, it is important to review the AERMOD documentation for further guidance ([EPA 2019a](#), [EPA 2019b](#)).

3.1 Overview and General Rules

HEM4 requires a series of Excel™ spreadsheet files to specify the emissions and configuration of the facilities (or facility) you are modeling. HEM4 accepts all recent Microsoft Excel™ versions using the xlsx spreadsheet format (e.g., Excel 2007 and later). It should be noted that Excel 2007/2010, 2013, 2016, and 2019 versions have a 1,048,576-row capacity (and 16,384-column capacity).

To use HEM4 to calculate ambient pollutant concentrations (using AERMOD), you will need the following three files at minimum:

- a facility list options file, which is the primary driver of the model run listing the facilities to be modeled and specifying the model run parameters and options;
- an emissions location file, which provides emission source locations and configurations for the 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 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 – this file is required if one or more of your sources is configured as a polygon; it specifies the location of the polygon(s) by providing coordinates of the vertices. (Note: this file is not needed for area sources.)
- a buoyant line parameter file – this file is required if one or more of your sources is a buoyant line; it defines the values for a single buoyant line source (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 building dimensions file – this file is required to model building downwash effects; it describes building dimensions or other obstructions near emission sources that would produce wake effects.
- An emission variations file – this file provides emission rate factors for individual sources for one or more of the facilities you specify and is required to model temporally-varying emissions (e.g., emissions reflecting diurnal, weekly, monthly, and seasonal variations) or emissions impacted by wind speed variations.

- a particle data file – this file is required to model particulate deposition; it specifies the particle size distribution for various size ranges.
- the gas parameter file (included in HEM4’s resources folder) – this file is required to model gaseous deposition; it specifies the parameters needed for modeling dry and/or wet deposition of gaseous (vapor) pollutants including diffusion coefficients, cuticular resistance and Henry’s Law coefficients. (Note: defaults are provided by the model automatically, but you should provide pollutant-specific parameters if available by editing the *Gas_param.xlsx* file as discussed in Section 3.5.4.)
- a land use and month-to-seasons files – these two files are required to model dry deposition of gaseous pollutants; they describe the land use and vegetative land cover surrounding emission source(s) for facilities listed in the files.
- a user-defined receptors file – this file specifies the locations of additional discrete receptors and is required if you want HEM4 to compute pollutant concentrations and risks at locations you specify (e.g., houses, schools, or other sites near a facility), in addition to U.S. census block receptors. (Note: your facility list options file must indicate the facilities to be modeled with user receptors.)
- an alternate receptor file – this file is required if you wish to use receptors other than U.S. Census block centroids in your modeling run and instead provide your own list of receptors for modeling within the U.S. or anywhere in the world; the file specifies the ID, location, elevation, hill height and population of the alternate receptors to be modeled.

These files are described in more detail below in Sections 3.2 through 3.5. In addition to the above list of input files, you can also optionally revise the census database (as described below in Section 3.5.9) and also revise the chemical health effect input files – the dose response values and target organ assumptions – used in the model (as described below in Section 3.5.10).

HEM4 will prompt you to provide the input files required for your model run by opening up Browse lines that allow you to search your computer for the location of each required input file. 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, HEM4 will not run successfully unless you have formatted the input files exactly as specified in the format guidelines. This section 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 “HEM4\Inputs” folder. **Note: If this is your first time running HEM4, it is highly recommended that you first run the model with the template input files provided, as practice, and to confirm that HEM4 installed properly on your computer.**

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. HEM4 will read these, including any extra hidden columns, as data.
- Use the number of header rows indicated in the template input files (included with the HEM4 download) at the top of each spreadsheet file for all required and optional input files.
- Do not include text in numerical data fields (for instance "<0.001"). HEM4 may read these fields as 0s (zeroes) or may accept only a portion of the number.
- For location coordinates, HEM4 will accept latitudes and longitudes in decimal degrees as well as Universal Transverse Mercator (UTM) coordinates. **The maximum precision HEM4 uses for latitude and longitude decimal degrees is 5 places after the decimal.** (HEM4 will convert latitudes/longitudes to UTMs for use in AERMOD.) You must enter coordinates in the World Geodetic System of 1984 (WGS84) format.¹ The 1983 North American Datum (NAD83) and the WGS84 are identical for most applications, so no conversion is needed if using coordinates based on NAD83. However, if coordinates are based on the 1927 North American Datum (NAD27) geographic system format, they would need to be converted to WGS84 before being used in HEM4.
- **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.
- Note that the length and decimal places indicated in the format guidelines for each field in the various input files is, in most cases, the suggested length based on HEM4's internal rounding conventions. For the Source ID field, however, it should be noted that AERMOD does not accept Source IDs longer than 8 characters.

3.2 Facility List Options File

The Facility List Options Excel™ file is the primary driver specifying the parameters and options of the modeling run and is required for any HEM4 run. This file is an enhanced version of the Facility List Options file used in Multi HEM-3, with several columns added allowing for additional features and several columns re-arranged for more intuitive grouping of fields. The Facility List Options file contains one row for every facility that will be run with the various modeling options

¹ WGS84, NAD83 and NAD27 are different world reference frames (a.k.a. geographic systems) that are used as the basis for projected coordinate systems like UTMs. HEM4 uses WGS84. For more information see <https://www.nga.mil/ProductsServices/GeodesyandGeophysics/Pages/WorldGeodeticSystem.aspx> and <https://gisgeography.com/wgs84-world-geodetic-system/>.

listed as columns for each facility row. **If you use all default modeling options, the only field requiring input is the Facility ID.** All other fields have defaults which are employed when the field in the Facility List Options file is left blank.

3.2.1 Fields in the Facility List Options File

Table 1 shows the fields included in the Facility List Options file. These fields are columns in the actual *Facility_List_Options.xlsx* input file that you must provide to HEM4, and each row is for a different facility as identified by the Facility ID. The rows in Table 1 are shown in the same column order required by HEM4 in the input file. (For a template, see *HEM4_Facility_List_Options.xlsx* in your HEM4 inputs folder.) The options listed in Table 1 are described in more detail following the table.

Table 1. Fields in the Facility List Options Input File (Required)

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Facility ID (FacilityID)		You must enter an alphanumeric string identifying the facility being modeled. This field is mandatory; all other fields have default values when blank.
Met Station (met_station)	Met station selected by model as closest to the facility	The name of the meteorological surface station (e.g., NAME02.SFC) to be used by AERMOD when modeling each facility. The met station closest to facility is chosen unless you specify a name.
Rural/Urban (rural_urban)	HEM4 determines when using U.S. Census block receptors; HEM4 defaults to rural for alternate receptors	Used to set the type of dispersion environment for AERMOD. “R” indicates rural land use surrounding the facility; “U” indicates urban land use. If left blank when modeling using U.S. Census block receptors, HEM4 will determine whether the closest census block to the facility is located in an urbanized area, based on the 2010 Census. When using alternate receptors instead of U.S. Census block receptors, a blank in this column will cause HEM4 to default to a rural dispersion environment.
Urban Population (urban_pop)	Defaults to 50,000 people if left blank, but only used and needed if “U” specified in Rural/Urban field	If you indicate “U” for urban land use (in Rural/Urban field above), then you should provide the model with the urban population size, otherwise leave blank. Note: If you specify “U” in the Rural/Urban field but provide no urban population value in this field, HEM4 will use a default urban population of 50,000 people.
Max distance (max_dist)	50,000 meters	The outside max radius of the modeling domain in meters (must be \geq the modeling distance and \leq 50,000 meters).
Modeling distance (model_dist)	3,000 meters	The cutoff distance (in meters) for individual modeling of ambient impacts at census blocks; beyond this distance ambient impacts are interpolated rather than explicitly modeled. Note: For polygon source types, set the modeling distance $>$ the largest distance across the polygon.
Radials (radials)	16	The number of radials in the polar receptor network emanating from the facility center (must be \geq 4).

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Circles (circles)	13	The number of concentric circles in the polar receptor network, centered on the facility center (must be ≥ 3).
Overlap distance (overlap_dist)	30 meters	The distance (in meters) between an emissions source and a census block or alternate receptor, within which you do not want the receptor to be considered as a point of maximum exposure/risk because it might be on facility property. Must be an integer value ≥ 1 meter and ≤ 500 meters.
First ring distance (ring1)	If left blank, calculated by HEM4 to be just outside the source locations, but not less than 100 m from facility center	The distance to the first ring (circle) of the polar network as measured from the facility center. You can override the default distance calculated by HEM4 to fit the size and shape of the facility properties to be modeled.
Facility Center	If left blank, calculated by HEM4 based on the source locations in the emissions locations input file	You can enter the facility center location in this field to override HEM4's (default) location. Enter as a comma separated list that should start with either "U" (if using UTM coordinates) or "L" (if using lat/lon coordinates). The list should contain two values if L for latitude followed by longitude (L, 35.91,-78.89) or three values if U for northing, easting and UTM zone number with hemisphere (U, 3975044, 690891, 17N). Hemisphere is S or N and defaults to N if omitted.
Ring Distances	HEM4 will automatically place 13 polar rings (circles) by default	You can override HEM4's placement of polar rings (circles) by specifying a list of distances in this field. Enter a comma separated list that contains at least 3 values representing the distance in meters for each polar ring from the facility center. The distances entered must be > 0 and $\leq 50,000$ meters, and the values must be increasing (e.g., 100,500,1000,5000,10000,50000).
Acute (acute)	N	Entering "Y" directs HEM4 to calculate short-term (acute) concentrations for that facility. If left blank or "N" is entered, acute impacts are not estimated in the model run.
Hours (hours)	1-hour	The short-term (acute) averaging period that AERMOD will use for ambient concentrations, for that facility. The averaging period options are: 1, 2, 3, 4, 6, 8, 12 and 24-hours. The default is 1-hour.
Acute Multiplier (multiplier)	10	The acute multiplier applied to the average annual emission rate and used to approximate the short-term emission rate (e.g., 10 times the rate entered in the HAP Emissions file). Note: HEM4 also assumes that this short-term rate can occur at the same time as the worst-case meteorological conditions. Two-decimal precision is accommodated; minimum value is 1.00
High Value (high_value)	Maximum acute value is used as the high value when this field is left blank	This field indicates which acute concentration to report as the high acute value in the outputs, for each facility. If you wish to use a value other than the maximum (e.g., the 98 th or 99 th percentile), then enter the value in this field. The number you enter must be an integer and is calculated based on the

Field	Default Setting (if field left blank)	Description of Facility List Options Field
		<p>number of hourly values in the modeled run. For example, if you want the 98th percentile acute value used from a data set of 8,760 hourly values (in one year), then enter 175 in this field, which is the truncated product of 0.02×8760. Similarly, if you want to use the 99th percentile acute value, then enter 87 in the text box, which is the truncated product of 0.01×8760. The default acute high value (if this field is left blank) is the maximum modeled acute concentration.</p>
Deposition (dep)	N	<p>Deposition is not modeled by default; entering “Y” directs the model to calculate deposition in the model run (particle, vapor, or both as designated below) and provide the deposition flux in the output files. You may model deposition with or without plume depletion (below). Note that you cannot model deposition/depletion for any facility that contains a buoyant line.</p>
Depletion (depl)	N	<p>Depletion is not modeled by default; entering “Y” directs the model to deplete the plume by the calculated deposition flux. Note: You may enter “Y” here even if you chose “N” for deposition; in that case the model will internally calculate deposition flux to deplete the plume but will not provide the deposition flux values in the output files. (This option saves space if you do not need the deposition flux.) Note that you cannot model deposition/depletion for any facility that contains a buoyant line.</p>
Particle Deposition (pdep)	NO	<p>The value “WD” directs the model to incorporate both wet and dry deposition for particles. Use “WO” for wet only particle deposition; use “DO” for dry only particle deposition; use “NO” (or leave blank) if not modeling deposition of particles. If you enter WD, WO or DO in this field for a given facility (or facilities), then HEM4 will prompt you to provide a particle size input file for that facility (or facilities), if you are using Method 1 for deposition. Note that you cannot model deposition/depletion for any facility that contains a buoyant line.</p>
Particle Depletion (pdepl)	NO	<p>The value “WD” directs the model to incorporate both wet and dry depletion of particles from the plume. Use “WO” for wet only particle depletion; use “DO” for dry only particle depletion; use “NO” (or leave blank) if not modeling depletion of particles from the plume. If you enter WD, WO or DO in this field for a given facility (or facilities), then HEM4 will prompt you to provide a particle size input file for that facility (or facilities), if you are using Method 1 for deposition. Note that you cannot model deposition/depletion for any facility that contains a buoyant line.</p>
Vapor (gaseous) Deposition (vdep)	NO	<p>The value “WD” directs the model to incorporate both wet and dry vapor deposition of pollutants; use “WO” for wet only vapor deposition; use “DO” for dry only vapor deposition; use “NO” (or leave blank) if not modeling deposition of vapor pollutants. If you entered WD or DO in this field, HEM4 will prompt you to provide a land use input file and a month-to-</p>

Field	Default Setting (if field left blank)	Description of Facility List Options Field
		seasons input file, which are needed for dry deposition/depletion modeling. Note that you cannot model deposition/depletion for any facility that contains a buoyant line.
Vapor (gaseous) Depletion (vdepl)	NO	The value "WD" directs the model to incorporate both wet and dry depletion of vapor pollutants from the plume. Use "WO" for wet only vapor depletion; use "DO" for dry only vapor depletion; use "NO" (or leave blank) if not considering depletion of vapor pollutants from the plume. If you entered WD or DO in this field, HEM4 will prompt you to provide a land use input file and a month-to-seasons input file, which are needed for dry deposition/depletion modeling. Note that you cannot model deposition/depletion for any facility that contains a buoyant line.
Elevations (elev)	Y	Elevations of receptors are accounted for by default; entering an "N" excludes elevations from the model run.
User receptors (user_recpt)	N	Enter "Y" to include user receptors in the modeling run, for each facility. User receptors are not included by default. Note: if you are modeling using user receptors, HEM4 will prompt you for a separate user receptor input file.
Building Downwash (bldg_dw)	N	Enter "Y" in this field for each facility containing point sources for which you wish to model downwash over a nearby building. Building downwash is not included by default. If you are modeling building downwash, HEM4 will prompt you for a separate input file that must contain building dimension information, for (applicable point sources in) each facility marked with a "Y" in this column. Note that building downwash may only be modeled with vertical point (P), capped point (C), and horizontal point (H) source types.
FASTALL (fastall)	N	Entering "Y" directs HEM4 to use AERMOD's control option FASTALL for modeling that facility, which conserves model run time by simplifying AERMOD's dispersion algorithms. FASTALL is not used by default. Note that you cannot use FASTALL for any facility that contains a buoyant line.
Emissions Variation (emiss_var)	N	Entering "Y" indicates that you want to vary the emissions of one or more sources at this facility. This field allows the application of variations to the emission inputs from specific sources by different user-supplied time scales (e.g., by season, month, hour of day, day of week), or by different wind speeds (6 ranges). If you enter a "Y" for a given facility, then HEM4 will prompt you for a separate emissions variation input file for that facility, and that file must contain variation factors for at least one source at each facility marked with a "Y".
Annual (annual)	Y	Entering an "N" in the annual field indicates that you want the modeling run to be based on meteorological data from a period other than an annual period. If you enter an "N" in this annual field, then you must enter values in the "period_start" and "period_end" fields (below). Leaving this field blank or

Field	Default Setting (if field left blank)	Description of Facility List Options Field
Period Start (period_start)	[Entry required if an "N" is entered in Annual field above]	entering a "Y" will cause HEM4/AERMOD to calculate annual concentration averages using the entire met data file, which is the default.
Period End (period_end)	[Entry required if an "N" is entered in Annual field above]	The period_start field indicates the start of the meteorological period during which AERMOD will run. You should enter a comma separated list of 3 or optionally 4 values here indicating the year, month, day and (optionally) hour of when the modeling period should begin. For example, if you enter 2016,02,11,12 then the model will use 2016 met data starting on February 11th at the 12th hour (noon) and end on the date and time indicated in the period_end field. Note that if you do not enter an hour here, then the model will use hour 1 as the default.

Note: Take care when filling out the Facility List Options File, as this file drives and controls the modeling run. To avoid error, this file must be consistent with your other input files. For example, if you indicate 100% particles in the Percent Particulate column of your [HAP Emissions input file](#) and you wish to model deposition and/or depletion, then you cannot choose to model vapor deposition and/or depletion (by entering a "Y" in either the vdep or vdepl columns of your Facility List Options file). In addition, the modeling options you indicate in the Facility List Options file may require additional input files for modeling. For example, if you indicate in the Facility List Options file that you would like [building downwash](#) modeled for certain facilities (by entering a "Y" in this field), then one or more point sources at those facilities must be included in the separate [building dimensions](#) input file that HEM4 will prompt you for. You will also need to provide consistent input files if you marked a "Y" for any facilities in the [user receptor](#) or [emissions variations](#) fields. The various modeling options driven by the Facility List Options file are discussed more in the next sections.

3.2.2 Meteorological Station and Period Options

HEM4's library of meteorological (met) station data is described in [Section 2.4.1](#). By default, HEM4 chooses the met station closest to the facility to be modeled (i.e., if this field is left blank). If you do not want HEM4 to choose the closest met station's data to use for your modeling run, in the meteorological station (met_station) column/field of the Facility List Options file, enter the name of the met surface station you want AERMOD to use when modeling each facility (e.g., NC13722.SFC). The names of all stations in the met library can be found in the

metlib_aermod.xlsx file in “HEM4\resources” folder, and the stations’ met data can be found in the “HEM4\aermod\MetData folder”. You can also add your own met station to the metlib_aermod.xlsx file in the HEM4’s resources subfolder and provide the new met station data as both SFC and PFL files in your “HEM4\aermod\MetData” folder, as explained in more detail in [Section 2.4](#).

The other fields related to met data are at the end of the Facility List Options file, on the far-right side of the spreadsheet, and include “annual”, “period_start”, and “period_end”. These columns, as noted above in Table 1, allow you to choose to model with a period other than the default annual period of met data. And the period start and period end fields allow you to specify exactly what met period HEM4 should instruct AERMOD to use for your modeling run, down to the year, month, day and even hour. **The period start and end dates you specify must be included in the meteorological files being used. If the set of meteorological files you specify, or that HEM4 chooses, does not cover the dates you specify, AERMOD will generate an error and that facility will not be modeled.** These period options are useful if modeling, for example, facilities that come on and offline during different parts of a year. The options may also be helpful in performing analyses to determine what time periods in the year produce the highest local concentrations and impacts.

It should be noted that the selection of the met station and met period for your modeling run can have a significant effect on the air concentrations and therefore risk and HI estimates that HEM4 produces. See Table 1 for HEM4’s default settings used in the Facility List Options for the [met station](#) and [period](#) options.

3.2.3 Rural and Urban Dispersion Options

The Rural or Urban column/field is used by HEM4 to set the type of dispersion environment for AERMOD, for each facility. If you are modeling using U.S. Census blocks as receptors, then by default HEM4 will find the nearest U.S. Census block to the facility center and determine whether that census block is located in an urbanized area, as designated by the 2010 Census ([FR 77:59](#)). If the block is in an urbanized area, then the population of the designated urbanized area will be used to specify the population input for AERMOD’s urban mode for that facility. If the block is not in an urbanized area, then AERMOD will use a rural dispersion environment for that facility.

If you are modeling using alternate receptors instead of census blocks (e.g., outside the U.S.), ideally you should determine which dispersion environment to use for each facility. If instead you leave the rural/urban field blank when using alternate receptors, then AERMOD will default to a rural dispersion environment, resulting typically in more conservative (higher) concentration predictions.

The EPA provides guidance on whether to select urban or rural dispersion in its [Guideline on Air Quality Models](#) (Appendix W). 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 should specify the population of the urban area surrounding the facility, if known, by entering it in the urban population column/field (urban_pop) of the Facility List Options file. This is true whether you are modeling with U.S. Census block receptors or with alternate receptors. If you choose to model using an urban dispersion

environment and do not provide a population, HEM4 will set your urban population column/field (urban_pop) to 50,000 people. As noted above, AERMOD uses the urban population value in its dispersion algorithms for urban areas.

3.2.4 Modeling Domain Options

You will provide HEM4 the parameters that define each facility's modeling domain in columns E through L of the Facility List Options file. The modeling domain is circular and centered on each facility, with a user-specified radius. HEM4 identifies all of the receptor locations in the modeling domain – census blocks for U.S. runs based on the census database, or alternate receptors for non-census modeling runs. The model then divides the blocks into two groups – inner and outer receptors – based on their distance from the facility. For the inner group of receptors (closest to the facility), each census block or alternate receptor location is modeled as a separate receptor in AERMOD.

Maximum Distance: In column E of the Facility List Options file, enter the maximum radius (in meters) to be modeled; this is the radius around each facility of the entire modeling domain. The maximum distance must be greater than or equal to the “modeling distance” (discussed next), but not greater than 50,000 meters because, as a Gaussian dispersion model, AERMOD is not recommended beyond 50 kilometers. If you leave this field blank, HEM4 will use a default maximum distance of 50,000 meters. The maximum distance is the radius of the circular study area for which HEM4 will model ambient impacts (at census block centroid receptors or alternate receptors, polar grid receptors, and user receptors, as explained below in this section). The center of this modeling domain is by default the geographical center of each facility (based on source locations for each facility) you are modeling, but you can change this center using the “facility center” column K, as discussed below.

Modeling Distance: In column F of the Facility List Options file, enter the distance (in meters) within which census blocks will be modeled individually. This is the cutoff distance around each facility for explicitly including census block or alternate receptors in the AERMOD run. Within this radial distance measured from the facility center, AERMOD will model each census block centroid or alternate receptor explicitly as a receptor. Outside of this radius, AERMOD will not model the census blocks or alternate receptors directly; ambient impacts at receptors beyond the modeling distance will be interpolated using dispersion modeling results for the polar receptor network, described below. If you leave this field blank, HEM4 will by default use a modeling distance of 3,000 meters. It should be noted that the Modeling Distance may not be greater than the Maximum Distance (above).

It should be noted that larger values for this cutoff modeling distance will require more time to model, because the number of receptors requiring explicit AERMOD modeling will be higher. However, you should set this cutoff value at a large enough distance so that the maximum risk receptor (discussed in Section 6.1.1) 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., U.S. 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.

Radials: In column G of the Facility List Options file, enter the number of radials in the area to be modeled. The polar grid receptors of the polar network are located at the intersection of a

radial and a polar ring (or “circle”, described next). A typical run would include 13 concentric rings and 12 or 16 radial directions. HEM4 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 degrees. If you leave this field blank, by default HEM4 will use 16 radial directions. If you choose to enter a different number of radials, you must specify at least 4 radials in this field.

Circles: In column H of the Facility List Options file, enter the number of concentric circles (rings) in the polar receptor network around each facility, centered on the facility center. You must enter at least 3 rings. If you leave this field blank, by default HEM4 will use 13 rings. Also, by default, HEM4 will calculate the inner radius of the polar network, unless you choose to specify a distance to the first ring (or “Ring1”, described below). This model-calculated first ring distance is based on the location of the emission sources and the facility center. HEM4 selects the distance that places the first modeling ring just beyond all emission sources, but not less than 100 meters from the facility center. HEM4 will place the concentric rings at a logarithmic progression of distances starting at the inner ring distance and ending at the outer radius of the modeling domain. However, you have the option to specify different ring distances (than HEM4’s calculated distances) in the “ring_dists” column, described below. 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.

Overlap Distance: In column I of the Facility List Options file, enter the distance (in meters) where source and receptor are considered to be overlapping. This distance must be greater than or equal to 1 meter and less than or equal to 500 meters. If you leave this field blank, HEM4 by default will use an overlap distance of 30 meters, which is approximately equal to the width of a narrow buffer and a roadway. Within this distance, 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, for example, wherein U.S. 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.) If a receptor falls within this distance, HEM4 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 (including polar receptors). An exception to this occurs when modeling polygon sources. Unlike other sources, when modeling polygons, overlapping of source and receptor is permitted. This allows the impacts, for example, of a U.S. 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.

Ring1 or First Ring: In column J of the Facility List Options file, enter the distance (in meters) to the first ring (circle) of the polar network for each facility, as measured from the facility center. As noted above (under “Circles”), if you leave this field blank then HEM4 will calculate the default value to the first ring to be just outside the source locations, but not less than 100 meters from the facility center. You can override the default distance calculated by the model to fit the size and shape of the facility properties to be modeled. For example, you should set the first receptor ring to less than 100 meters (or conversely greater than what HEM4 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. 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 described in Section 3.2.8). Note that **the first ring distance must be less than the modeling cutoff distance** (for explicit modeling of receptors).

Facility Center: In column K of the Facility List Options file, you may specify the facility center location to override HEM4's determination of where the facility center is located. If you leave this field blank, HEM4 will by default choose the facility center by determining the geographic center of the locations of all emission sources for that facility in your Emissions Location file (discussed in Section 3.4). If you wish to specify a different facility center location, then enter its location in this field as a comma separated list that should start with either "U" (if using UTM coordinates) or "L" (if using latitude/longitude coordinates). The list should contain two values if L for latitude followed by longitude (L, 35.91,-78.89) or three values if U for northing, easting and UTM zone number with hemisphere (U, 3975044, 690891, 17N). Hemisphere is S or N and defaults to N if omitted.

Ring distances: In column L of the Facility List Options file, you may override HEM4's placement of polar rings (circles) by specifying a list of distances in this field. To do so, enter a comma separated list that contains at least 3 values representing the distance in meters for each polar ring from the facility center. The distances entered must be greater than 0 and less than or equal to 50,000 meters, and the values must be increasing (e.g., 100,500,1000,5000,10000, 50000). If you leave this field blank, HEM4 will by default place 13 polar rings (circles), as noted above under "Circles".

A note about the Polar Network: Columns G and H of the Facility List Options file, and optionally columns J, K and L, define HEM4's polar network. In addition to ambient impacts at receptors (census block centroids or alternate receptors) within the modeling cutoff distance, HEM4 (using AERMOD) also explicitly models ambient impacts at polar grid receptors within the polar network. This polar network extends beyond the modeling cutoff distance to the maximum (outside) radius. The polar receptor network in HEM4 serves three functions:

- (1) it is used to estimate default impacts if one or more U.S. Census block receptor or alternate receptor 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) it is used to interpolate long- and short-term impacts at receptors (U.S. Census block locations or alternate receptors) that are outside the cutoff distance for modeling of individual receptors

Note that, if modeling with terrain effects, the elevation of each polar grid receptor is based on the elevation of nearby individually (explicitly) modeled or "discrete" receptors (including census blocks, alternate receptors 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.** The importance of the polar network is discussed further in Section 5.

3.2.5 Acute Options

As introduced in Section 1.2, you can use HEM4 to estimate *chronic* health risks and, optionally, *acute* (short-term) health risks as well. 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: the default is generally one year when running AERMOD, although periods other than one year can be chosen as discussed in Section 3.2.2 above regarding met station and period options. Acute health risks are based on short-term average exposures such as 1, 2, 3, 4, 6, 8, 12 and 24 hours.

You can choose to model acute health risks using columns M, N, O and P of the Facility List Options file. HEM4 uses what you input in these fields for each facility to direct AERMOD to model acute concentrations, and then HEM4 uses these acute concentration predictions by AERMOD to estimate acute health risks. Enter a Y (for “yes”) in column M “acute” to indicate you want HEM4/AERMOD to model short-term (acute) concentrations for that facility. (If you leave this field blank then by default HEM4 will not model acute impacts, regardless of what you put in columns N, O and P.) Next, in column N “hours”, enter the short-term (acute) averaging period that AERMOD will use for ambient concentrations, for each facility. The averaging period options are: 1, 2, 3, 4, 6, 8, 12 and 24 hours. (If you entered Y in column M and leave column N blank, then HEM4 will by default use an averaging period of 1 hour.)

In column O “multiplier”, enter the acute multiplier for each facility. This multiplier is applied to the average annual emission rate (in tons/year from your HAP Emissions input file, which the model converts to grams/second) and used to approximate the short-term emission rate. If you entered a Y in column M, but leave this field blank, then by default HEM4 will use a multiplier of 10 for that facility (e.g., the default of 10 times the average annual emission rate entered in the HAP Emissions file might be used to approximate short-term emission spikes). Regarding short-term spikes, it is important to note that AERMOD applies this short-term rate over the course of the entire met period chosen (in Section 3.2.2) and **the peak acute value will occur at the same time as the worst-case meteorological conditions**. Therefore, the acute results produced with an appropriate multiplier can be viewed as conservative estimates. Two-decimal precision is accommodated in the multiplier column O, but the multiplier entered must be greater than or equal to 1.00.

The peak acute value reported by HEM4 is also impacted by what you enter in column P “high value”. This field indicates which acute concentration to report as the high acute value in the outputs, for each facility. If you wish to use a value other than the maximum (e.g., the 98th or 99th percentile), then enter the associated value in this field. The number you enter must be an integer and is dependent on the number of hourly values in the modeled run. For example, if you want the 98th percentile acute value used from a dataset of 8,760 hourly values (in one year), then enter 175 in this text box, which is the truncated product of $0.02 \times 8,760$. Similarly, if you want to use the 99th percentile acute value, then enter 87 in the text box, which is the truncated product of $0.01 \times 8,760$. If instead you leave column P blank, then HEM4 will by default use the maximum modeled acute concentration as the “high value”.

3.2.6 Deposition and Depletion Options

Deposition and Depletion: Deposition and depletion are not modeled by default by HEM4. However, depending on the deposition and depletion options you choose in the Facility List Options file in columns Q through V, HEM4 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 sources by removing pollutants from the plume. Air concentrations will be depleted as pollutants are

deposited to the ground. Alternatively, you may choose to calculate the deposition flux, but not deplete the plume (to allow for non-depleted air concentrations that a standard run would produce). Deposition without plume depletion will not affect the air concentrations but will provide a deposition flux in the outputs. Whether you choose to deplete the plume or not, 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 2018e](#)).

Enter a Y (for “yes”) in column Q of your Facility List Options file if you would like AERMOD to model deposition and HEM4 to output a deposition flux column (in g/m²/y)² for all polar receptors and for the inner discretely modeled receptors. Enter a Y in column R if you would like AERMOD to model depletion (i.e., deplete the plume based on a calculated deposition flux). If you enter a Y in both columns Q and R, then HEM4 will output a deposition flux column AND deplete the plume. If you enter a Y in only column R (and leave column Q blank or enter an “N”), then no deposition flux will be provided, but the plume will be depleted (based on an internally calculated deposition flux). If you do not need the deposition flux output by the model, this option saves space.

HEM4 uses AERMOD to calculate deposition and depletion effects for particulate matter, vapor (gaseous) pollutants, or both. The make-up of your emissions – that is, the percentage particulate and gas – is dictated to HEM4 by your [HAP Emissions](#) input file. Specifically, column E in the HAP Emission input file (“Fraction emitted as particulate matter (%)\") indicates to HEM4 whether your emissions are 100% particle (if column E is populated with 100 for all pollutants), 100% gas (if column E is left blank or populated with 0 for all pollutants), or a mixture of particles and gas. However, for each facility, you can choose to model deposition and/or depletion for merely the particulate portion of your emissions (if you have a particulate portion), the vapor portion of your emissions (if you have a gas portion), or both (if you have both particle and gas, as indicated in column E of your HAP Emissions input file).

Particle and Vapor Deposition and Depletion Types (Wet and Dry; Wet Only; Dry Only; None): If you entered “Y” in column Q and/or R regarding modeling deposition and/or depletion, you must also indicate what type of deposition and/or depletion you wish HEM4 to direct AERMOD to model: wet and dry (WD), dry only (DO), wet only (WO), or none (No or leave blank). Use columns S, T, U and V of your Facility List Options file to indicate what kinds of deposition and/or depletion you want modeled for particulates and vapor (gas). In column S “pdep” you should indicate the type of deposition of particles you want modeled, if any. In column T “pdepl”, you should indicate the type of depletion of particles you want modeled, if any. Do likewise in columns U “vdep” and V “vdepl” for the types of deposition and depletion of your vapor pollutants, respectively. See the AERMOD User’s Guide ([EPA 2019a](#)) and AERMOD Implementation Guide ([EPA 2019b](#)) for a more detailed discussion of these processes.

You can mix and match the type of deposition and depletion you tell HEM4 to model. For example, you can direct HEM4 to model wet and dry (WD) deposition, and then deplete the plume based on those wet and dry (WD) deposition processes. Alternatively, you can choose wet and dry deposition (WD), but then only deplete the plume based on the wet deposition process (WO). In addition, the “none” option (No or blank) 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 in column S “pdep” what type of deposition to model for your particle emissions (WD, WO or DO) and then leave column U “vdep” blank or enter “No”. You

² If you specify a PERIOD average instead of an ANNUAL average, deposition results will be given in g/m².

may use these same options for depletion-only modeling. Table 2 below provides a partial list of some deposition/ depletion combinations and their modeling results.

Table 2. Sample Deposition and Depletion Options and Model Results

Entries in Columns Q - V of the Facility List Options File*						Model Results*
Q: dep	R: depl	S: pdep	T: pdepl	U: vdep	V: vdepl	
Y	Y	WD	WD	WD	WD	Deposition flux will be provided and the plume will be depleted, using wet and dry processes for both particles and vapor, for both deposition and depletion
Y		WO		DO		Deposition flux will be provided with no depletion of the plume, using wet-only processes for particles and dry-only processes for vapor
	Y		WD		WD	No deposition flux will be provided but the plume will be depleted using both wet and dry processes for particle and vapor
Y	Y	DO	WO			Deposition flux will be provided and the plume will be depleted, using dry only processes for particle-only deposition and wet-only processes for particle-only depletion
	Y				WO	No deposition flux will be provided but the plume will be depleted using wet-only processes for vapor only
Y		WD				Deposition flux will be provided with no depletion of the plume, using wet and dry processes for particle-only deposition
Y	Y	WD	WO	WD	DO	Deposition flux will be provided and the plume will be depleted, using wet and dry processes for particle and vapor deposition, but wet-only processes for particle depletion and dry-only processes for vapor depletion
<i>[The above is merely a partial list of some of the possible deposition/depletion combinations, for illustration purposes. Many more variations may be chosen that are not illustrated here.]</i>						

*Note: These Model Results will happen if your column entries are consistent with your emissions (e.g., you cannot model deposition and/or depletion of particulates if your emissions have no particulates in [column E](#) of your HAP Emissions file).

Concentration Outputs Broken Out into Particle and Vapor: Also, if your pollutants are a mixture of both particles and vapor and you would like the concentration outputs broken down by particle and vapor (instead of combined, as is the default in a standard run), you can also use the deposition/depletion fields in the Facility List Options file to do this. In other words, you can direct HEM4 merely to produce more detailed concentration outputs, showing the breakdown of particle and vapor concentration at each receptor location, without modeling either deposition or depletion. To do so, enter "Y" in column Q "dep" but leave all other deposition/depletion fields blank (indicating No or None). Neither deposition nor depletion will be modeled in this case.

However, the outputs will show distinct rows for particles ("P") and vapor ("V") at each location, rather than the standard combined ("C") row. Again, this is helpful only if your HAP Emissions file shows a mixture of particles and gas.

Additional Deposition/Depletion Input Files: Depending on the type of deposition and/or depletion you indicate in columns Q through V for each facility, and depending also on the method of particle deposition you indicate for each source at these facilities in your Emissions Location file (explained further in Section 3.4.2), HEM4 will prompt you to provide additional files. These files are introduced below and described in detail in Sections 3.5.3 and 3.5.4.

If you want to model deposition and/or depletion of particles in your emissions using Method 1 (described further in Section 3.4.2), HEM4 requires a [particle data file](#). This additional input file will need to contain particle size (diameter) information, mass fraction percentages for each size, and particle density for each size, for emissions from each source (for which you wish to model particle deposition and/or depletion using Method 1). The particle data file is described further in Section 3.5.3.

If you want to model dry deposition and/or depletion of gaseous/vapor pollutants, HEM4 requires a [land use input file](#) and a [month-to-seasons input file](#). These additional input files are needed to describe the land use and vegetation surrounding each facility at which you wish to model dry only (DO) or wet and dry (WD) deposition and/or depletion of gaseous pollutants, as discussed in Section 3.5.4. If you wish to model wet only (WO) deposition and/or depletion of gaseous pollutants, these additional input files are not needed by HEM4. (These files are also not needed for 100% particulate emissions.)

Finally, you should check to ensure that the gaseous pollutants in your HAP Emissions file are included in the Gas Parameter ([Gas Param](#)) reference file, described further in Section 3.5.4. 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 3.5.4. Otherwise, generic default gas parameter values will be used.

It should be noted that HEM4 requires additional modeling time compared to a standard run (with no deposition and/or depletion modeling). Furthermore, HEM4 requires *significantly* more time to run if you opt to model deposition and/or depletion and you are also modeling acute impacts. 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, or more, per facility.

Deposition and plume depletion have more of an effect on ambient concentrations farther from the facility than these processes do 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 HEM4 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.

It should also be noted that HEM4 does not model deposition and/or depletion at census block and alternate receptors beyond the [modeling distance](#), except at the polar receptors. This means that deposition and/or depletion is modeled at only the "inner receptors" (discussed in Section 6.1.10) and the polar receptors. If you need deposition and/or depletion modeled for the entire modeling domain at all census block or alternate receptors, you should set the modeling distance equal to the [maximum distance](#). HEM4 will require additional modeling time in this

scenario, compared to using a smaller modeling distance. As noted above, you may save modeling time by performing two separate runs, especially if you are also modeling acute impacts.

3.2.7 Elevation Option

HEM4 includes terrain elevations by default in your modeling run if you leave column W “elev” blank or enter a “Y” in this field in your Facility List Options file. To exclude terrain elevations in your modeling run (i.e., to model as flat terrain), enter an “N” in this field for a given facility.

Elevated terrain around the facility can cause local impacts to increase, though impacts will differ for each set of sources and elevations. It is especially important to include terrain elevations 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. If you choose to include elevations in the model run, you can specify elevations for each source in the [Emissions Location file](#). If you do not provide elevations in the Emissions Location file, HEM4 will calculate source elevations from neighboring census block elevations. Note: You should provide elevations for every source or for no sources at each facility, as noted in Section 3.4 regarding the Emissions Location file.

3.2.8 User Receptors Option

If you would like to include additional “user receptors” in your model run for one or more facilities – in addition to the census block or alternate receptors, enter a “Y” in column X “user_rcpt” of your Facility List Options file. HEM4 does not include user receptors by default, so if this column is blank then user receptors will not be included for that facility. If you are modeling impacts at user receptor locations, HEM4 will prompt you for a separate input file containing the user receptor information, for each facility marked with a “Y”. The user receptor input file is described in Section 3.5.6.

3.2.9 Building Downwash Option

If you would like to model building downwash over a building, which is under or near a point source, then enter “Y” in column Y “bldg_dw” of your Facility List Options file. HEM4 does not model building downwash by default and you should simply leave this field blank if you do not wish to model it as part of the plume dispersion. If you are modeling building downwash, HEM4 will prompt you for a separate input file that must contain building dimension information, for applicable point sources in each facility marked with a “Y” in this column. Note that building downwash may only be modeled with vertical point (P), capped point (C), and horizontal point (H) source types. The building dimension input file is described in more detail in Section 3.5.5.

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 2019d](#)). A building may impact emissions from multiple sources. To model the impact of building downwash, HEM4 requires information on the configuration of the building when viewed from different wind directions, and this information is contained in the building dimensions input file, described further in Section 3.5.5.

3.2.10 FASTALL Option

To conserve model run time by simplifying the dispersion algorithms used to model a given facility's emissions, enter a "Y" in column Z "fastall" of your Facility List Options file. HEM4 does not employ FASTALL by default, so if you leave this field blank AERMOD will use the more rigorous (non-simplified) dispersion algorithms.

The FASTALL 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 2019a](#)). For faster runs, you may want to select the FASTALL option which includes these plume and source simplifications. (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>.)

Note that if a facility listed in your Facility List Options file includes buoyant line sources in your accompanying Emissions Location file, you cannot use the FASTALL option for that facility. You may, however, use FASTALL for the other facilities in your Facility List Options file.

3.2.11 Emissions Variation Option

Enter a "Y" in column AA "emiss_var" of your Facility List Options to apply variations to the emissions from one or more sources at a given facility. You may vary emissions by different user-supplied time scales (e.g., by season, month, day of week, hour of day), or by different wind speeds (6 ranges). Note: HEM4 will prompt you for an emissions variation file if you entered "Y" for one or more facilities, and that file must contain variation factors for at least one source at each facility marked with a "Y". The emission variation input files are described in more detail in Section 3.5.7.

Finally, it should be noted that these emission variation factors will compound the effects of the [acute multiplier](#) (specified in column O "multiplier") on the short-term/acute emission rates used by AERMOD. For example, whatever factors you supply in an emission variations input file (described in Section 3.5.7) 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 emission

variation factors, you may want to set the acute multiplier to 1, unless it is reasonable to assume that the short-term rate may still exceed the hour-of-day factors by an additional multiple.

3.3 HAP Emissions File

The HAP Emissions Excel™ file, like the [Facility List Options file](#), is required for any HEM4 modeling run. This file includes emissions in tons per year (tpy) for each HAP emitted from modeled sources, for all facilities listed in the Facility List Options 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 HEM4 Inputs folder named *HEM4_HAP_Emiss.xlsx*. The pollutants emitted per source at each facility are required in every HAP Emissions file and are discussed in Section 3.3.1. The percent particulate emitted from each source is generally only required if you are modeling deposition or depletion (see Section 3.2.6) and is discussed in Section 3.3.2.

Table 3. Format Guidelines for the HAP Emissions Input File (Required)

Field	Type	Description
Facility ID	Character	An alphanumeric string identifying the facility being modeled
Source ID	Character	An alphanumeric character string up to 8 characters long . It must contain at least one alphabetic character and all Source IDs must match a Source ID used in the Emissions Location file . Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.
Pollutant	Character	The pollutant name must correspond to one of the chemical names listed in the dose response library . (see <i>Dose_Response_Library.xlsx</i> in the resources folder)
Emission Amount	Numeric	The emitted amount of the pollutant in tons per year (tpy).
Percent Particulate	Numeric	The percent of pollutant emitted as particulate. Required if deposition and/or depletion will be modeled, or if a breakdown by particulate and vapor 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 HEM4.

Table 4. Sample HAP Emissions Input File

Facility ID	Source ID	Pollutant	Emissions (tons/year)	Fraction Emitted as Particulate Matter (%)
Fac2-IL	CT0001	Antimony compounds	1.2E-01	100.0
Fac2-IL	CT0001	Chromium (VI) compounds	3.2E-04	100.0
Fac2-IL	CT0001	Mercury (elemental)	4.2E-02	50.0
Fac2-IL	CV0001	Dibenzofuran	1.1E-01	90.0
Fac2-IL	CV0001	Xylenes (mixed)	1.3E+00	0.0
Fac1-NC	SR0001	Benz(a)anthracene	7.3E-06	11.9
Fac1-NC	SR0001	Benzo(a)pyrene	2.5E-08	23.9
Fac1-NC	SR0001	Benzo(b)fluoranthene	2.8E-06	17.8
Fac1-NC	MS0001	Chrysene	3.2E-05	52.3
Fac1-NC	MS0001	Dibenz(a,h)anthracene	3.6E-08	99.3
Fac1-NC	MS0001	Indeno(1,2,3-cd)pyrene	1.1E-07	98.9
Fac1-NC	RW0001	Chromium (VI) compounds	3.8E-05	100.0
Fac1-NC	RW0001	Mercury (elemental)	3.6E-04	50.0
Fac1-NC	RV0001	Nickel compounds	4.8E-03	100.0
Fac1-NC	RV0001	Selenium compounds	2.1E-04	100.0

3.3.1 Pollutant Emissions per Source

You should include one record (row) for each combination of facility (Facility ID), emission source (Source ID) and chemical (Pollutant) in your HAP Emissions file. The Source ID is a key parameter in the HAP Emissions file, because HEM4 uses the Source ID to link the emitted HAP at that source to other input files, such as the [Emissions Location](#) input file (discussed in Section 3.4) and other optional input files (discussed in Section 3.5). The Source ID should provide each source a distinct name, and different sources should have unique Source IDs even if they will be modeled at the same location. **AERMOD requires that the Source ID be restricted to eight (8) characters (or fewer)** and it must consist of all alphanumeric characters. Do not use spaces at the beginning or in the middle of the Source ID. In addition, AERMOD converts all letters in the Source ID string to upper case. Therefore, **upper and lowercase characters cannot be discriminated between**; so "ABC" and "abc" would be treated as the same Source ID. While each source should have a unique Source ID, it is advantageous to group certain types of sources within part of the Source ID. For example, "ST" could be used in the Source ID to indicate a storage tank and each distinct storage tank could be given a number (e.g., ST01, ST02). Such grouping is important for certain summary programs, as discussed in [Section 4.5](#).

Each chemical you name in the HAP Emissions file (under "Pollutant" in the sample shown in Table 4) must match one of the chemical names listed in the dose response table located in the HEM4 resources folder. The dose response values are part of HEM4's [Chemical Health Effects Library](#), described in Section 2.2. If necessary, you can add pollutants to the two Excel™ spreadsheets comprising HEM4's Chemical Health Effects Library: the dose response table and

the target organ endpoints table. [Section 3.5.10](#) explains how to make changes to the Chemical Health Effects Library. Finally, **emission amounts for each HAP emitted from each Source ID must be expressed in tons/year. Be sure your input files use the correct units.**

3.3.2 Percent Particulate for Deposition and Depletion

If you are modeling deposition or depletion, or if you want separate records for particle phase and vapor phase at each receptor location in the concentration outputs, then you must provide HEM4 with the breakdown between vapor and particulate matter in the emission inputs. Provide this breakdown in column E of the HAP Emissions file, expressed as the fraction emitted as particulate for each emission record (each combination of source and pollutant). For a given facility, if you are not modeling deposition or depletion, then HEM4 will ignore the field. If you are modeling deposition or depletion and have left this field blank, then HEM4 assigns the blank a default value of 0% particulate. Note that if you are modeling deposition or depletion, you will need additional input files depending on the type of deposition to be modeled, as described in Section 3.2.6 and Sections 3.5.3 and 3.5.4. (Note: You do not need any additional input files if you merely want a breakdown of particle and vapor in your outputs.)

3.4 Emissions Location File

The Emissions Location Excel™ file, like the HAP Emissions file and the Facility List Options file, is required for any HEM4 run. The file includes emission source locations and types (e.g., the latitude and longitude of a stack) for all Source IDs listed in the [HAP Emissions file](#), for all facilities listed in the [Facility List Options file](#). Tables 5 and 6 display the [format guidelines](#) for the fields in the Emissions Location file and a [sample](#) file, respectively. A template input file is provided in the HEM4 Inputs folder named *HEM4_Emiss_Loc.xlsx*. For each Source ID at every facility, the Emissions Location file includes the location, source type and required parameters, as discussed in Section 3.4.1. Additionally, the Emissions Location file includes the particle deposition method you will identify, for any sources for which you wish to model particle deposition or depletion, as discussed in Section 3.4.2.

Table 5. Fields in the Emissions Location Input File (Required)

Field	Type	Source type(s)*	Description
Facility ID	Character	all	An alphanumeric string identifying the facility being modeled
Source ID**	Character	all	Source ID is a unique alphanumeric character string up to 8 characters long , with no spaces. It must match exactly the Source ID in other input files (e.g., the HAP Emissions file). Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.

Field	Type	Source type(s)*	Description
Coordinate system	Character	all	Type of coordinates: L = latitude, longitude; U = UTM. Base all coordinates on the WGS84 geographic system. Note: NAD83 and WGS84 are identical for most applications, but coordinates based on NAD27 need to be converted to WGS84 before being used in HEM4.
X-coordinate	Numeric	all	UTM east coordinate, in meters (if coordinate system = U) or decimal longitude (if system = L) of the center of point or volume sources, the southwest corner of area sources, 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	all	UTM north coordinate, in meters (if coordinate system = U) or decimal latitude (if system = L) of the center of point or volume sources, the southwest corner of area sources, 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	Character	all	UTM zone where the source is located if the coordinate system = U; leave this field blank if the coordinate system = L. If using the UTM coordinate system, enter the UTM Zone from 1 to 60 followed by the hemisphere (S or N). For example, 17N. If you do not include a hemisphere, HEM4/AERMOD will default to N.
Source type	Character	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	A, N	Length in meters in x-dimension direction for area and line sources. For area source types, the x direction refers to the direction before the source is rotated (if it is rotated). For line source types, enter the width (m), which must be >= 1 meter.
Length - y	Numeric	A	Length in meters in y-dimension direction for area sources. This is the length in the y direction before the source is rotated (if it is rotated).
Angle	Numeric	A	Angle of rotation: blank except for area sources. For area source types, enter the angle of rotation (from North) between 0 and 90 degrees. (HEM4 defaults to 0 if left blank).
Lateral	Numeric	V	Initial lateral/horizontal dimension (in meters) for volume sources.
Vertical	Numeric	V, A, I, N	Initial vertical dimension (in meters) for volume sources. Optional for area, polygon & line sources.

Field	Type	Source type(s)*	Description
Release height	Numeric	V, A, I, N, B	Height of release (in meters) for area, volume, polygon, line and buoyant line sources. Use the height (top) of the source for area and polygon sources and the vertical center for volume sources. Note: that for buoyant line sources, AERMOD requires a minimum release height of 2 meters.
Stack height	Numeric	P, C, H	Release height above ground (in meters) for all point source types.
Diameter	Numeric	P, C, H	Diameter of stack (in meters) for all point source types.
Velocity	Numeric	P, C, H	Velocity at which emissions are released from the stack (in meters/second) for all point source types.
Temperature	Numeric	P, C, H	Temperature (in Kelvin) at which emissions exit the stack for all point source types.
Elevation	Numeric	all	Elevation above sea level in meters at the source location. Use when modeling terrain effects and user-specified elevations are desired. This field is optional; HEM4 will calculate if <u>all</u> 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	N, B	Second X (end) 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	N, B	Second Y (end) 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.
Method	Numeric	Any but B	The Method field indicates the type of particle deposition AERMOD should use. Enter 1 or leave blank for Method 1 (which is the default); enter 2 for Method 2. Use Method 1 when greater than 10 percent of the total particulate mass has a diameter of 10 μm or larger, or when the particle size distribution is known. For Method 1, these source-specific particle size distributions must be provided in a separate particle data file (described in Section 3.5.3). Method 2 may be used when the particle size distribution is not well-known and when a small fraction (less than 10 percent of the mass) is in particles with a diameter of 10 μm or larger. The

Field	Type	Source type(s)*	Description
			particle data required for Method 2 is less specific than Method 1 but requires that you enter the mass fraction of fine particles and the mass-mean particle diameter for the given source in the next two fields.
Mass Fraction	Numeric	All, except B	The Mass Fraction field refers to the fraction of the particle mass emitted from this source in the fine particle category (less than 2.5 microns). Leave this field blank if you are using Method 1. For Method 2, you should enter a number between 0 and 1 that is the fraction of particles emitted in the fine category (a blank will be interpreted as a 1, the default, meaning that all are emitted as fine particles). For example, if one-half of the emissions from this source are fine particles (< 2.5 microns), enter a mass fraction in this field of 0.50.
Particle Diameter	Numeric	All, except B	The Particle Diameter field is the representative mass-mean aerodynamic particle diameter in microns emitted from this source when using Method 2 for particle deposition (a blank is interpreted as 1 micron, the default). Leave this field blank for Method 1. For Method 2, enter the mass-mean particle diameter in microns.

Table Notes:

* Source types for which the parameter is used: all = needed for every source type, A = area, P = vertical point, C = capped point, H = horizontal point, V = volume, I (capital "I") = polygon, N = line, B = Buoyant line. Note that currently AERMOD cannot model deposition/depletion for buoyant lines (B), nor can the FASTALL option be used with buoyant lines. For additional information on these source types, including what additional fields are needed, see the AERMOD User's Guide at https://www3.epa.gov/ttn/scram/models/aermod/aermod_userguide.pdf

** If you are modeling deposition or depletion and pollutant properties are known to vary, use a separate record for each pollutant and source. Thus, if you are modeling vapor 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 by pollutant, not just source. If you are not modeling vapor 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 generally should be entered in order from West to East, and from South to North. However, in the case where the buoyant lines are parallel to the Y axis, the order that the lines should be entered is dependent on which endpoint is entered first, the southern or northern endpoint of the lines. If the southern endpoint is entered first, the lines should be entered in the order of the eastern most line to the western most line. If the northern endpoint is entered first, lines should be ordered west to east. Incorrect ordering of these parameters will result in an AERMOD error stating "Input buoyant line sources not in correct order"

Table 6. Sample Emissions Location Input File

Facility ID	Source Locations & Types						Dimensions & Release Height (non-point sources)						continued
	Source ID	Coordinate system (U = UTM, L= latitude/ longitude) (All source types)	X-coordinate Longitude (decimal) or UTM East (m) (All source types)	Y-coordinate Latitude (decimal) or UTM North (m) (All source types)	UTM zone	Source type (P, C, H = point, A = area V= volume I = polygon N = line B = buoyant line)	Length in x- direction (m) A & N sources (width for N sources)	Length in y- direction (m) A sources	Angle (degrees) A sources	Lateral Dim. (m) V sources	Vertical Dim. (m) V sources or optionally A, I and N sources	Release height (m) A, V, I, N and B sources	
Fac2-IL	CT0001	L	-88.257293	41.480164		P [or C or H]							...
Fac2-IL	CV0001	L	-88.256715	41.481944		A	130	120	45			2	...
Fac1-NC	SR0001	L	-78.883686	35.900628		V				20	3	10	...
Fac1-NC	MS0001	L	-78.888792	35.905920		I						5	...
Fac1-NC	RW0001	L	-78.888430	35.901810		N	20					50	...
Fac1-NC	RV0001	U	690891	3975044	17	B						40	...

...continued from above (Source type indicated for reference)	Point Source Parameters					Buoyant & Line Endpoints			Particle Deposition Method		
	Stack height (m) P, C, or H sources	Stack Diameter (m) P, C, or H sources	Exit Velocity (m/s) P, C, or H sources	Exit Temperature (K) P, C, or H sources	Elevation (m) HEM4 will calculate if blank for every source	X-coord.2 Longitude (decimal) or UTM East (m) B & N sources	Y-coord.2 Latitude (decimal) or UTM North (m) B & N sources	Method (1 or 2; defaults to 1) All sources, except B	Mass Fraction (decimal > 0 and < 1 for Method 2 only) All sources, except B	Particle Diameter (microns, for Method 2 only) All sources, except B	
...(P, C or H)	50	2.8	21.83	322				2	0.04	0.0006	
...(A)											
...(V)											
...(I)											
...(N)						-78.886303	35.902183				
...(B)						691291	3975044				

3.4.1 Source Types and Parameter Requirements

Generally, the Emissions Location file should include one record for each individual source (e.g., stack/point source, area source, line source, buoyant line source) to be modeled, at each facility. For certain modeling situations, more than one record per source is recommended.³ This record provides information on the location, size, height, and configuration for each source. You must enter every Facility ID to be modeled in column A of the Emissions Location file. Enter each Source ID in column B, taking care to match each named Source ID with a corresponding Source ID in the HAP Emissions file, described in Section 3.3.

Source Locations: In column C “Coordinate system”, you can enter source locations as UTM coordinates, or as latitude and longitude (which HEM4 will convert to UTM coordinates for use in AERMOD). 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). Enter the location coordinates for each source in column D “X coordinate, Longitude (decimal) or UTM East (m)” and in column E “Y coordinate, Latitude (decimal) or UTM North (m)”. (The endpoints for line and buoyant line source types, discussed further below, will be entered in columns S and T.) If you are using longitudes and latitudes, 5-decimal places are recommended which corresponds to an accuracy of roughly 1 meter. See Table 5 above for further specifications for these fields. You must base all coordinates on the WGS84 geographic system. As noted in [Section 3.1](#), NAD83 and WGS84 are identical for most applications, so no conversion is needed if using coordinates based on NAD83. However, if coordinates are based on NAD27, they would need to be converted to WGS84 before being used in HEM4. There are various commercial computer programs available that can perform this conversion.

Source Types: Use the source type field in column G 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)⁴. For additional information on these source types, including assumptions used by AERMOD to model their emissions as well as the additional parameters needed for each, you should consult the AERMOD User’s Guide at https://www3.epa.gov/ttn/scram/models/aermod/aermod_userguide.pdf.

Point Sources - Vertical stack, Horizontal stack, and Capped stack: Point source types include vertical stacks (P), horizontal stacks (H) and capped stacks (C) source types. These point sources require you to specify the stack height (in meters in column N), the stack diameter (in meters in column O), the exit velocity (in meters/second in column P), and the exit/release temperature (in Kelvin in column Q) for the pollutant plume. Although capped and horizontal

³ If modeling deposition or depletion (described in Section 3.2.6) at a facility, and pollutant properties are known to vary, we recommend you include a separate Source ID 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 vapor deposition/depletion and for modeling of particulate deposition/depletion if the size or density distributions are known for each pollutant (HAP) and vary for each pollutant. If you are not modeling deposition/depletion of vapor phase pollutants, and the same particulate properties are assumed for all pollutants being emitted from a given source, one record per source in the emissions location input file is sufficient.

⁴ Note that the current AERMOD version 19191 cannot model deposition or depletion for buoyant lines (B), nor can the FASTALL option in the Facility List Options file be used with buoyant lines.

stacks (C and H, respectively) require the same user-specified parameters as vertical stacks (P), AERMOD models these point sources differently than vertical stacks ([EPA 2019a](#), [EPA 2019b](#)).

Non-Point Sources: Columns H through N in the Emissions Location file pertain to area (A) sources, volume (V) sources, polygon (I for capital “i”) sources, line (N) sources, and buoyant line (B) sources. Table 5 above provides guidance on what you should provide in each of these fields. Fugitive 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 U.S. Census tract from which a source is modeled as a uniform emission (e.g., for mobile sources). Polygon source types require a Polygon Vertex file as an additional input, as discussed in [Section 3.5.1](#). 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 source types (P, C, or H), 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 point sources (P, C or H), are released at elevated (non-ambient) temperature and with a non-zero release velocity. However, unlike tall stack 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 3.5.2](#). These non-point source types are discussed in more detail below.

Area Sources: 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 (in column M) 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 (in column J), which specifies the rotation of the source from north (in the clockwise direction), to better fit the orientation of the source you are modeling. The X and Y coordinates you choose (in columns D and E) should reflect the southwest corner of the area source. The length in the X direction you enter (in column H) should reflect the length of the area source in the easterly direction, or in the southeasterly direction if the source is rotated. The length in the Y direction you enter (in column I) should reflect the length of the area source 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 HEM4 area sources must be between 0 and 90 degrees. You can use this angle to represent any possible orientation by switching the X and Y lengths (shown in [Figure 3](#)). You can also optionally enter an initial vertical dimension of the area source (in column L).

Volume Sources: Volume source (V) types – such as multiple vents and conveyor belts – are specified by a lateral /horizontal dimension (you enter in column K), a vertical dimension (you enter in column L), and a release height (you enter in column M). Emissions from a volume source are assumed to be released at ambient temperature and with zero or negligible velocity. Both the release height (in column M) and the source location coordinates (in columns D and E) should reflect the center of the source.

Polygon Sources: You can create a polygon source (I, for capital “i”) type to represent a polygon with 3 sides or many more (up to 20 sides). This source type provides considerable flexibility in specifying the shape of an area source. You can use a polygon source type to reflect U.S. 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 3.5.1](#) 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 (in columns D and E) as the location of the first vertex of the polygon. You can also optionally enter an initial vertical dimension of the polygon (in column L). Emissions from polygon source types are assumed to be released at ambient temperature and zero or negligible velocity.

Line Sources: The line source (N) type allows you to specify long, narrow sources, such as roadways or airport runways. You must enter a start-point (in columns D and E) and end-point of the line (in columns S and T), as well as the width of the line (a value equal to or greater than 1 meter that you enter in column H). Optionally, you can also specify an initial vertical dimension (in column L). In this way, the line source can be used as an alternative to a rectangular area source (A). [Note: According to the AERMOD User’s Guide ([EPA 2019a](#), p.3-100) 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.

Buoyant Line Sources: Like the line source, for the buoyant line source (B), you must enter the starting coordinates (in columns D and E) and the end coordinates (in columns S and T).⁵ 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 meters⁴/seconds³) as well as the average building dimensions (in meters) of the building(s) on which the buoyant line source is located. You must provide HEM4 with these inputs for your buoyant line source type in a Buoyant Line Parameters Input file, as discussed in [Section 3.5.2](#). It should be noted that AERMOD 19191 requires a minimum release height (in your Emissions Location file) of 2 meters and a minimum wind speed (determined from your met station data) of 1 meter-per-second for buoyant line sources. (If you enter a release height less than 2 meters, AERMOD will change it to 2 meters.) Also, as noted previously, AERMOD 19191 cannot model deposition or depletion for buoyant lines, nor can the FASTALL option in the Facility List Options file be used with buoyant lines. For more detailed information regarding the necessary inputs for the buoyant line source type, see the AERMOD

⁵ You may wish to use a series of buoyant lines to represent multiple roof vent lines. AERMOD requires a strict ordering of these lines in order to run properly. The start/end coordinates for buoyant line sources generally should be entered in order from West to East, and from South to North. However, in the case where the buoyant lines are parallel to the Y axis, the order that the lines should be entered is dependent on which endpoint is entered first, the southern or northern endpoint of the lines. If the southern endpoint is entered first, the lines should be entered in the order of the eastern most line to the western most line. If the northern endpoint is entered first, lines should be ordered west to east.

User's Guide ([EPA 2019a](#)), as well as documentation for the buoyant line and point source (BLP) dispersion model ([ERT 1980](#)).

Elevation: If you wish to consider terrain impacts in your modeling, you can specify the elevation above sea level in meters for each emission source. Enter elevations (in column R) for every source or for no sources; do not enter a partial list, because in that case blanks/non-entries will be interpreted by the model as a zero (0) elevation if a value is entered for one or more other sources. If you leave the elevation field blank for all sources, and if you chose to [model elevations](#) in the Facility List Options file, then HEM4 will estimate an elevation for the emission sources based on the elevations of nearby U.S. Census blocks or alternate receptors. Note that if you chose to not [model elevations](#) in your Facility List Options file, then no elevations will be considered in the model run including for sources in the Emissions Location file.

It should be noted that HEM4 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 opt to model with [no elevations](#) in the Facility List Options file, or break-up the source into smaller pieces with uniform elevations.

It should also be noted that “release height” (in column M) 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 reported in the preceding paragraphs discussing the elevation field). For point sources, fill in the “stack height” field (in column N) to designate the release height (for vertical stack, horizontal stack and capped stack source types). For all other source types (area, volume, polygon, line and buoyant line), you should fill in the “release height” (in column M) with the source’s height above the ground (in meters). If you leave this field blank, HEM4 will assume the release height is zero (0), meaning at ground level.

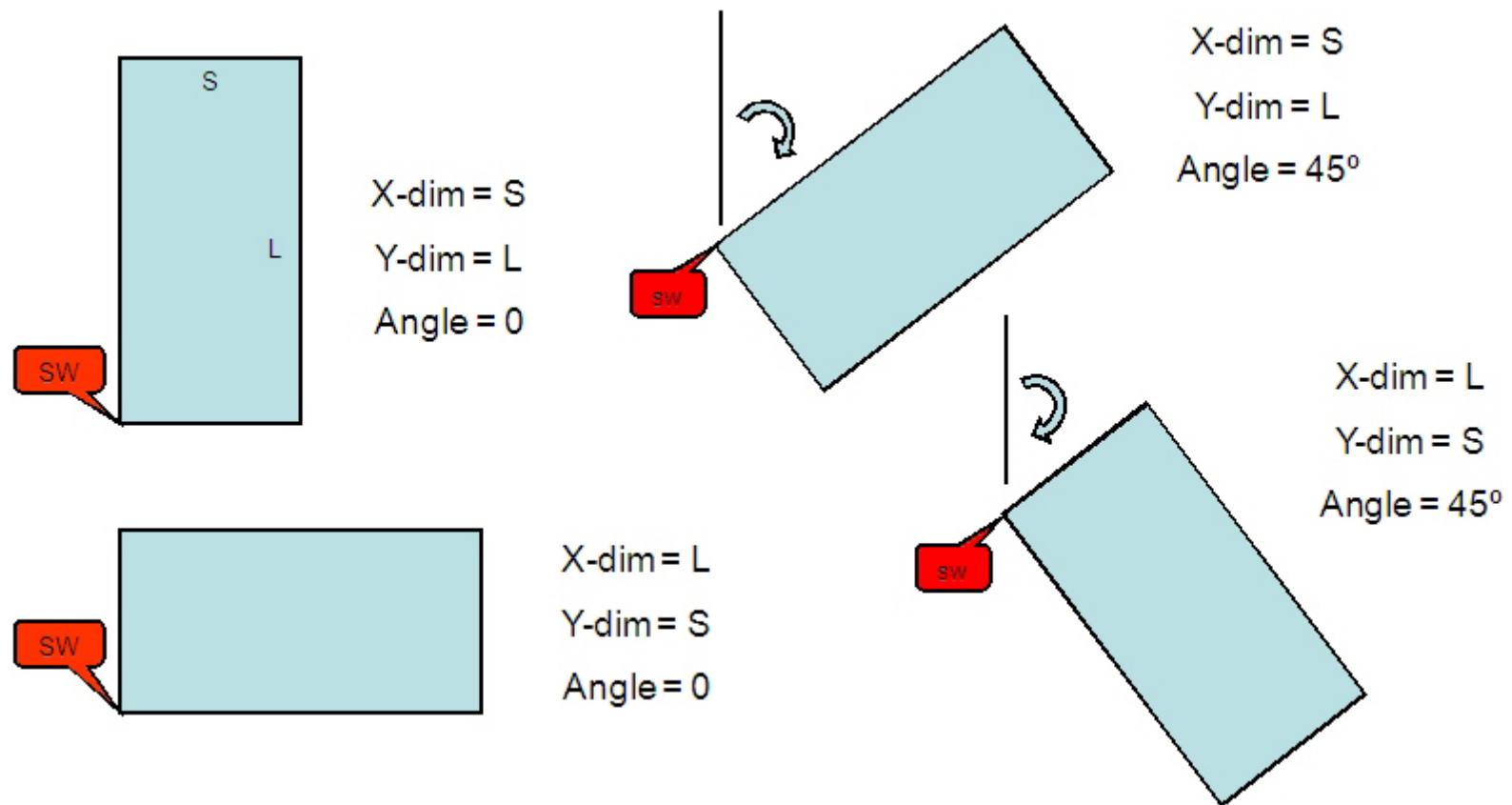


Figure 3. Example Orientations of Area Emission Sources for the HEM4 Model

3.4.2 Particle Deposition Method

Columns U (Method), V (Massfrac), and W (Partdiam) of the Emissions Location file should only be filled in if you wish to model particle deposition or depletion using Method 2. If you do not wish to model particle deposition/depletion or if you wish to use AERMOD's Method 1 to model particle deposition/ depletion, then leave these fields blank for those sources.

Particle Deposition/Depletion Method: The Method field (in column U) indicates to HEM4 the type of particle deposition AERMOD should use. As noted above, you should enter 1 or leave this field blank for Method 1 (which is the default). Method 1 should be used when a significant fraction (greater than about 10 percent) of the total particulate mass has a diameter of 10 μm or larger, or when the particle size distribution is known. The particle size distribution must be known reasonably well in order to use Method 1 and these source-specific particle size distributions must be provided in a separate Particle Data file, as discussed in [Section 3.5.3](#). You should also leave this field (column U) blank if you are not modeling particle deposition/ depletion at all. Enter 2 in this field if you wish to model particle deposition or depletion for the given source using AERMOD's Method 2. Method 2 may be used when the particle size distribution is not well known and when a small fraction (less than 10 percent of the mass) is in particles with a diameter of 10 μm or larger. The particle data required for Method 2 is less detailed than Method 1 but does require that you enter the mass fraction of fine particles and the mass-mean particle diameter for the given source in the next two fields.

Mass Fraction for Method 2: The Mass Fraction field (in column V) refers to the fraction of the particle mass emitted from this source in the fine particle category (less than 2.5 microns). Leave this field blank if you are using Method 1, or if you are not modeling particle deposition/ depletion at all. For Method 2, you should enter a number between 0 and 1 that is the fraction of particles emitted in the fine category (a blank will be interpreted by the model as a 1, the default, meaning that all are emitted as fine particles). For example, if one-half of the emissions from this source are fine particles (< 2.5 microns), enter a mass fraction in this field of 0.50.

Particle Diameter for Method 2: The Particle Diameter field (in column W) is the representative mass-mean aerodynamic particle diameter in microns emitted from this source when using Method 2 for particle deposition (a blank is interpreted by the model as 1 micron, the default). Leave this field blank for Method 1, or if you are not modeling particle deposition/depletion at all. For Method 2, enter the mass-mean particle diameter in microns.

3.5 Additional Input Files

In addition to the three required input files (Facility List Option, HAP Emissions, and Emissions Location) discussed in Sections 3.2, 3.3 and 3.4, other files may be required for your modeling run depending on (a) what modeling options you chose in the Facility List Options file, (b) what source types you are modeling in your Emissions Location file, (c) what kinds of receptors you are modeling with, and/or (d) what changes you may wish to make to HEM4's underlying databases and resource files. These additional input files are discussed in the next sections.

3.5.1 Polygon Vertex Input File for Modeling Polygon Emission Sources

If your Emissions Location input file contains one or more polygons (source type "I"), then HEM4 will prompt you for a Polygon Vertex file. This file provides HEM4 with the locations of the polygon vertices. Polygons are useful for complex source configurations at a facility, and for modeling U.S. Census tracts as sources (e.g., for mobile source emissions modeled uniformly across a tract).

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 ≤ 20). Each record must include information for one vertex of the polygon. As noted in [Section 3.4.1](#), 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 your [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 as longitudes and latitudes. If using UTM coordinates, you must specify the UTM zone. Base all coordinates on the WGS84 reference system.

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 U.S. Census tract. In this case, you may wish to use the U.S. Census tract ID as the polygon ID and enter it in the last column of the Polygon Vertex file.

Tables 7 and 8 give the format guidelines for the Polygon Vertex file, and a sample Polygon Vertex file, respectively. A template input file is provided in the HEM4 Inputs folder named *HEM4_polygon_vertex.xlsx*.

Table 7. Format Guidelines for the Polygon Vertex File

Field	Type	Description
Facility ID	Character	An alphanumeric character identifying the facility being modeled
Source ID	Character	An alphanumeric character string up to 8 characters long, with no spaces. The Source ID must be listed as polygon (Type = I) source types in the Emissions Location file . Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.
Coordinate system	Character	Type coordinates: L = longitude, latitude; U = UTM [WGS84].
X-coordinate	Numeric	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	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.

Field	Type	Description
UTM zone	Numeric	If using the UTM coordinate system (U), enter the UTM Zone from 1 to 60 followed by the hemisphere (S or N). For example, 17N (default hemisphere is N if not specified). If using longitudes/latitudes, leave this cell blank.
Num of Vertices	Numeric	Number of vertices in the polygon. This number must be 3 or greater. The upper limit is 20.
Area	Numeric	Size of area within polygon, in meters squared.
Polygon ID	Character	Optional ID to indicate the name of the polygon (e.g., a U.S. Census tract is sometimes modeled as a polygon and the polygon ID may be the U.S. Census tract ID).

Table 8. Sample Polygon Vertex File

Facility ID	Source ID	Coordinate system (U = UTM, L = latitude, longitude)	Longitude (decimal) or UTM East (m)	Latitude (decimal) or UTM North (m)	UTM zone	Num of Vertices (≥ 3 and ≤ 20)	Area (m ²)	Polygon ID (optional)
Fac1-TX	SAMPLE4	L	-95.3586	29.7674		9	402939.4	
Fac1-TX	SAMPLE4	L	-95.3524	29.7685			0	
Fac1-TX	SAMPLE4	L	-95.3515	29.7663			0	
Fac1-TX	SAMPLE4	L	-95.3533	29.7654			0	
Fac1-TX	SAMPLE4	L	-95.3533	29.7622			0	
Fac1-TX	SAMPLE4	L	-95.3574	29.7634			0	
Fac1-TX	SAMPLE4	L	-95.3582	29.7651			0	
Fac1-TX	SAMPLE4	L	-95.3575	29.7661			0	
Fac1-TX	SAMPLE4	L	-95.3586	29.7674			0	
Fac1-TX	SAMPLE5	L	-95.3512	29.7688		11	710176.8	
Fac1-TX	SAMPLE5	L	-95.3524	29.7685			0	
Fac1-TX	SAMPLE5	L	-95.3515	29.7663			0	
Fac1-TX	SAMPLE5	L	-95.3509	29.7653			0	
Fac1-TX	SAMPLE5	L	-95.3533	29.7654			0	
Fac1-TX	SAMPLE5	L	-95.3533	29.7622			0	
Fac1-TX	SAMPLE5	L	-95.3574	29.7634			0	
Fac1-TX	SAMPLE5	L	-95.3582	29.7651			0	
Fac1-TX	SAMPLE5	L	-95.3575	29.7661			0	
Fac1-TX	SAMPLE5	L	-95.3586	29.7674			0	
Fac1-TX	SAMPLE5	L	-95.3512	29.7688			0	

3.5.2 Buoyant Line Parameter Input File for Modeling Buoyant Line Sources

If your Emissions Location input file contains one or more buoyant line sources (source type "B"), then HEM4 will prompt you for a Buoyant Line Parameter file. 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 [Section 3.4.1](#). Because building downwash effects are especially important with buoyant line source types, the Buoyant Line Parameter file must provide HEM4 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).

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 (K), the ambient temperature (K) 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](#)).⁶ **These parameters should be average values for the array of buoyant line sources, if multiple parallel buoyant line sources are present ([EPA 2019a](#)).** 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, of the individual lines (in meters);
- Average Building Separation, between the individual lines (in meters); and
- Average Buoyancy Parameter (in meters⁴/seconds³)

Note: The current AERMOD version 19191 allows modeling only a single buoyant line source (comprised of one or multiple lines) per modeling run, so HEM4 allows a single buoyant line source per facility. Multiple model runs are recommended to adequately model the emissions from multiple non-parallel buoyant line sources at a given facility. (See the AERMOD User's Guide page 3-85 for further information; [EPA 2019a](#).)

Tables 9 and 10 provide the format guidelines for the Buoyant Line Parameter input file and a sample input file, respectively. A template input file is provided in the HEM4 Inputs folder named *HEM4_buoyant_line_param.xlsx*. See also the resources shown in footnote 6 below for helpful guidance in setting up a buoyant line source.

⁶ 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.

Table 9. Format Guidelines for the Buoyant Line Parameter Input File

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
Average Building Length	Numeric	The average length of the building or buildings on which the parallel buoyant line source types are located (in meters)
Average Building Height	Numeric	The average height of the building or buildings on which the parallel buoyant line source types are located (in meters)
Average Building Width	Numeric	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	The average width of the individual buoyant line source types (in meters)
Average Building Separation Distance	Numeric	The average building separation distance between the (parallel) individual buoyant lines (in meters)
Average Buoyancy Parameter	Numeric	The average buoyancy parameter for the buoyant line emission plumes (in meters ⁴ /seconds ³); See BLP Dispersion Model documentation (ERT 1980).

Table 10. Sample Buoyant Line Parameter Input File

Facility ID	Avg Building Length (m)	Avg Building Height (m)	Avg Building Width (m)	Avg Line Source Width (m)	Avg Building Separation (m)	Avg Buoyancy (m ⁴ /s ³)
Fac1-NC	454.3	16.76	40	5.73	40.95	3335.49

3.5.3 Particle Data Input File for Modeling Particulate Deposition and Depletion

AERMOD can implement dry and wet deposition and plume depletion of both particulate and vapor emissions ([EPA 2019a](#)). This section describes the input file needed for modeling particulate deposition and/or particulate depletion.

If you indicated in your [Facility List Options file](#) that your run will model deposition or depletion of particulate emissions AND you chose (in your [Emissions Location file](#)) to use Method 1 for particle deposition for one or more sources, then you must provide HEM4 with a separate Particle Data input file describing the particle size distribution. In this file, include a separate record for each particle size range emitted by each emission source, for which HEM4/AERMOD will model particle deposition/depletion using Method 1. 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 (for which you are modeling particle deposition/depletion using Method 1). Tables 11 and 12 provide format guidelines for the Particle Data input file and a sample input file, respectively. A template input file is provided in the HEM4 Inputs folder named *HEM4_particle_data.xlsx*.

Table 11. Format Guidelines for the Particle Data Input File

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
Source ID	Character	The Source ID is a unique alphanumeric character string up to 8 characters long with no spaces. It must match a Source ID in the HAP Emissions and Emissions Location file. Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.
Particle diameter	Numeric	The average diameter (in μm) for the particle size range covered by this record.
Mass fraction	Numeric	The percentage (by mass) of particulate matter in this size range. Must add up to 100% for each Source ID.
Particle density	Numeric	The average density of the particles in this size range (in g/cm^3).

Table 12. Sample Particle Data Input File

Facility ID	Source ID	Particle diameter (μm)	Mass fraction (%)	Particle density (g/cm^3)
Fac1-TX	SAMPLE1	0.50	72.0	1.00
Fac1-TX	SAMPLE1	1.50	8.0	0.75
Fac1-TX	SAMPLE1	2.50	4.0	0.50
Fac1-TX	SAMPLE1	4.00	4.0	1.00
Fac1-TX	SAMPLE1	10.00	12.0	0.35
Fac1-TX	SAMPLE2	0.50	60.0	1.00
Fac1-TX	SAMPLE2	1.50	8.0	0.80
Fac1-TX	SAMPLE2	2.50	4.0	0.15
Fac1-TX	SAMPLE2	4.00	4.0	0.90
Fac1-TX	SAMPLE2	10.00	24.0	1.00

3.5.4 Input Files Required for Modeling Vapor Deposition and Depletion

As described in [Section 3.2.6](#), AERMOD can model dry and wet deposition of both particulate and vapor (gaseous) emissions and the resulting plume depletion ([EPA 2019a](#)). This section describes the inputs required for modeling vapor deposition and vapor depletion.

Gas Parameter File for Modeling Deposition/Depletion of Vapor Pollutants: To model wet and/or dry deposition or depletion of vapor pollutants, you must provide HEM4 with the necessary information to evaluate the scavenging of these pollutants in precipitation and deposition on vegetation and other surfaces. When modeling any type of vapor deposition or depletion (wet, dry, or both wet and dry), HEM4 accesses a gas parameter file containing pollutant properties related to gaseous deposition. Note: The Gas Parameter file is included in HEM4's resources folder, which is included in the model's installation files; therefore, HEM4 will NOT prompt you for this file. (The default file pathway is "*HEM4\resources\Gas_Param.xlsx*".) This file includes the following four parameters for each pollutant:

- diffusivity in air (D_a , in cm^2/sec);
- diffusivity 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 vapor/gaseous pollutant that is not listed in the Gas_Param file, HEM4 uses the following default parameters:

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

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., polycyclic aromatic hydrocarbons, 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 vapor/gaseous pollutants. It is not required to model deposition (of any type) of particulate emissions.

Land Use and Month-to-Seasons Input Files for Modeling Dry Deposition of Vapor Pollutants

If you chose to model dry (or wet and dry) vapor deposition or dry (or wet and dry) vapor depletion in your [Facility List Options](#) file, then HEM4 will prompt you to provide two additional input files described in this section. To quantify dry deposition of vapor (gaseous) pollutants to vegetation, AERMOD requires information on the land use and vegetation surrounding the emission source. You must provide this information in Excel™ spreadsheets called the land use and month-to-seasons input files.

Land Use Input File: In the land use input file, you must enter a code characterizing the average land use for 36 directions from the emission sources (which emit vapor pollutants at a facility you chose to model dry deposition or dry depletion at), at increments of 10 degrees compass bearing. Table 13 gives the [format guidelines](#) for the land use input file, and Table 14 shows a [sample](#) land use input file. A template input file is provided in the HEM4 Inputs folder named *HEM4_landuse.xlsx*.

Month-to-Seasons Input File: You must also provide HEM4 the month-to-seasons input file containing further information on the typical stage of vegetation in the modeled region during each month of the year. As the [format guidelines](#) in Table 15 show, this file associates each month with a season code, describing the stage of vegetation ranging from lush midsummer vegetation to winter snow coverage. Table 16 shows a [sample](#) input table for the month-to-seasons input file. A template input file is provided in the HEM4 Inputs folder named *HEM4_month-to-seasons.xlsx*.

Again, **it should be noted that the Land Use and Month-to-Seasons input files are required only if you choose to model dry (or wet and dry) vapor deposition or dry (or wet and dry) vapor depletion** in your [Facility List Options](#) file. These files are not required for modeling wet deposition or depletion of vapor emissions, nor are they required for modeling any kind of (wet or dry) deposition/depletion of particulate emissions.

Table 13. Format Guidelines for Land Use Input File

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
Direction Sector 1	Numeric	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	Land use code at a bearing of $n \times 10$ degrees
Direction Sector 36	Numeric	Land use code at a bearing of 360 degrees

Table 14. Sample Input File for Land Use

Facility ID	D01 (10°)	D02 (20°)	D03 (30°)	D04 (40°)	D05 (50°)	...	D36 (360°)
Fac1-NC	1	9	5	5	6	...	1

Table 15. Format Guidelines for Month-to-Seasons Input File

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
January	Numeric	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	Seasonal category (value = 1-5) for month 11
December	Numeric	Seasonal category (value = 1-5) for month 12

Table 16. Sample Month-to-Seasons Input File

Facility ID	M01	M02	M03	M04	M05	...	M12
Fac1-NC	4	4	5	5	1	...	4

3.5.5 Building Dimensions Input File for Modeling Building Downwash

If you chose to model building downwash in your [Facilities List Options](#) file for one or more facilities, then HEM4 will prompt you for a Building Dimensions input file, which is required by AERMOD to model building downwash effects. The following parameters are required in the building dimensions input 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 for PRIME (BPIPPRM). You can download the BPIPPRM 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#bpipprm>.

Table 17 gives the [format guidelines](#) for the Excel™ Building Dimensions input file, and Table 18 shows a [sample](#) Excel™ Building Dimensions file. A template input file is provided in the HEM4 Inputs folder named *HEM4_bldg_dimensions.xlsx*.

Table 17. Format Guidelines for the Building Dimensions File

Field	(notes)	Type	Description
Facility ID	--	Character	An alphanumeric character string identifying the facility being modeled
Pathway	--	Character	"SO" should always be entered in this field because it represents a source pathway record, which corresponds to the code used in the AERMOD input file.
Keyword	--	Character	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

Field	(notes)	Type	Description
Source ID	--	Character	The Source ID is a unique alphanumeric character string up to 8 characters long with no spaces. It must match a Source ID in the HAP Emissions and Emissions Location file. Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.
Value 1	(n = 1)	Numeric	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	Dimension or distance of the building at a bearing of 20 degrees.
Value n	(n = 3 to 35)	Numeric	Dimension or distance of the building at a bearing of [n × 10] degrees.
Value 36	(n = 36)	Numeric	Dimension or distance of the building at a bearing of 360 degrees.

Table 18. Sample Building Dimensions Input File

Facility ID	Pathway	Keyword	Source ID	Value 1 (10°)	Value 2 (20°)	Value 3 (30°)	...	Value 36 (360°)
Fac1-NC	SO	BUILDHGT	SAMPLE1	26.00	26.00	26.00	...	26.00
Fac1-NC	SO	BUILDWID	SAMPLE1	111.07	107.16	100.00	...	111.60
Fac1-NC	SO	BUILDLEN	SAMPLE1	128.17	115.85	100.00	...	136.60
Fac1-NC	SO	XBADJ	SAMPLE1	-93.97	-98.48	-100.00	...	-86.60
Fac1-NC	SO	YBADJ	SAMPLE1	55.54	53.58	50.00	...	55.80

3.5.6 User-Defined Receptors File

If you opted to include user receptors in your [Facility List Options](#) file for one or more facilities, then HEM4 will prompt you for a User Receptors file. HEM4 will automatically calculate ambient concentrations and resultant cancer risks and noncancer hazard indices for all U.S. Census blocks or for all alternate receptors 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 Receptors input file, using a separate record to indicate the location of each user receptor. You must enter locations of each user receptor using UTM coordinates, or in longitude and latitude. If using UTM coordinates, you must specify the UTM zone. Base all coordinates on the WGS84 reference system.

If you chose in your Facility List Options file to include [elevations](#) in your model run, you can enter the elevation above sea level for each user receptor. If you leave this field blank in the User Receptors input file (but did choose to include elevations in your model run in your Facility List Options file), then HEM4 will assume an elevation for each user receptor based on the surrounding U.S. Census block elevations or alternate receptor elevations. Specifically, if you leave the elevation field empty in the User Receptor file for every receptor, then HEM4 will use the elevation of the closest U.S. Census block or alternate receptor (if not using U.S. Census blocks in your modeling run). Note: You should enter an elevation for every user receptor, or leave the elevation field blank for all, to allow HEM4 to provide the elevations. (Otherwise, if you enter an elevation for some but not all user receptors, HEM4 will assign a 0 value to the receptors you left blank.)

In addition, you may provide hill heights in the User Receptor file, or you may leave the hill height field blank for HEM4 to calculate these values. 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 and calculation of controlling hill heights using an algorithm in AERMAP, the AERMOD terrain processor ([EPA 2018c](#)), see [Section 2.3.1](#).] If you leave the hill height field blank in the User Receptors file (but did choose to include [elevations](#) in your model run in your Facility List Options file), then HEM4 will assign the hill height of that user receptor to be the maximum of: 1) the hill height of the closest U.S. Census block or alternate receptor (if not using U.S. Census blocks in your modeling run), 2) the elevation of the closest U.S. Census block or alternate receptor, or 3) the user receptor elevation that you provide. Note: As cautioned above for user receptor elevation, you should enter a hill height for every user receptor, or leave the hill height blank for all, to allow HEM4 to provide the hill heights. (Otherwise, if you enter a hill height for some but not all user receptors, HEM4 will assign a 0 value to the receptors you left blank.)

In the User Receptor file, you should specify a “receptor type code” indicating the type of receptor. A code of “P” represents populated sites like houses/residences, “B” represents facility boundary sites, and “M” represents ambient monitors. **You may name your user receptors with up to 9 characters** and HEM4 will display these names in the output files for ease of reference. **Each user receptor name must be unique.**

Tables 19 and 20 give [format guidelines](#) for the User Receptors file and a [sample](#) input file, respectively. In addition, a template input file is provided in the HEM4 Inputs folder named *HEM4_user_receptors.xlsx*.

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

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
Coordinate system	Character	Type of coordinates: L = longitude, latitude; U = UTM [WGS84]
X-coordinate	Numeric	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	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	If using the UTM coordinate system (U), enter the UTM Zone from 1 to 60 followed by the hemisphere (S or N). For example, 17N (default hemisphere is N if not specified). If using longitudes/latitudes, leave this cell blank.
Elevation	Numeric	Elevation of the receptor above sea level, in meters. Optional: HEM4 will calculate if left blank and you are modeling terrain effects.*
Receptor type	Character	Type of receptor: P = populated site (e.g., house or school); B = facility boundary; M = monitor.
Receptor ID	Alpha-numeric	Name of receptor provided by user, containing letters and numbers, no symbols or spaces. The name you provide must be 9 characters or less. This name will be displayed in the outputs.
Hill Height	Numeric	Hill height scale, in meters. Optional: HEM4 will calculate if left blank and you are modeling terrain effects.* (You may leave all hill heights blank, even if you enter elevations for your user receptors in the elevation field.)

*Note: Fill-in for every receptor or for none. If you enter one or more values, then HEM4 will assign a zero (0) to any blank values.

Table 20. Sample Input File for User-Defined Receptors

Facility ID	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 = populated site, B = facility boundary, M = monitor)	Receptor ID	Hill Height (m)
Fac1	L	-78.88875	35.90016		100	P	UHouse12	
Fac2	U	560005	441000	16	244	M	UMonitor3	

3.5.7 Emissions Variation Input Files

If you chose to model emissions variations for one or more facilities in your [Facility List Options](#) file, then HEM4 will prompt you for a separate Emissions Variation input file. 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 HEM4 to calculate temporal or wind speed emissions variations, AERMOD requires information on the type of variation and the factors to use for each variation. These variation types and factors will be applied to one or more sources at each of the facilities you indicated in your Facility List Options file. You must supply this information in an Emissions Variation input file in the form of an Excel™ spreadsheet. The types of variations AERMOD can apply include the following (with the HEM4 template file provided in parentheses, as well as the “n” number of factors):

- **SEASON** (*HEM4_emisvar_season.xlsx*): emission rates vary seasonally (n=4);
- **MONTH** (*HEM4_emisvar_month.xlsx*): emission rates vary monthly (n=12);
- **HROFDY** (*HEM4_emisvar_hrofdy.xlsx*): emission rates vary by hour-of-day (n=24);
- **HRDOW** (*HEM4_emisvar_hrdow.xlsx*): emission rates vary by hour-of-day, and day-of-week [M-F, Sat, Sun] (n=72);
- **SEASHR** (*HEM4_emisvar_seashr.xlsx*): emission rates vary by season and hour-of-day (n=96);
- **HRDOW7** (*HEM4_emisvar_hrdow7.xlsx*): emission rates vary by hour-of-day, and the seven days of the week [M, Tu, W, Th, F, Sat, Sun] (n=168);
- **SHRDOW** (*HEM4_emisvar_shrdow.xlsx*): emission rates vary by season, hour-of-day, and day-of-week [M-F, Sat, Sun] (n=288);
- **SHRDOW7** (*HEM4_emisvar_shrdow7.xlsx*): emission rates vary by season, hour-of-day, and the seven days of the week [M, Tu, W, Th, F, Sat, Sun] (n=672);
- **MHRDOW** (*HEM4_emisvar_mhrdow.xlsx*): emission rates vary by month, hour-of-day, and day-of-week [M-F, Sat, Sun] (n=864);
- **MHRDOW7** (*HEM4_emisvar_mhrdow7.xlsx*): - emission rates vary by month, hour-of-day, and the seven days of the week [M, Tu, W, Th, F, Sat, Sun] (n=2,016); and
- **WSPEED** (*HEM4_emisvar_wspeed.xlsx*): emission rates vary by wind speed (n=6) (Note: the 6 factors are applied to the wind speed categories used by AERMOD that have the following default upper bound speeds in m/s of 1.54, 3.09, 5.14, 8.23, 10.8 and no upper bound).

Table 21 provides the [format guidelines](#) for the Emissions Variation input files. Tables 22, 23, 24, and 25 provide sample Emissions Variation input files for a sample of the variations AERMOD can accommodate including: 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. Table 26 provides a sample input file for varying source-specific emissions by [wind speed](#). It should be noted that HEM4 expects a maximum of 12 factor columns across these Emissions Variation input spreadsheets (for a total of 15 columns, including the Facility ID, Source ID and Variation keyword).

It should also be noted that although the types of emission variations described above and the samples provided below are for a single type of emissions variation, you can also choose to use different variation types for different sources and/or facilities, within the same input file. The only limitation is that each source can only have a single type of variation applied in a model run. A template input file containing multiple emissions variations in one file is also provided in the HEM4 Inputs folder and is named *HEM4_emisvar_multiple_variations.xlsx*. See the AERMOD User's Guide ([EPA 2019a](#)) for more detailed information regarding the temporal and wind speed factors available for varying source-specific emissions.

Table 21. Format Guidelines for the Emissions Variation Input Files

Field	Type	Description
Facility ID	Character	An alphanumeric character string identifying the facility being modeled
Source ID	Character	The Source ID is a unique alphanumeric character string up to 8 characters long with no spaces. It must match a Source ID in the HAP Emissions and Emissions Location file. Note: AERMOD allows a maximum of 8 characters for the Source ID; and all Source IDs will be converted to upper case by AERMOD.
Variation	Character	Type of variable emission rates being used (SEASON, MONTH, HROFDY, HRDOW, SEASHR, HRDOW7, SHRDOW, SHRDOW7, MHRDOW, MHRDOW7 or WSPEED).*
Factor 1	Character	First factor to be applied to emission rate.
Factor 2	Character	Second factor to be applied to emission rate.
Factor 3	Character	Third factor to be applied to emission rate.
...
Factor n	Character	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: SEASON=4, MONTH=12, HROFDY=24, HRDOW=72, SEASHR=96, HRDOW7=168, SHRDOW=288, SHRDOW7=672, MHRDOW=864, MHRDOW7=2,016, WSPEED=6. See HEM4's template input files for examples and consult the AERMOD User's Guide for additional information.

Table 22. Sample Emissions Variation File based on Seasons (4 factors)

Facility ID	Source ID	Variation	Winter	Spring	Summer	Fall
Fac1	SAMPLE1	SEASON	0.50	0.75	1.00	1.00

Table 23. Sample Emissions Variation File based on Hour of Day (24 factors)

Facility ID	Source ID	Variation	Hour factor (1)	Hour factor (2)	Hour factor (3)	Hour factor (4)	Hour factor (5)	Hour factor (6)	...	Hour factor (12)
Fac1	SAMPLE1	HROFDY	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	...	1.4356
			(13)	(14)	(15)	(16)	(17)	(18)	...	(24)
Fac1	SAMPLE1	HROFDY	1.3959	1.2728	0.1079	1.5255	1.5255	1.5519	...	1.799

Table 24. Sample Emissions Variation File based on Month (12 factors)

Facility ID	Source ID	Variation	JAN	FEB	MAR	APR	MAY	JUN	...	DEC
Fac1	SAMPLE1	MONTH	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	...	1.4356

Table 25. Sample Emissions Variation File based on Season and Hour of Day (96 factors)

Facility ID	Source ID	Variation	Season-hour Factor							
			Winter 1	Winter 2	Winter 3	Winter 4	Winter 5	Winter 6	...	Winter 12
Fac1	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
Fac1	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
Fac1	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
Fac1	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
Fac1	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
Fac1	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
Fac1	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
Fac1	SAMPLE1	SEASHR	0.2138	0.1433	1.2928	0.098	0.1342	0.3301	...	1.4356

Table 26. Sample Emissions Variation File based on Wind Speed (6 factors)

Facility ID	Source ID	Variation	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Cat. 6
Fac1	SAMPLE1	WSPEED	0.2138	0.1433	1.2928	0.098	0.1342	0.3301

3.5.8 Alternate Receptors file

As noted previously, HEM4 can model based on U.S. Census blocks or based on alternate receptors you provide. If you check “Use alternate receptors” on the required inputs user interface (discussed below in [Section 4.1](#)), then HEM4 will prompt you for an Alternate Receptor file, in lieu of using U.S. Census blocks for the model run. This allows you to model with HEM4 anywhere in the world, both within the U.S and outside the U.S.

The Alternate Receptor file must be a CSV file and provide HEM4 with a list of receptor locations, the type of each receptor (populated “P” or various types of non-populated receptors, such as boundary “B” and monitor “M” receptors), and the populations represented by each receptor. It is important to note that only populated “P” receptors are chosen by HEM4 to be the sites of maximum risk or hazard index; and only “P” receptors are used by HEM4 in cancer incidence calculations. This is discussed further below in Sections 5 and 6. **Note: For HEM4 to run using alternate receptors, you must provide population values for every Alternate Receptor of type “P”. The population you provide may be any integer value, 0 or greater.** Even if only one populated Alternate Receptor is missing a value in its population field, HEM4 will not commence the modeling run.

In addition, if you chose in your Facility List Options file to include [elevations](#) in your model run, then you must also provide HEM4 the elevation above sea level for each alternate receptor, as well as the hill height of each receptor. To model terrain effects, the alternate receptor file must be filled-in completely for every elevation and hill height. **Any blanks in the elevation fields or hill height fields of the Alternate Receptors file will cause AERMOD to be run in the FLAT mode with no terrain effects.**

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 and suggested calculation of controlling hill heights using an algorithm in AERMAP, the AERMOD terrain processor ([EPA 2018c](#)), see [Section 2.3.1](#). It is important to again note that if you leave any hill height field blank in the Alternate Receptors file, then AERMOD will be run in the FLAT mode with no terrain effects (even if you opt to include [elevations](#) in your model run in your Facility List Options file and also provide elevations for your alternate receptors).

Alternatively, you can choose to model with the [elevation option](#) turned off in your Facility List Options file. In such a modeling run, you do not need to provide any elevations or hill heights in the Alternate Receptor file, as HEM4 will model everything on a flat plane.

Tables 27 and 28 give [format guidelines](#) for the Alternate Receptors file and a [sample](#) input file, respectively. In addition, a template input file is provided in the HEM4 Inputs folder named *HEM4_alternate_receptors.csv*.

Table 27. Format Guidelines for Alternate Receptors File (CSV)

Field	Type	Sample Value	Description
Receptor ID	Numeric	1	A unique number identifying the Receptor
Type of receptor	Character	P	Type of receptor: P = populated (e.g., house), B = boundary, M = monitor
Coordinate system	Character	L	Type of coordinates: L = longitude, latitude; U = UTM [WGS84]
X-coordinate	Numeric	-52.74629	UTM east coordinate, in meters (if Coordinate System = U) or decimal longitude (if System = L). 5 decimal place precision is recommended for longitude, corresponding to 1 meter
Y-coordinate	Numeric	47.53796	UTM north coordinate, in meters (if Coordinate System = U) or decimal latitude (if System = L). 5 decimal place precision is recommended for latitude, corresponding to 1 meter
UTM zone with hemisphere	Character	17N	UTM zone where the receptor is located if Coordinate System = U
Elevation	Numeric	219.7	Elevation of the receptor above sea level, in meters. Required if you are modeling terrain effects (i.e. choose to model elevations in the Facility List Options file)
Hill Height	Numeric	219.7	Hill height scale, in meters. Required if you are modeling terrain effects (i.e. choose to model elevations in the Facility List Options file)
Population	Numeric	45	Population represented by the alternate receptor; required by HEM4 for every "P" type alternate receptor for incidence calculations.

Table 28. Sample Input File for Alternate Receptor Input File

Receptor ID	Type of Receptor (P, B, M)	Coordinate System (U = UTM L = latitude, longitude)	X-coordinate: Longitude (decimal) or UTM East (m)	Y-coordinate: Latitude (decimal) or UTM North (m)	UTM zone with hemisphere	Elevation (m)	Hill Height (m)	Population
1	B	L	-52.746286	47.53880		219.7	219.7	0
2	P	L	-52.74685	47.54225		219.3	219.3	5
3	P	L	-52.74817	47.53796		220.6	220.6	25
4	P	L	-52.74760	47.53683		262.7	262.7	7
5	M	L	-52.75023	47.53795		263.4	263.4	0
6	P	L	-52.74708	47.53599		292.1	292.1	45
n

3.5.9 Census Update file

HEM4 provides you the option to change the census file, as discussed below in Section 4.7. Before you use this option, it should be noted that these changes are permanent to your census files. For this reason, it is recommended that you save your original census files to a separate location before using this file to change the official census database provided on EPA's HEM4 webpage.

With the Census Update file, you can:

- (1) Zero-out the population of a specific U.S. Census block;
- (2) Move a block to a new latitude and longitude location; and/or
- (3) Delete a U.S. Census block.

You may wish to **Zero-out** the population of the block if it is clear no residences are present in the block. This change will keep the block in the dataset, so concentrations and risks are modeled, but this receptor will not be considered for maximum risk purposes.

You may wish to **Move** a block to different coordinates that better represent the population.

You may wish to **Delete** or remove a block from the dataset; for example, because there are no people living in the block. However, it should be noted that once removed, the block cannot be added back.

Tables 29 and 30 give [format guidelines](#) for the Census Update file and a [sample](#) update file, respectively. In addition, a template input file is provided in the HEM4 Inputs folder named *HEM4_Census_block_update_template.xlsx*.

Table 29. Format Guidelines for the Census Update File
(used to permanently change your U.S. Census files)

Field	Type	Sample Value	Description
Facility ID	Character	Fac2	The Facility ID field in the Census Update file is optional and may be left blank. You may wish to use it outside of HEM4 to track the source of changes.
Run Group	Character	Landfills	The Run Group field in the Census Update file is optional and may be left blank. You may wish to use it outside of HEM4 to track the source of changes.
Block ID	Character (not numeric)	170010001001003	In this field, enter the 15-digit U.S. Census block ID. Enter the block ID as text characters rather than numerals, because some block IDs have leading zeroes.
Latitude	Numeric	39.96789	If the Change is a “Move”, enter the Latitude (decimal) of where the block should be moved. 5 decimal places are recommended, corresponding to 1-meter accuracy. You may leave this field blank for “Zero” and “Delete” changes.
Longitude	Numeric	-91.37989	If the Change is a “Move”, enter the Longitude (decimal) of where the block should be moved. 5 decimal places are recommended, corresponding to 1-meter accuracy. You may leave this field blank for “Zero” and “Delete” changes.
Change	Character	Move	The potential changes include: Zero, Move, and Delete

Table 30. Sample Census Update File

Facility ID	Run Group	Block ID	Latitude (decimal)	Longitude (decimal)	Change
Fac1-TX	Landfills	170010001001003			Zero
Fac1-TX	Landfills	170010001001009	39.96789	-91.37989	Move
Fac1-TX	Landfills	170010001001010			Delete
Fac1-TX	Landfills	370010201001001			Zero
Fac1-TX	Landfills	370010201001002	36.34567	-79.45678	Move
Fac1-TX	Landfills	370010201001003			Delete

3.5.10 Updating 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 HEM4’s resources folder. You can add new pollutants to these files or edit the values for the chemicals already in the files. If you want to keep your files consistent with the data EPA uses in their HAP risk assessments, check for updated toxicity values on EPA’s Dose Response Assessment webpage ([EPA 2018a](#)).

When adding new chemical names to the Dose Response Library file, 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 pollutant, then the URE will be assumed to be 0 (zero) and cancer risks will not be evaluated for that pollutant. Similarly, if you do not specify a noncancer chronic RfC or acute benchmark for a new pollutant, HEM4 will not calculate adverse noncancer chronic or acute health effects, respectively. **If a noncancer chronic RfC is indicated in the Dose Response Library file for a pollutant you add, you must also enter the pollutant in the Target Organ Endpoints file and indicate what organs or organ systems may be impacted.**

For future model 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 for the files in HEM4’s resources folder, then download the newer files from EPA’s HEM download webpage (from link above) and replace your outdated Dose Response Library and/or Target Organ Endpoints files. You may also manually modify the files in your HEM4’s resources folder based on updated values from EPA’s HEM download page, or from EPA’s Dose Response Assessment webpage ([EPA 2018a](#)).

4. Step-by-Step Instructions for Running HEM4

Before you initiate a HEM4 modeling run⁷, you should ensure you have the necessary input files prepared for your specific modeling needs. Section 3 provides detailed descriptions of all HEM4 input files, and template input files for each are provided in the HEM4 Inputs folder. Table 31 provides a summary of the template files provided in your HEM4 Inputs folder and for what kind of run each file is needed. In addition to the files listed in Table 31, a HEM4 run requires the U.S. Census (if not using alternate receptors) and meteorological databases, and the files located in HEM4's resources folder. These include the *Dose_Response_Library.xlsx* file, the *Target_Organ_Endpoints.xlsx* file, and, for vapor deposition/depletion, the *Gas_Param.xlsx* file.

Table 31. Summary of HEM4 Template Input Files

Template Input File Name	Description	When Needed
HEM4_Fac_List_Options.xlsx	Facility List Options file	Every run
HEM4_HAP_Emiss.xlsx	HAP [Pollutant] Emissions file	Every run
HEM4_Emiss_Loc.xlsx	Emissions Location file	Every run
HEM4_alternate_receptors.csv	Alternate Receptor file	Required if modeling with alternate receptors (whether outside or inside the U.S.) instead of census block receptors
HEM4_user_receptors.xlsx	User Receptor file	Required if the user receptor column in the FacList has a "Y" for one or more facilities
HEM4_buoyant_line_param.xlsx	Buoyant Line Source Parameter file	Required if a source in the Emissions Location file is a buoyant line
HEM4_polygon_vertex.xlsx	Polygon Vertex file	Required if a source in the Emissions Location file is a polygon
HEM4_bldg_dimensions.xlsx	Building Dimensions file	Required if the building downwash column in the FacList has a "Y" for one or more facilities
HEM4_particle_data.xlsx	File containing particle size distribution of emissions per source	Required if the deposition OR depletion column AND Pdep OR Pdepl column in FacList has a "Y", AND if Method 1 (the default) is indicated in EmissLoc. (HAP Emiss must also contain particulates)
HEM4_landuse.xlsx	File describing land use surrounding emissions source	Required if the deposition OR depletion column AND Vdep OR Vdepl column in FacList has a "Y". (HAP Emiss must also contain gases/vapor)
HEM4_month-to-seasons.xlsx	File describing monthly stage of vegetation surrounding emissions source	Required if the deposition OR depletion column AND Vdep OR Vdepl column in FacList has a "Y". (HAP Emiss must also contain gases/vapor)
HEM4_emisvar_season.xlsx	Emissions Variation file	Required if the Emissions Variation column in FacList has a "Y" and seasonal variations are desired (4 factors)
HEM4_emisvar_month.xlsx	Emissions Variation file	Required if the Emissions Variation column in FacList has a "Y" and monthly variations are desired (12 factors)
HEM4_emisvar_hrofdy.xlsx	Emissions Variation file	Required if the Emissions Variation column in FacList has a "Y" and hour-of-day variations are desired (24 factors)

⁷ Note: It is advisable to close and re-start HEM4 between modeling runs, which clears memory for each new run and avoids potential issues by ensuring a full reset.

Template Input File Name	Description	When Needed
HEM4_emisvar_hrdow.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and hour-of-day + type-of-day (M-F, Sat, Sun) variations are desired (72 factors)
HEM4_emisvar_seashr.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and season + hour-of-day variations are desired (96 factors)
HEM4_emisvar_hrdow7.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and hour-of-day + day-of-week (7) variations are desired (n=168);
HEM4_emisvar_shrdow.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and season + hour of day + type-of-day (weekday, Sat, Sun) variations are desired (288 factors)
HEM4_emisvar_shrdow7.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and season + hour-of-day + day-of-week (7) variations are desired (672 factors)
HEM4_emisvar_mhrdow.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and month + hour-of-day + type-of-day (weekday, Sat, Sun) variations are desired (864 factors)
HEM4_emisvar_mhrdow7.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and month + hour-of-day + day-of-week (7) variations are desired (2,016 factors)
HEM4_emisvar_wspeed.xlsx	Emissions Variation file	Required if the Emissions Variation column in Faclist has a "Y" and wind speed (m/s) variations are desired (6 factors)

Finally, to ensure you have the most recent model version, as well as the most recent chemical health effect (toxicity) values, U.S. Census data, and meteorological data, you should check EPA's HEM download webpage for updates (<https://www.epa.gov/fera/download-human-exposure-model-hem>). EPA updates these files periodically. If EPA's update is more recent than the version of HEM4 on your computer, then download the newer model version from EPA's HEM download webpage (from link above) and start the newer model. If the chemical health effect files (e.g., Dose Response Library file, Target Organ Endpoints file) on EPA's website are more recent than the ones currently in HEM4's resources folder, then replace the files in your subfolder with the ones you download from EPA's website. Likewise, check the timestamp and update your U.S. Census data (in HEM4's "census" subfolder) and the meteorological data (in HEM4's "aermod" subfolder), as necessary.

After you have ensured the HEM4 model and integrated databases are up-to-date and after you have prepared the input files for the modeling application, start HEM4 by using Windows File Explorer™ to navigate to the folder where HEM4 was unzipped and double click on the HEM4 executable file. The HEM4 title screen will be displayed, as shown below in Figure 4. Note that the buttons near the bottom of the menu bar on the left – the **HEM4 USER GUIDE** and the **AERMOD USER GUIDE** buttons – link to this HEM4 guide (at <https://www.epa.gov/fera/risk-assessment-and-modeling-human-exposure-model-hem>) and to AERMOD's user guide (at https://www3.epa.gov/ttn/scram/models/aermod/aermod_userguide.pdf), respectively, and you

should access them whenever you need further instruction and understanding regarding the inputs or outputs of HEM4, or when troubleshooting a modeling run issue.

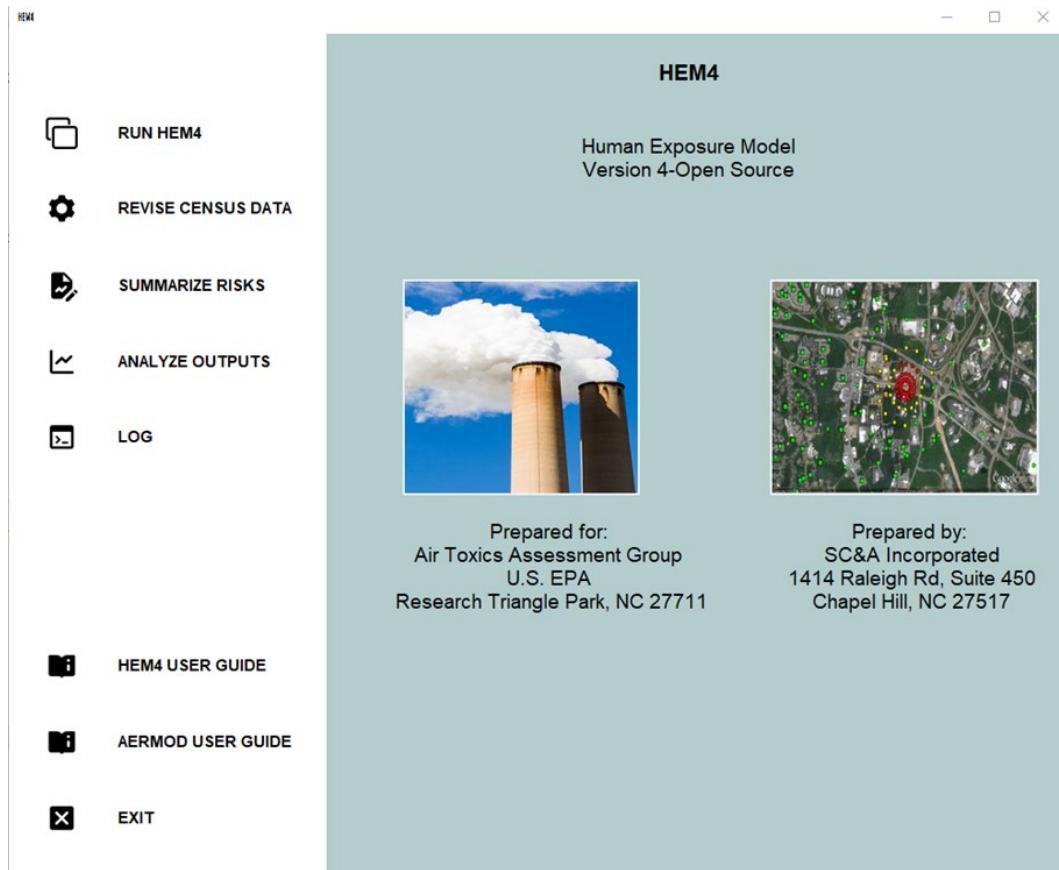


Figure 4. HEM4 Title Screen

The **RUN HEM4** button at the top of the menu bar on the left will take you to the next screen, from which you can initiate a model run. To view this HEM4 User's Guide or the AERMOD User's Guide, on this screen or any subsequent screen, click on the buttons on the bottom of the menu bar.

4.1 Provide Standard Input Files and Indicate Receptors

On the initial input screen (**RUN HEM4**) shown below in Figure 5, you must first indicate whether you will use U.S. Census receptors or alternate receptors for your model run. Within the U.S., you can use either U.S. Census receptors or alternate receptors that you provide. For modeling runs outside the U.S., you must use alternate receptors. Figure 5 shows the input selection buttons for the three required input files: the Facility List Options file, the HAP Emissions file, and the Emissions Location file. Clicking on each of these buttons will allow you to browse your computer to select the appropriate file. The [Facility List Options file](#), [HAP Emissions file](#), and [Emissions Location file](#) are described in detail in Sections 3.2, 3.3 and 3.4, respectively.

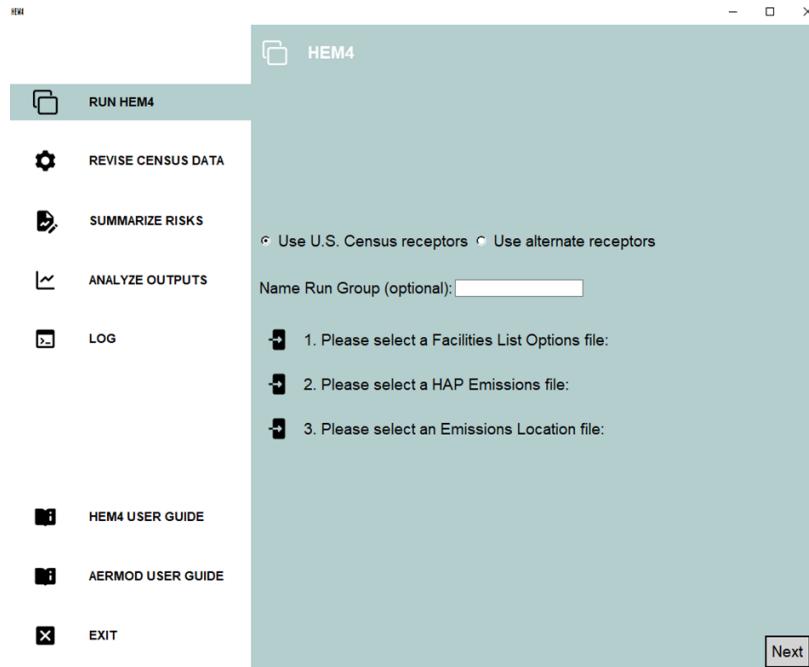


Figure 5. Run HEM4 with U.S. Census Receptors

If you choose to use alternate receptors, then an additional input selection button will appear near the bottom middle of the screen, as shown in Figure 6, that requires you to browse for and select an alternate receptor CSV file. (**Note: It may take several minutes for your Alternate Receptor file to upload for modeling. Do not click Next until it has uploaded.**) The [Alternate Receptors file](#) is described in Section 3.5.8. As with all modeling runs, for a run using alternate receptors, you must also browse for and select the Facility List Options, HAP Emissions, and Emissions Location input files.

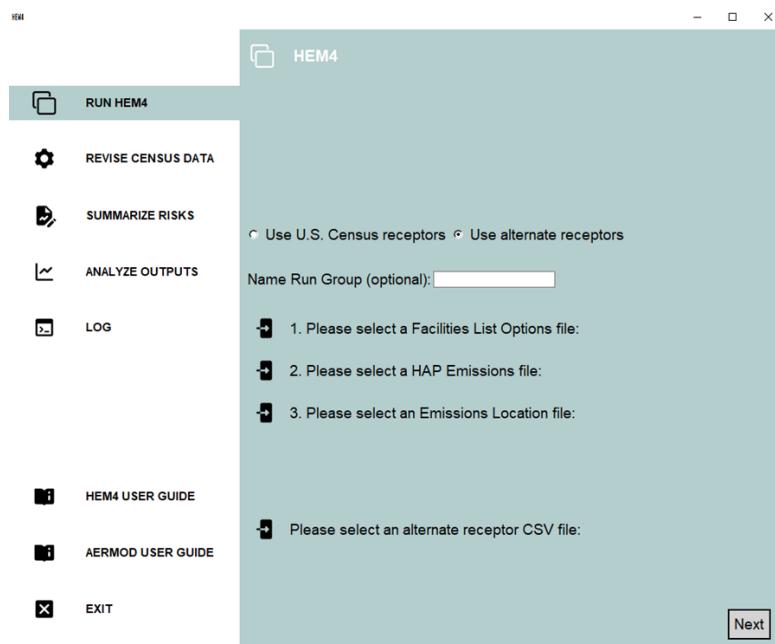


Figure 6. Run HEM4 with Alternate Receptors

For either type of run, you can (optionally) enter a run group name in the **Name Run Group** box provided. This is recommended because the name will be used to identify the subfolder containing the results of your run, located within the “output” folder, and will be helpful in identifying which folder the post-modeling tools for summarizing, viewing and analysis should be pointed towards. The name you enter in the “Name Run Group” box will also be prepended to the output files containing the results for the run as a whole.

After you have indicated what type of receptors should be used for the modeling run and entered the three required input files on this initial screen, click **Next** at the bottom right corner of the screen to continue. If no additional input files are needed beyond the Facility List Options, Emissions Location and HAP Emissions files already entered, then a pop-up box will appear asking you to confirm the start of the HEM4 run, as shown below in Figure 7.

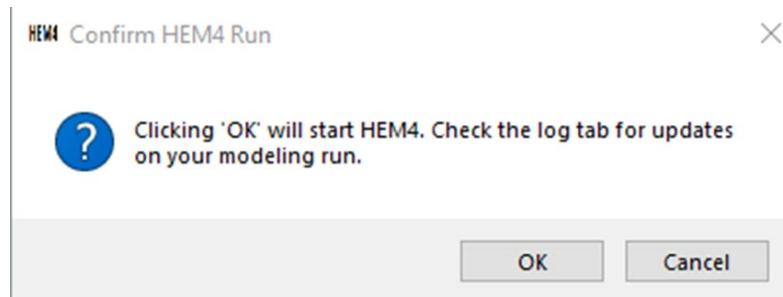


Figure 7. Confirm HEM4 Run Pop-Up Start Box

Clicking ‘OK’ in this box will initiate the modeling, and a log of the modeling progress will appear as shown and described in Section 4.4. Click *Cancel* if you need to change any input files already entered. If additional input files are required, one or two additional screens will appear after you click **Next**, which are discussed in Sections 4.2 and 4.3

4.2 Provide Additional Input Files

If additional inputs are required, one of two screens will appear next, depending on the nature of your sources in the Emissions Location file and the modeling options you indicated in your Facility List Options file. One screen that may appear is shown below in Figure 8. The other input screen which may appear is shown and discussed in Section 4.3.

This screen will prompt you for one or more of the following additional input files: a user receptors file; an emissions variation file; a buoyant line parameters file; a polygon vertex file; and/or a building dimensions file. For example, if you indicated in your Facility List Options file that you’d like to include emissions variations for one or more facilities to be modeled, then a button will appear on this screen asking for the location of your Emissions Variation file (as shown in Figure 8). Likewise, if one of the sources in your Emissions Location file is a buoyant line source, then a button will appear prompting you to browse your computer and select a buoyant line parameter file. If other input files are needed based on your Facility List Options file and Emissions Location file, additional buttons will appear and request that you browse for and select the required file. When you hover over each of these input file buttons, instructions will be displayed on the top of the screen describing each file type.

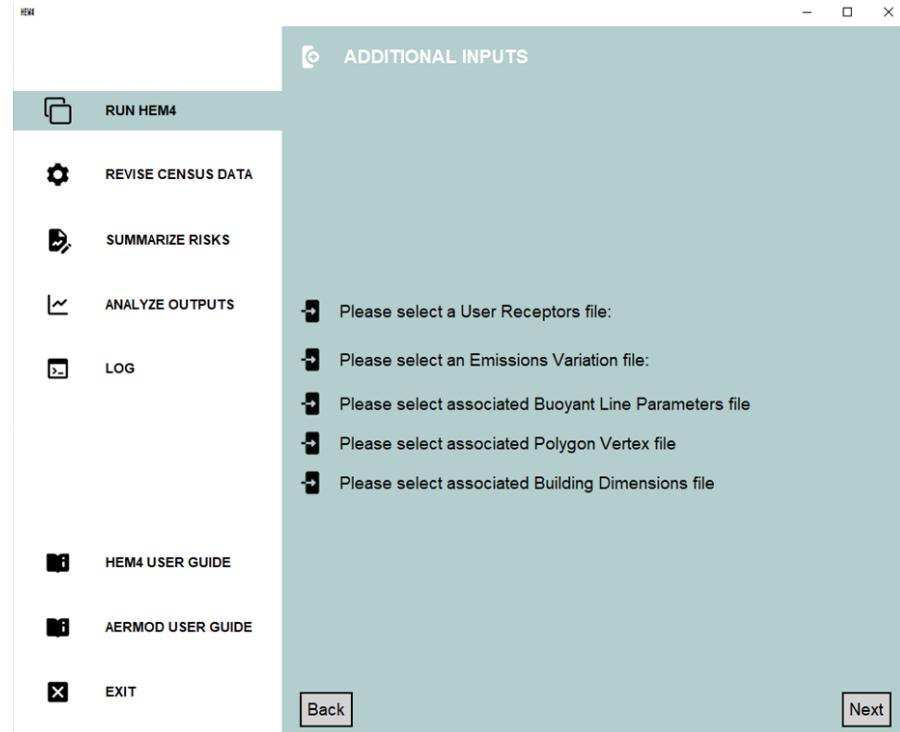


Figure 8. Provide Additional Input Files

After you have entered these additional input files, click **Next** at the bottom right corner of the screen to continue. If no other inputs are needed, HEM4 will display the pop-up box, shown above in Figure 7, stating “*Clicking ‘OK’ will start HEM4. Check the log tab for updates on your modeling run.*” Click **Cancel** if you need to change any input files. If you are ready for HEM4 to start your modeling run, click **OK**, and a log of the modeling progress will appear as shown and described in Section 4.4. If additional inputs are needed for deposition and depletion modeling, another input screen will open next, as shown and discussed in Section 4.3.

4.3 Provide Deposition and Depletion Input Files

When modeling deposition/depletion, HEM4 can direct AERMOD to (1) calculate a deposition flux and (2) deplete the plume based on the calculated deposition. You can direct HEM4 to provide the deposition flux in the outputs, or not (to save space). 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. Deposition and plume depletion have more of an effect on ambient concentrations farther from the facility than it does closer to the facility where the maximum impact generally occurs. Alternatively, you may choose to calculate the deposition flux, but not deplete the plume (to allow for higher, more conservative air concentrations). Either way, the modeled deposition flux may be used as an input to a separate multipathway model such as the Total Risk Integrated Methodology (TRIM) ([EPA 2018e](#)).

In most cases, if you chose to model deposition and/or depletion in the Facility List Option file, HEM4 will require additional input files⁸. HEM4 uses AERMOD to calculate deposition and depletion effects for particulate matter, vapor (gaseous) pollutants, or both. The make-up of your emissions – that is, the percentage particulate and gas – is dictated to HEM4 by your [HAP Emissions](#) input file. Specifically, the fifth column in the HAP Emission input file (“Fraction emitted as particulate matter”) indicates to HEM4 whether your emissions are 100% particle (if this column is populated with 100 for all pollutants), 100% vapor (if this column is left blank or populated with 0 for all pollutants), or a mixture of particles and gas. You will need to browse your computer and select the additional files needed for modeling of deposition and/or depletion on the screen depicted in Figure 9. You will be prompted to provide between 1 and 3 deposition/depletion related input files, depending on your modeling options and the nature of the emissions to-be-modeled.

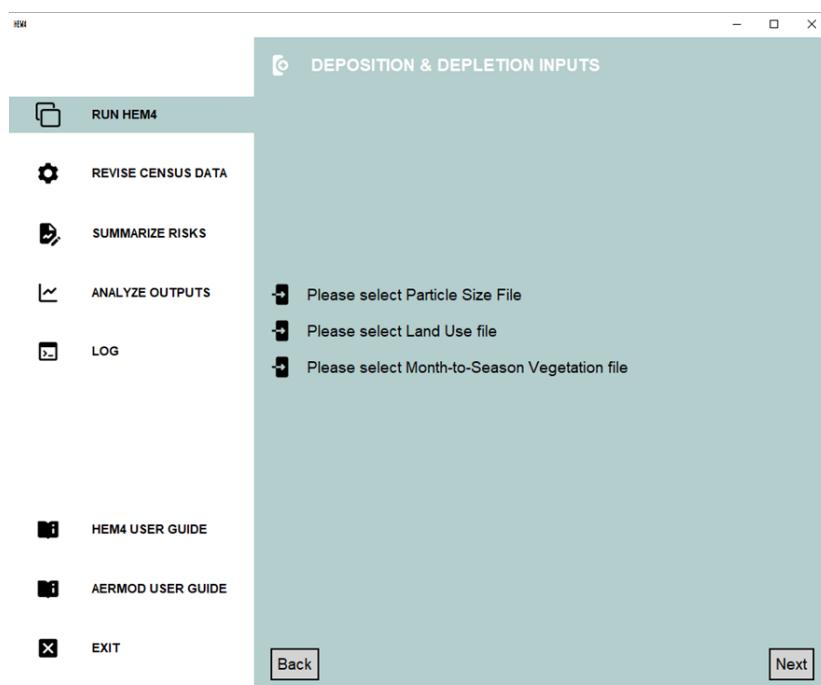


Figure 9. Provide Deposition and Depletion Input Files

If your Facility List Options file indicates that you chose to model particle deposition and/or particle depletion using AERMOD's Method 1 (as discussed in [Section 3.4.2](#)) AND your HAP Emissions file indicates that some of the emissions are in particle form, then a particle data file is required by HEM4/AERMOD. Upload the [particle data input file](#) containing the particle size information, mass fraction and particle size density for each pollutant (HAP) by browsing your computer for it at the first Browse button on this screen, as shown in Figure 9.

⁸ Note: The one deposition and/or depletion modeling case, which requires no additional inputs and therefore no deposition/depletion input screen, is if you are modeling only particle deposition and/or depletion AND chose in your Emissions Location input file to use Method 2 for the Deposition Method. It should also be noted that AERMOD does not model deposition or depletion of emissions from buoyant line sources. Therefore, if you indicate in your Facility List Options file that deposition or depletion should be modeled for a facility with buoyant line sources in your Emissions Location file, AERMOD will not run successfully. In this case, remove the buoyant line source IDs from your input files and model that source separately, without deposition or depletion.

If your Facility List Options file indicates that you chose to model vapor (gaseous) deposition and/or vapor depletion AND your HAP Emissions file indicates that some of the emissions are in vapor form, then HEM4 will instruct AERMOD to model vapor deposition and/or depletion. Depending on the type of vapor deposition/depletion you indicated in your Facilities List Option file, two additional inputs may be required by HEM4/AERMOD: a [land use input file](#) and a [month-to-seasons input file](#). These additional input files are needed only to quantify dry (or “wet and dry”) deposition and/or depletion of vapor emissions, as discussed in [Section 3.5.4](#). If you wish to model “wet only” deposition and/or depletion of gaseous pollutants, these additional input files are not needed by HEM4. (These files are also not needed to model particle-only deposition and/or depletion.) Upload these files by browsing your computer for them at the second and third buttons on this screen shown in Figure 9.

As noted in Section 3.5.4, you should also check to ensure that the vapor (gaseous) pollutants in your HAP Emissions file are included in the [Gas Parameter](#) 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 located in HEM4’s resources folder, as discussed in Section 3.5.4. Otherwise, generic default gas parameter values will be used. (The default file pathway is “HEM4\resources\Gas_Param.xlsx”.)

It should be noted that HEM4 requires significantly more time to run if you opt to model deposition and/or depletion. The exact run time will depend on the particular source configuration and modeling domain but can be over an hour or more per facility. You can utilize the FASTALL option in the Facility List Options file to expedite the run. As noted in [Section 3.2.10](#), FASTALL conserves model runtime by simplifying the AERMOD algorithms used to represent the meander of the pollutant plume ([EPA 2019a](#)).

After you enter the required files on the deposition/depletion input screen, click **Next** on the bottom right and HEM4 will display the pop-up box (shown above in Figure 7) stating “*Clicking ‘OK’ will start HEM4. Check the log tab for updates on your modeling run.*” Click **Cancel** if you need to change any file locations on this screen, and the **Back** button to change any input files on the previous screen. If you are ready for HEM4 to start your modeling run, click **OK** and a log of the modeling progress will appear as shown and described in Section 4.4.

4.4 Check HEM4 Log

After HEM4 starts modeling your facilities (or facility), the **LOG** screen will appear to show you HEM4’s progress in real-time including any errors in processing, if there are any. The Log screen is shown below in Figure 10. (Note: The cursor is visually disabled on the log screen, but it is recommended that you not place your cursor on the log tab screen itself, because doing so may reset where the log displays the next line of progress and result in seemingly non-sequential progress messages; rather use the scroll bar on the right to show more of the log screen, as needed.) Once the modeling run is complete, HEM4 also produces a log text file as a permanent record of the modeling.

The Log screen and text file will provide you with the following modeling run information:

- the meteorological period used, whether annual (the default) or a different period you selected;
- the full list of input files uploaded for the modeling run;

- any mismatch between input files prior to you correcting the mismatched files (e.g., mismatched Source IDs between the HAP Emissions and Emissions Location files);
- the default values used for any parameters with out-of-range (unacceptable) values specified in your input files;
- the run group name;
- the Facility IDs modeled and the location of each facility's center;
- the start and end time for the AERMOD portion of the modeling run;
- the full list of outputs produced; and
- the number of minutes required for HEM4 to model each facility and produce the facility-specific outputs.

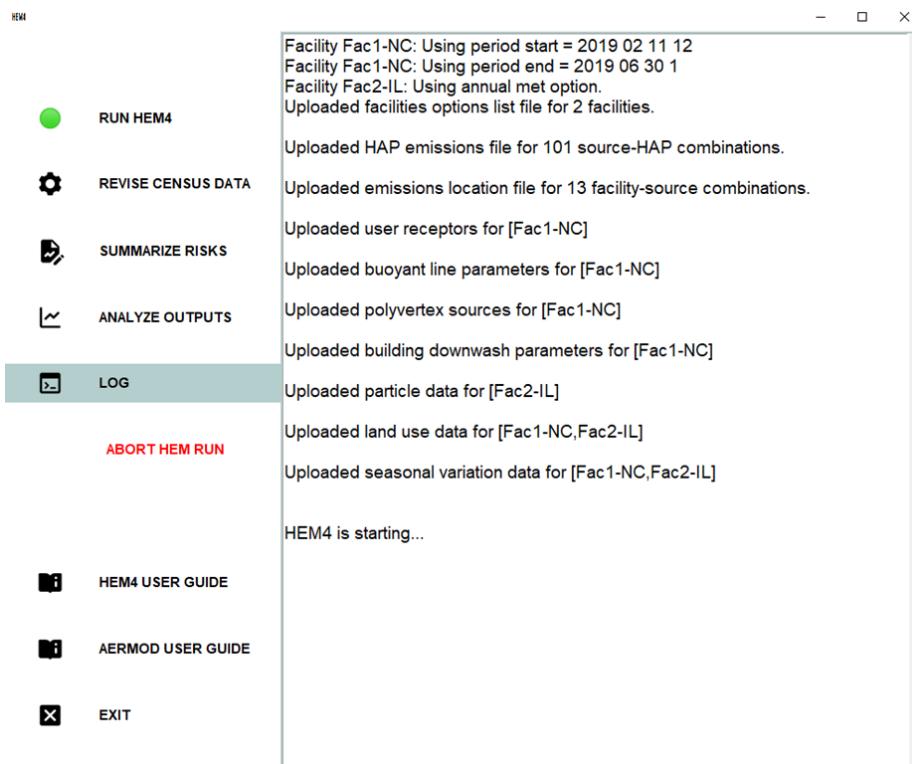


Figure 10. Log Screen

After the modeling is complete, the log text file, named HEM4.log, will be located in the run group folder you name (as discussed in Section 4.1) and will contain information about the facilities modeled in your run. The log file will also indicate what default values HEM4 used (listed in Sections 3.2, 3.3, and 3.4) for the three required input files, in lieu of erroneous out-of-range values you may have included in your input files, as discussed further in Section 4.8. Finally, the log file will also indicate what facilities failed to run successfully, including what errors caused the failure, which is also discussed further in Section 4.8.

The Appendix includes a sample HEM4 log file produced for a two-facility modeling run. The log file will also list any risk summary program outputs you opted to produce. The next section discusses how to run the risk summary programs.

4.5 Summarize Risks

The **SUMMARIZE RISKS** button on the menu bar on the left allows you to summarize HEM4 results using one or more summary programs to produce the following risk summary reports, which are based on all facilities modeled in the run group:

- Max Risk Report;
- Cancer Drivers;
- Hazard Index Drivers;
- Risk Histogram;
- Hazard Index Histogram;
- Incidence Drivers;
- Acute Impacts;
- Multipathway; and
- Source Type Risk Histogram.

The Summarize Risks screen is shown in Figure 11. Note: Before you choose to summarize your risk results via these reports, you may wish to perform certain QA checks on the modeled facility-specific results, as described in [Section 9](#).

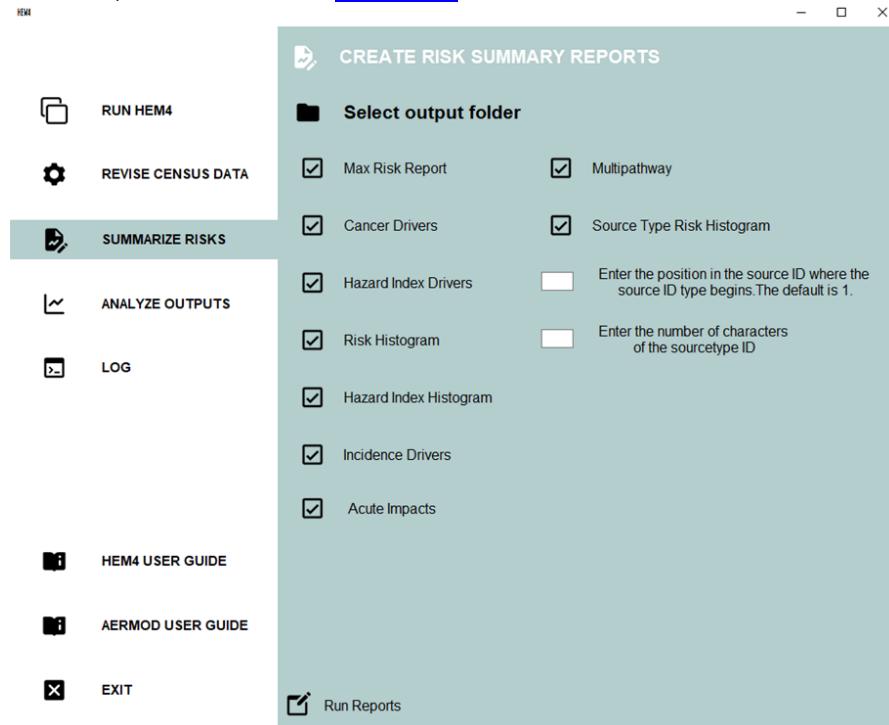


Figure 11. Run the Risk Summary Programs

First, click on the **Select output folder** button to browse for the folder where the HEM4 outputs you want summarized are located. Next, select which summaries you would like to run by checking the box before each, and then click on the “Run Reports” button to initiate the selected summaries. The outputs produced by these risk summary programs are report summaries of all facilities modeled in your run as group, rather than facility-specific outputs, and are described in Section 8.

The Source Type Risk Histogram summary requires you to indicate where in your Source IDs the source type begins and ends. As discussed in [Section 3.3.1](#), it's helpful to create your Source IDs so that the type of source is identified always in the same location in the Source ID string. For example, if you are modeling a series of storage tanks and wastewater vessels, you could identify them with IDs such as ST01, ST02, ST03, WW01, WW02, and so on. In this example, the source type starts in location 1 of the Source ID string and is 2 characters long (i.e., ST and WW). Therefore, in this case, after you check the Source Type Risk Histogram box (shown above in Figure 11), you would enter a 1 next to "Enter the position in the Source ID where the source type begins." You would then enter a 2 next to "Enter the number of characters in the source type."

After you have selected the summaries you want run, check the Log screen for progress. The *HEM4.log* text file will also report any errors. The Risk Summary Reports you choose to run will be placed in the same output folder where you indicated the HEM4 results are located (which were summarized using these programs).

4.6 Analyze Outputs

The **ANALYZE OUTPUTS** button on the menu bar on the left allows you to view and analyze the HEM4 facility-specific modeling results as well as the run group-wide Risk Summary outputs. The View and Analyze Outputs screen is show below in Figure 12.

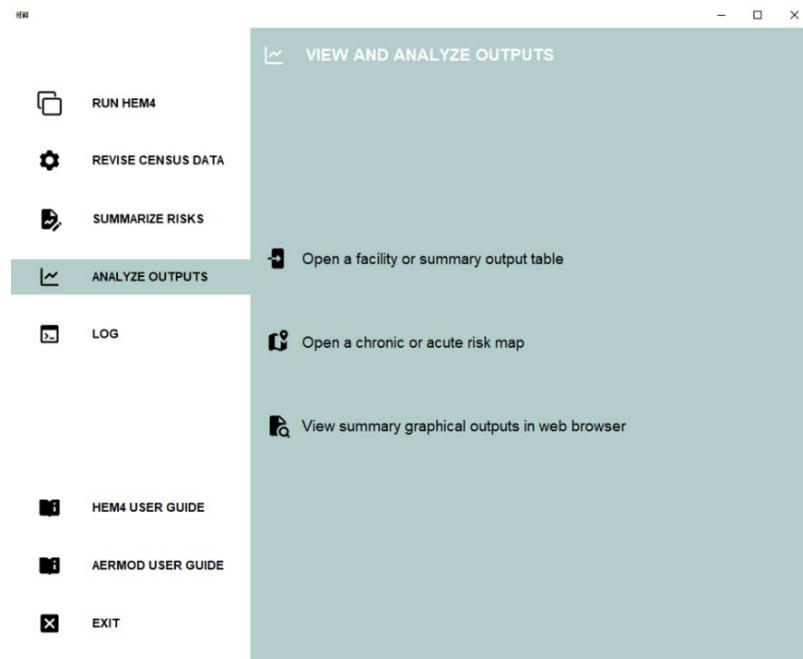


Figure 12. View and Analyze Outputs

This screen consists of three buttons that allow you to (1) open a facility or summary output table via a spreadsheet app for further analysis and graphing; (2) open a chronic or acute risk map; and (3) view summary graphical outputs in web browser. After you click on these buttons, HEM4 will prompt you to identify the location of the output files you wish to view and analyze further.

If you choose to open a facility or summary Excel or CSV output table using the first button (shown in Figure 12), HEM4 will open the file within a spreadsheet app with numerous widgets available for further analysis and graphing. This widget is provided by a pandastable library as an interactive way to review and analyze HEM4's tabular output data (see <https://pandastable.readthedocs.io/en/latest/description.html>.) An example of a Hazard Index Drivers output (spreadsheet) opened via this first button is shown in Figure 13. The spreadsheet and graphing widgets along the right-hand side include: Load table; Save; Import CSV; Load Excel file; Copy table to clipboard; Paste table; Select data to plot; Transpose; Aggregate; Pivot; Melt; Merge, concatenate or join; Prepare a sub-table; Filter table; Calculate; Model fitting; Clear table; Contract columns; Expand columns; Zoom out; and Zoom in.

	Facility_ID	HI_Type	HI_Total	Source_ID	Pollutant	Hazard_Index	Percentage
1	Fac1-NC	Developmental HI	9.479141	SR000001	arsenic compounds	9.431920	99.500000
2	Fac1-NC	Kidney HI	1.570466	SR000001	cadmium compounds	1.506065	95.900000
3	Fac1-NC	Respiratory HI	0.47091	RW000001	acrolein	0.29061	61.710000
4	Fac1-NC	Respiratory HI	0.47091	FU000001	bis(2-ethylhexyl)phthalate	0.132177	28.070000
5	Fac1-NC	Respiratory HI	0.47091	RW000001	acrolein	0.0321697	6.830000
6	Fac1-NC	Liver HI	0.190013	FU000001	bis(2-ethylhexyl)phthalate	0.144408	76.000000
7	Fac1-NC	Liver HI	0.190013	RW000001	trichloroethylene	0.0312142	16.430000
8	Fac1-NC	Reproductive HI	0.090131	RV000001	1,3-butadiene	0.0887254	98.440000
9	Fac1-NC	Neurological HI	0.065151	RW000001	trichloroethylene	0.0348731	53.530000
10	Fac1-NC	Neurological HI	0.065151	FU000001	mercury (elemental)	0.0229932	35.290000
11	Fac1-NC	Neurological HI	0.065151	RW000001	trichloroethylene	0.00386036	5.930000
12	Fac1-NC	Immunological HI	0.039509	RW000001	trichloroethylene	0.0348731	88.260000
13	Fac1-NC	Immunological HI	0.039509	RW000001	trichloroethylene	0.00386036	9.770000
14	Fac2-IL	Liver HI	0.024612	FU000001	bis(2-ethylhexyl)phthalate	0.0225351	91.560000
15	Fac2-IL	Respiratory HI	0.024087	FU000001	bis(2-ethylhexyl)phthalate	0.0225351	93.550000
16	Fac2-IL	Neurological HI	0.016217	FU000001	mercury (elemental)	0.0141467	87.230000
17	Fac2-IL	Neurological HI	0.016217	FU000001	mercury (elemental)	0.00155341	9.580000
18	Fac1-NC	Hematological HI	0.000931	FU000001	selenium compounds	0.00090521	97.180000
19	Fac2-IL	Hematological HI	0.000522	FU000001	selenium compounds	0.000517802	99.180000
20	Fac1-NC	Skeletal HI	0.000481	RW000001	hydrofluoric acid	0.000451516	90.030000
21	Fac1-NC	Endocrine HI	7.09803e-05	RV000001	cumene	5.67842e-06	80.000000
22	Fac1-NC	Endocrine HI	7.09803e-05	RV000001	cumene	1.41961e-06	20.000000
23	Fac2-IL	Reproductive HI	1.28789e	FU000001	benzo[a]pyrene	9.69533e-07	75.280000
24	Fac2-IL	Developmental HI	1.28789e	FU000001	benzo[a]pyrene	9.69533e-07	75.280000
25	Fac2-IL	Reproductive HI	1.28789e	FU000001	benzo[a]pyrene	3.18352e-07	24.720000
26	Fac2-IL	Developmental HI	1.28789e	FU000001	benzo[a]pyrene	3.18352e-07	24.720000

Figure 13. Hazard Index Drivers File Opened via Spreadsheet App

As a further example of this tool, if you click on the “Select-data-to-plot” widget on the right-hand side of the spreadsheet, a data plot automatically pops-up with numerous formatting options for graphing. A depiction of one plot is shown in Figure 14.

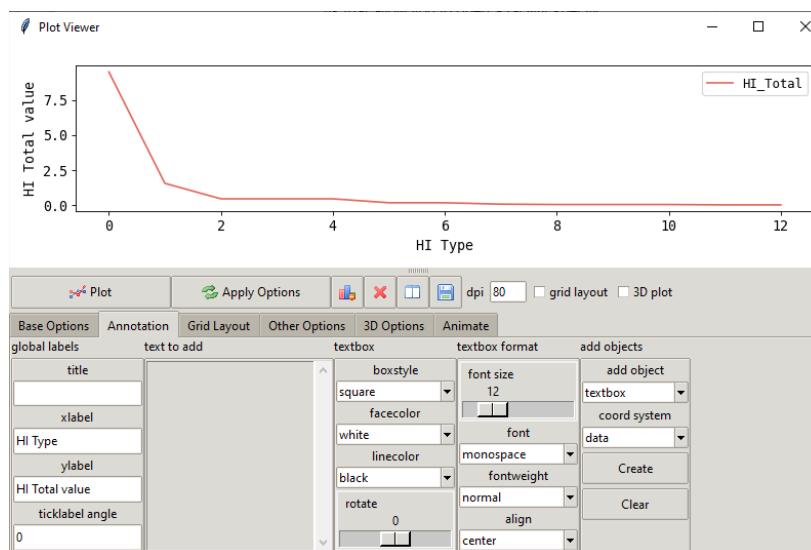


Figure 14. Select Data to Plot Widget

If you choose to open a chronic or acute risk map with the second button (shown in Figure 12), you will be asked to select a chronic kmz file from your modeled outputs, which HEM4 will launch in Google Earth™. Or you can select an acute map html file to view on a satellite street map. An example of a chronic kmz file is shown below in Figure 15 displayed via Google Earth™, with the cancer and noncancer chronic results overlaid on the map. These results are discussed further in Section 6. Note: The first time you run HEM4, your computer may take several minutes to open Google Earth™; but the application will open quickly after subsequent runs.

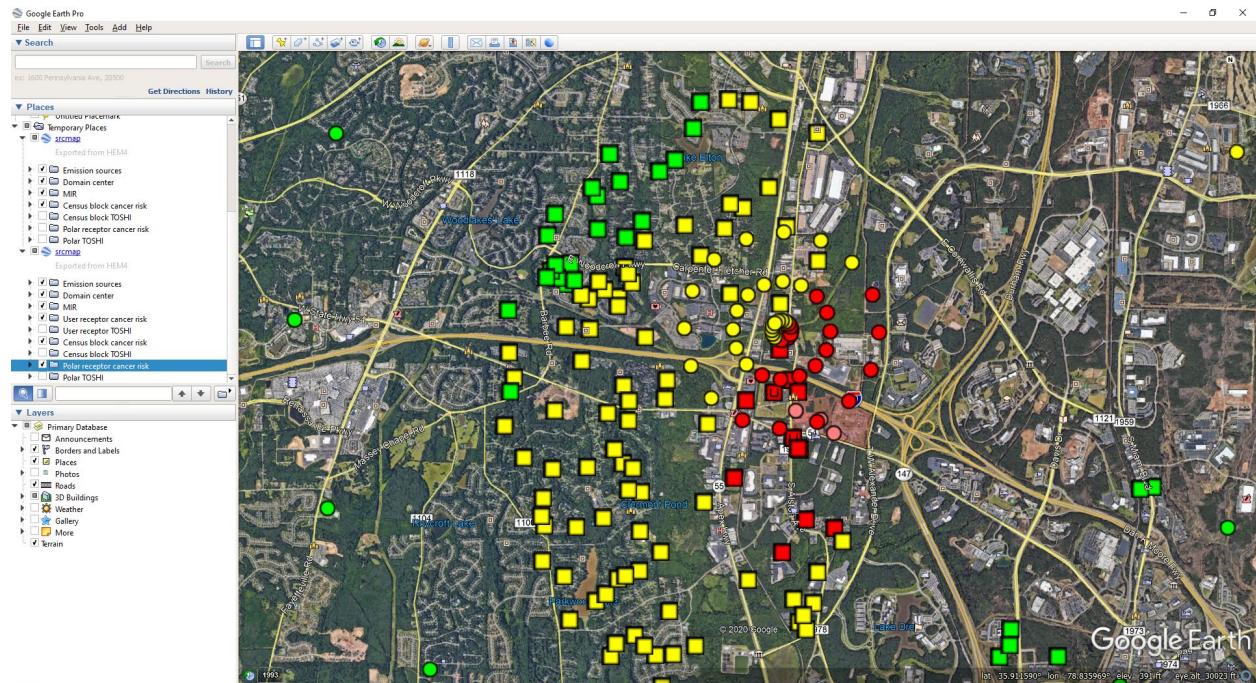
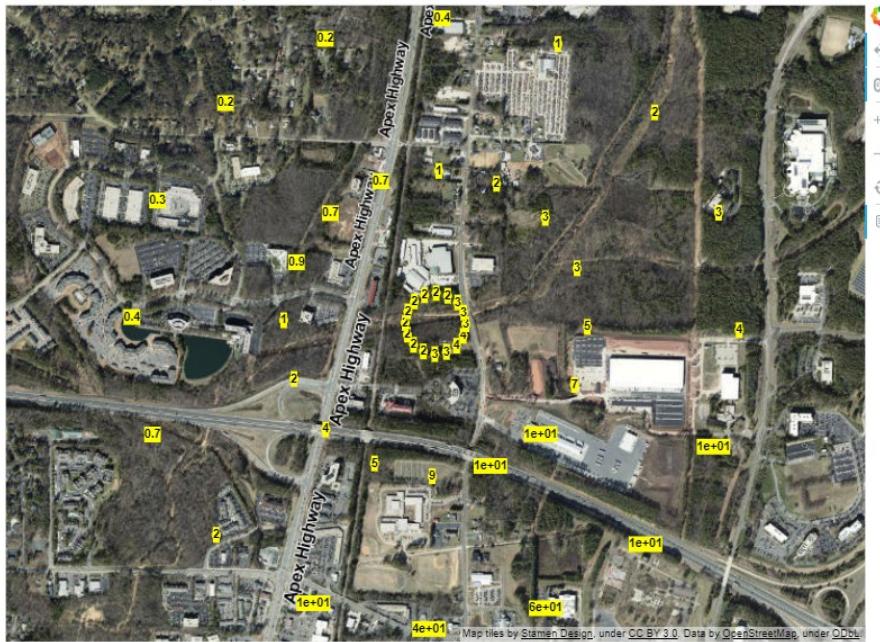


Figure 15. Chronic Risk Map shown in Google Earth™

To open an acute map, you must first run the Acute Impacts summary from the Summarize Risks (“Create Risk Summary Reports”) screen, shown in Figure 11. After you run the Acute Impacts summary program, HEM4 will produce an output subfolder called “Acute Maps”, which will be located in the same place where the other facility-specific and summary outputs from your run are located. Click on the “Open a chronic or acute map” button on the View and Analyze Outputs screen (shown in Figure 12) and then HEM4 will ask you to select the html file you wish to view. Choose an html file from any of the html files located in the “Acute Maps” subfolder and HEM4 will display your map in your default browser window. An example html acute map is shown in Figure 16, for one of the acute benchmarks (REL) based on modeled acrolein results. The acute output files underlying these mapped results are explained in Sections 6 and 7.

Fac1-NC Acrolein Acute HQ (REL)

**Figure 16. Acute Map View of HTML File**

Finally, you can choose to view summary graphical outputs in your default web browser by clicking on the third button (shown in Figure 12). **To use these statistical and graphical visualization tools, you must choose a folder containing Risk Summary reports run from the Summarize Risk screen (shown in Figure 11).** Note that all risk summary reports must be present in your selected folder to use these statistical and graphing tools, except the Max Risk report, Multipathway report and Acute Impact report: these three reports may be present in your selected folder but are not required. After you select your desired output folder, the graphical visualizations of your results that appear in your default web browser are constructed via the Dash app, which is a Python framework for building interactive web applications. The graphical displays of your results offered by this application include:

- a map of your modeled facilities;
- pie charts based on the cancer incidence percentages by pollutant and source type;
- bar charts showing the number of people at increasing levels of cancer risk (e.g., less than 1-in-1 million risk, greater than or equal to 1-in-1 million risk, greater than or equal to 10-in-1 million risk, greater than or equal to 100-in-1 million risk);
- bar charts showing the number of people at increasing noncancer hazard index levels for each of the 14 modeled target organ specific hazard indices (e.g., less than or equal to 1, greater than 1, greater than 10, greater than 100, greater than 1000);
- bar charts showing the source and pollutant risk drivers of your modeling run for both cancer and noncancer;
- bar charts showing the acute screening hazard quotients by benchmark and pollutant for each facility with modeled acute impacts; and
- an interactive and exportable spreadsheet displaying the maximum cancer risk and noncancer hazard index values for each modeled facility.

An example of one of the several graphical visualizations of your results offered by this application is shown in Figure 17, which displays pie charts based on the cancer incidence percentages by pollutant and source type, for a modeling run based on 5 different pollutants and 8 different source types.

Cancer Incidence by Pollutant and Source Type

(Total Incidence is 4.80E-02)

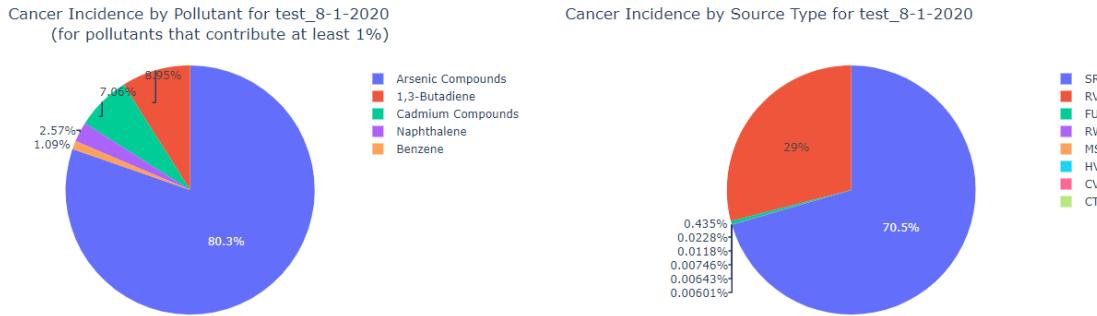


Figure 17. Example Graphical Visualization of Incidence by Pollutant and Source Type

The output files underlying these results are explained in Sections 6 and 7.

4.7 Revise Census Data Option

The **REVISE CENSUS DATA** button on the menu bar on the left allows you to change your U.S. Census file using the census update file described in Section 3.5.9. On this screen, shown in Figure 18, click on the “Please select a census update file” button to select an update file from your computer. Once your census update file is selected, click on the “Revise” button on this screen, which will change the census files that HEM4 uses to model any facilities after the change. (Note: this revision is permanent to your census files unless you change your census files back to their original. For this reason, it is recommended that you save your original census files to a separate location before clicking on “Revise” using this screen.)

You can use the census update file described in Section 3.5.9 to (1) zero-out the population of a specific U.S. Census block, (2) move a block to a new latitude and longitude location, and/or (3) delete or remove a census block. The reasons for making such revisions to your census dataset are also discussed in Section 3.5.9.

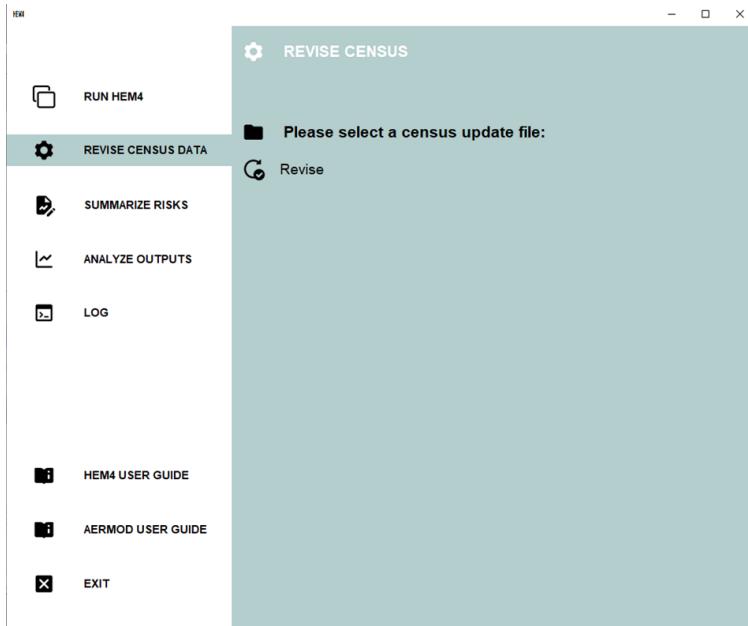


Figure 18. Revise Census Data Screen

4.8 Error Messages and Failed Runs

When initiating a model run, HEM4 will perform a series of checks on your inputs to identify obvious errors that would cause the model (including AERMOD) to fail. Identifying these input errors prior to HEM4 attempting to model the erroneous values avoids most unsuccessful model runs and provides you with instructions to rectify the problem. Reviewing the AERMOD documentation is also important and helpful if you receive an error from HEM4 or from AERMOD (in the aermod.out file, described in Section 6.1.13) when running your inputs and the resolution of the error is not clear ([EPA 2019a](#), [EPA 2019b](#)).

For example, on the user interfaces that instruct you to select input files (discussed above in Section 4), if you attempt to upload an input file with the wrong number of columns (a.k.a. fields), then an error message will pop-up indicating that the file you uploaded had “x” columns, but should have “y” columns. HEM4 will also compare the Source IDs in your input files to ensure they match. If the Source IDs in your Emissions Location file do not match the Source IDs in your HAP Emissions file, then an error message will pop-up indicating that “Your Emissions Location and HAP Emissions files have mismatched Source IDs. Please correct one or both files with matching sources and upload again.” A sample of the kinds of pop-up error messages and their meanings are listed in Table 32.

Additionally, if you entered a value for an input parameter that is out-of-range of the acceptable values for that parameter, then HEM4 will replace your problematic value with the default value, and indicate the replacement in the log file, as noted above in Section 4.4. The values HEM4 defaults to are listed for applicable parameters within each standard input file starting in Section 3.2.

Table 32. Sample List of Error Messages and Causes in HEM4

Pop-Up Error Message	Meaning / Cause
"One or more facility IDs are missing in the <file> List."	The uploaded file contains records without a valid Facility ID.
"One or more met stations referenced in the Facility List are invalid."	The uploaded Facility List Options file contains facilities with met station references that are not present in the master list of met stations.
"One or more source IDs are missing in the <file> List."	The uploaded file contains records without a valid Source ID.
"One or more pollutants are missing in the <file> List."	The uploaded file contains records without a valid pollutant (HAP).
"One or more locations are missing a coordinate system in the <file> List."	The uploaded file contains records without valid coordinate system values.
"One or more source types are missing a valid value in the Emissions Locations List."	The uploaded Emissions Location file contains records without a valid source type value for one or more fields.
"The following pollutants were not found in HEM4's Dose Response Library: [list of HAP names not found]. Would you like to amend your HAP Emissions file? (They will be removed otherwise.)"	One or more HAP listed in the HAP Emissions file is not included in the Dose Response Library. Note: If you do not revise your HAP Emissions file to include only HAP listed in your Dose Response library, then HEM4 will drop those HAP for the current run. Alternatively, you may exit the run and amend the Dose Response Library before starting a new run.
"Facility <fac>: [lat/lon] value out of range in the Emissions Locations List."	The uploaded Emissions Location file contains an out-of-range latitude or longitude value for one or more sources.
"Facility <fac>: UTM zone value malformed or invalid in the Emissions Locations List."	The uploaded Emissions Location file contains an invalid UTM zone value.
"Error: Some non-numeric values were found in numeric columns in this data set."	The uploaded file contains non-numeric values in a field that should have only numbers.
"Length Mismatch: Input file has x columns but should have y columns."	The uploaded file contains the wrong number of columns.
<file> parameters are specified in the Facilities List Options file. Please upload a <file> File."	The Facility List Options file specifies modeling options requiring additional input files that have not been uploaded.
"AERMOD models building downwash from point sources only (i.e., vertical P, horizontal H, or capped C point sources). Your building dimensions file includes non-point sources. Please edit your building dimensions file to remove all non-point sources."	AERMOD models building downwash of emissions from vertical point (P), capped point (C), and horizontal point (H) source types only. The uploaded Facility List Options file indicates building downwash for one or more facilities and the Source IDs for those facilities in the uploaded building dimensions input file include sources other than P, C, or H types.

Pop-Up Error Message	Meaning / Cause
"AERMOD cannot currently model deposition or depletion of emissions from buoyant line sources, and the Emissions Location file includes a buoyant line source for one or more facilities. Please disable deposition and depletion for each of these facilities or remove the buoyant line source(s)."	AERMOD version 19191 can model deposition and/or depletion from all source types except buoyant lines. The uploaded Facility List Options file indicates deposition and/or depletion for one or more facilities and one or more Source IDs for those facilities in the uploaded Emissions Location file are buoyant lines.
"AERMOD's FASTALL option cannot be used with buoyant line sources, and the Emission Location file includes a buoyant line source for one or more facilities. Please disable FASTALL for each of these facilities or remove the buoyant line source(s)."	AERMOD version 19191 does not allow the FASTALL option with buoyant line sources. The uploaded Facility List Options file indicates FASTALL for one or more facilities and one or more Source IDs for those facilities in the uploaded Emissions Location file are buoyant lines.
"AERMOD ran unsuccessfully. Please check the error Section of the aermod.out file in the <fac> output folder."	AERMOD didn't run successfully, for a reason specified in the aermod.out file.
"Cannot generate summaries because there is no Facility_Max_Risk_and_HI Excel file in the folder you selected."	The Risk Summary reports could not be run because the Facility_Max_Risk_and_HI output file is needed, but is missing.

If HEM4 is unable to model a facility or facilities due to errors in the inputs, HEM4 will not only note the errors in the log file but will also produce an Excel file entitled "Skipped Facilities" in the run group's output subfolder. You can use the list of skipped facilities in column A of this output file to create a new Facility List Options file, after you fix the errors, to model these facilities. This is discussed further in Section 9.

Finally, **in the event of a failed modeling run, you should close down HEM4 and then re-start before your next modeling run.** A full shutdown and re-start of HEM4 ensures the memory has been cleared, which will reset values in the underlying model code and avoid a variety of potential issues in the next run.

5. HEM4 Modeling Calculations for each Facility

Section 3 describes the HEM4 input files and Section 4 describes the step-by-step instructions for the user to initiate a HEM4 modeling run. This section describes the internal modeling algorithms and simplifying assumptions employed by HEM4, once initiated, during a modeling run. We list the AERMOD options used to model emission dispersion from each facility and describe the method HEM4 implements to transform AERMOD's single pollutant concentration modeling into multiple pollutant concentration estimations. This section also discusses HEM4's post-dispersion computation of health impacts at modeled receptors, including cancer risk and noncancer health hazards, as well as HEM4's calculations to estimate the contributions of individual pollutants and emission sources to the estimated concentrations and health impacts at the modeled receptors.

5.1 Dispersion Modeling

As noted previously in this guide, HEM4 carries out dispersion modeling by running the AERMOD dispersion model. Section 3 describes a number of input 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 HEM4 implements by default. In addition, this section describes the dilution factor methodology used in HEM4 for modeling multiple pollutants based on AERMOD's single pollutant modeling.

5.1.1 Regulatory Default, ALPHA and BETA Options

HEM4 uses primarily the regulatory default options when running AERMOD. These options include the following:

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

However, it should also be noted that AERMOD (version 19191) includes model option keywords ALPHA and BETA for certain modeling options. The ALPHA keyword indicates one or more options are being used that are scientific/formulation updates considered to be in the research phase and have not been fully evaluated and peer reviewed by the scientific community; and/or non-scientific model options in development that still need rigorous testing and for which EPA is seeking feedback from the user community. The BETA keyword indicates one or more options are being used that have been fully vetted through the scientific community with appropriate evaluation and peer review. BETA options are planned for future promulgation as regulatory options in AERMOD. See the AERMOD users guide for more information ([EPA 2019a](#)).

For the current version of HEM4, the only ALPHA options available are Method 2 particle deposition and gaseous (vapor) deposition. The only current BETA option in AERMOD, RLINE (a source type intended mainly for roadway modeling), is not currently an option in HEM4. To keep HEM4 general, the ALPHA and BETA keywords will always be included in the AERMOD runstream file prepared by HEM4, even when no ALPHA or BETA options are being used.

5.1.2 Dilution Factors

HEM4 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, HEM4 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. As noted in [Section 3.4](#), you can create multiple Source IDs using the same locations and source parameters to accommodate different pollutants when modeling deposition or depletion.

5.2 Estimating Risks and Hazard Indices

HEM4 estimates the total cancer risk, noncancer hazard index (HI) and optionally acute hazard quotient (HQ) for all U.S. Census block locations or alternate receptor locations in the modeling domain, all user receptors, and all receptors in the polar network. Receptors in the HEM4 domain fall into two categories: those with impacts explicitly modeled by HEM4/AERMOD, and those with impacts estimated via interpolation rather than explicit modeling. Section 5.2.1 describes methods used to calculate cancer risks and noncancer health hazards for receptors that HEM4/AERMOD explicitly models. Section 5.2.2 describes the interpolation approach used to estimate cancer risks and noncancer health hazards at receptors not explicitly modeled.

Based on the results for U.S. Census blocks or alternate receptors, and other receptors, HEM4 estimates the maximum individual risk (MIR), maximum HI, and optionally high acute value for populated receptors ([Section 5.2.3](#)); as well as the maximum impacts for all offsite receptors, including unpopulated locations ([Section 5.2.4](#)). For these locations, the model calculates the contributions of individual pollutants and emission sources to cancer risks, chronic HI, and optionally acute HQ ([Section 5.2.5](#)).

5.2.1 Explicit Modeling of Inner Receptors, User Receptors and Polar Receptors

HEM4 calculates cancer risks, target-organ-specific HI, and optionally acute HQ for three types of discrete receptors that are explicitly modeled by AERMOD. These are (1) U.S. Census blocks or alternate receptors within the user-defined [modeling “cutoff” distance](#) for explicit modeling of individual receptors, (2) all [user receptors](#), and (3) the user-defined [polar receptor network](#).

As noted above in Section 5.1.2, Dilution Factors, HEM4 combines pollutants into two categories — particulates and gases (vapor) — for the purposes of dispersion modeling. The model retains these categories to calculate cancer risks, noncancer HI and optionally acute HQ. HEM4 uses the following algorithms:

For cancer risk:

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

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

For noncancer hazard indices:

$$HI_T = \sum_{i,j} HQ_{i,j}$$

$$HQ_{i,j} = DF_{i,j} \times CF \times \sum_k [E_{i,k} / (RfC_k \times 1000 \text{ } \mu\text{g/mg})]$$

where:

- CR_T = total cancer risk at a given receptor (probability for one person)
- $\sum_{i,j}$ = 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 [$(\mu\text{g/m}^3) / (\text{g/sec})$] at the given receptor for source i and pollutant type j
- CF = conversion factor, 0.02877 [$(\text{g/sec}) / (\text{tons/year})$]
- \sum_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 [$1/(\mu\text{g/m}^3)$] for pollutant k
(cancer risk for an individual exposed to $1 \text{ } \mu\text{g/m}^3$ over a lifetime)
- HI_T = TOSHI at a given receptor and for a given organ
- $HQ_{i,j}$ = organ-specific hazard quotient 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:

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

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

where:

- $AC_{i,k}$ = ambient concentration ($\mu\text{g/m}^3$) 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 pollutant, then that pollutant is not included in the calculation of cancer risk. Likewise, if the noncancer reference concentration (RfC) is not available for a given pollutant, that pollutant is not included in the calculation of HI.

Note that separate reference concentrations are used for acute HQ and chronic HQ. As discussed in [Section 2.2.1](#), for acute impacts, instead of the chronic RfC, the short term concentration is compared with various threshold or benchmark levels for acute health effects (e.g., the California EPA reference exposure level [REL] for no adverse effects).

5.2.2 Interpolated Modeling of Outer Receptors using the Polar Receptor Network

For U.S. Census blocks and alternate receptors outside of the user-defined [modeling “cutoff” distance](#) for individual block modeling, HEM4 estimates cancer risks, noncancer HI and optionally acute HQ by interpolation from the [polar receptor network](#). HEM4 estimates impacts at the polar grid receptors using AERMOD modeling results and the algorithms described in Section 5.2.1. If you choose to model terrain effects with the [elevation option](#) in your Facility List Options file, then HEM4 estimates an elevation for each polar receptor. HEM4 estimates elevations and controlling hill heights for the polar grid receptors based on values from the U.S. Census library for modeling runs using the U.S. Census, or from the [alternate receptor file](#) for runs not based on the U.S. Census. HEM4 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.

HEM4 then assigns each polar grid receptor an elevation based on the **highest elevation** for any U.S. Census block receptor, user receptor, or alternate receptor 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 census blocks or alternate receptors, the model defaults to the elevation and controlling hill height of the nearest block or nearest alternate receptor 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 or alternate receptor outside its sector).

HEM4 interpolates the impacts at each outer U.S. Census block receptor or alternate receptor 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, chronic HI or acute HQ) 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

5.2.3 Maximum Individual Risks, Hazard Indices, and Hazard Quotients

HEM4 evaluates the predicted chronic impacts for all populated receptors to identify the locations of the MIR and the highest HI for various target organs (maximum TOSHLs). For these calculations, populated receptors include all U.S. Census block locations or alternate receptors and any user receptors you included in the run designated as type P (for populated). In general, type P receptors should include houses near the facility boundary, as well as other residences not represented well by the location of the U.S. Census blocks or alternate receptors.

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. HEM4 performs a separate evaluation of the maximum impact location for each health impact.

The model also tests for instances where U.S. Census blocks, alternate receptors or type P user receptors appear to be located on plant property. To do so, HEM4 calculates the distance between each receptor and each emission source. These distances are compared with the [overlap distance](#) that you specified in the Facility List Options file. If a populated-type receptor is located within the overlap distance, then HEM4 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 (e.g. polar receptors), as long as they do not overlap plant property.

If you chose to model acute (short-term) impacts in the Facility List Options file, HEM4 will also evaluate predicted acute impacts for all receptors to identify the locations of the highest acute HQs. For the acute calculations, all receptors are evaluated – both populated and unpopulated receptors – including U.S. Census blocks or alternate receptors, all user receptors you may have specified and all polar receptors. As described in the preceding paragraph, HEM4 also checks to ensure that the maximum populated acute receptor is not overlapped. In the case of an overlapped populated receptor, then the next highest non-overlapped populated receptor is chosen.

5.2.4 Maximum Offsite Impacts

In addition to evaluating the maximum cancer risks, chronic HI, and acute HQ (if modeled) for populated receptors, HEM4 evaluates maximum offsite impacts for all receptors. All U.S. Census blocks or alternate receptors, all user receptors (populated and unpopulated), and all points (receptors) 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.

5.2.5 Contributions of Different Pollutants and Emission Sources

HEM4 calculates the contributions of different pollutants and emission sources to cancer risks, chronic HI, and acute HQ (if modeled) at the receptors where impacts are highest, both for populated receptors and for all offsite receptors. As noted in [Section 5.2.1](#), HEM4 groups pollutants together when calculating total risks, HI and HQ (if modeled) 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 pollutants and emission sources for all receptors. However, HEM4 retains the information needed to determine the contributions of individual pollutants and emission sources at the receptors where impacts are highest. HEM4 calculates these contributions using the following equations:

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

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

$$HQ_{i,k,m} = AC_{i,k,m} / (RfC_k \times 1000 \text{ } \mu\text{g/m}^3)$$

where:

- $AC_{i,k,m}$ = the predicted ambient concentration ($\mu\text{g/m}^3$) 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 [$(\mu\text{g/m}^3) / (\text{g/sec})$] for source i, receptor m, and pollutant group j, which includes pollutant k
- CF = conversion factor, 0.02877 [$(\text{g/sec}) / (\text{ton/year})$]
- $CR_{i,k,m}$ = the estimated cancer risk from source i, and pollutant k, at receptor m
- URE_k = cancer unit risk estimate [$1/(\mu\text{g/m}^3)$] for pollutant k
(cancer risk for an individual exposed to 1 $\mu\text{g/m}^3$ over a lifetime)
- $HQ_{i,k,m}$ = the 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)

Note that the methodology outlined above for cancer and chronic noncancer impacts is similar for acute impacts, although acute emissions are used (including any acute factor/multiplier you may have indicated in your Facility List Options files) as well as acute benchmarks discussed in [Section 2.2.1](#).

5.3 Population Exposures and Incidence

Using the predicted impacts for U.S. Census blocks or alternate receptors, HEM4 estimates the populations exposed to various cancer risk levels and noncancer HI levels. To do so, the model adds up the populations for receptors that have predicted cancer risks or noncancer HI above a given threshold. For cancer risk, around each facility HEM4 predicts the number of people exposed to a risk greater than or equal to the following thresholds:

- 1 in 1,000 (or 1,000-in-1 million) risk;
- 1 in 10,000 (or 100-in-1 million) risk;
- 1 in 20,000 risk;
- 1 in 100,000 (or 10-in-1 million) risk;
- 1 in 1,000,000 (or 1-in-1 million) risk; and
- 1 in 10,000,000 (or 0.1-in-1 million) risk.

For noncancer HI, around each facility HEM predicts the number of people exposed to each of the 14 TOSHIIs above the following thresholds:

- Greater than 100;

- Greater than 50;
- Greater than 10;
- Greater than 1.0;
- Greater than 0.5; and
- Greater than 0.2.

If you opt to model acute impacts, HEM4 will provide the acute concentration for every pollutant at every receptor, including every populated receptor, and will also include the population of those receptors (whether U.S. Census blocks or alternate receptors). Because of the transitory nature of acute exposures, acute health impacts are modeled not only where people reside but at all receptors in the modeling domain. Therefore, the highest acute health impacts often occur at unpopulated polar receptor locations. It is important to note that the maximum acute impacts will occur at different times for different spatial locations (receptors) and are therefore not additive. For these reasons, population exposures are not tallied by HEM4 for acute health impacts, only for cancer and chronic noncancer TOSHI.

HEM4 also estimates the contributions of different pollutants and emission sources to total annual cancer incidence for the overall modeling domain using the following equations:

$$CI_{i, k, m} = CR_{i, k, m} \times P_m / LT$$

$$CI_m = \sum_{i, k} [CI_{i, k, m}]$$

$$TCI = \sum_m [CI_m]$$

where:

$CI_{i, k, m}$ = the estimated annual cancer incidence (excess cancer cases/year) for populated receptor m due to emissions from pollutant k and emission source i

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

P_m = the population of populated receptor m

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

$\sum_{i, k}$ = the sum over all modeled pollutants k and emission sources i

CI_m = the estimated total cancer incidence for populated receptor m due to emissions from all modeled pollutants and emission sources

\sum_m = the sum over all populated receptors m in the modeling domain

TCI = the estimated total annual cancer incidence (excess cancer cases/year) for the population living within the modeling domain from all modeled pollutants and emission sources

It should be noted that the above incidence calculations are made for the pollutant types “j” being modeled (whether particulate, gas, or combined).

For each facility, HEM4 provides the estimated total annual cancer incidence (excess cancer cases/year) predicted to be caused by all modeled pollutants emitted from all modeled sources. Increasing in specificity, HEM4 also provides the annual cancer incidence predicted to be caused by each emission source at a facility for all pollutants emitted from that source, as well as by each pollutant from all sources emitting that pollutant at a facility. At the greatest level of specificity, HEM4 provides the estimated cancer incidence broken down by both pollutant and emission source – that is, for every pollutant individually from each source separately.

5.4 Summarizing Human Health Impacts

Section 5.1 above discusses how HEM4 uses AERMOD for dispersion modeling of your inputs to produce multi-pollutant concentration predictions at the receptors in your modeling domain, around a given facility. Sections 5.2 and 5.3 above discuss the methodology and algorithms used by HEM4 to transform predicted concentrations into human health impacts around each modeled facility. The following sections describe the outputs produced by HEM4 for each facility and for your run group as a whole, which allow you to summarize the risk and health impacts per facility and across all facilities you choose to group together in a modeling run.

6. HEM4 Output Files

After running the AERMOD dispersion model to determine receptor-specific concentrations, HEM4 completes the post-AERMOD risk and exposure calculations (explained in Section 5) and then produces a variety of facility-specific concentration, cancer risk, noncancer hazard quotients (HQ) and hazard indices (HI), incidence and population exposure output files. These facility-specific outputs are discussed in Section 6.1. HEM4 also produces three summary output files, based on the results for the entire RUN group (e.g., source category/sector) of modeled facilities. These multi-facility outputs are updated after the output files for the individual facilities have been created and essentially concatenate the individual facility results into group-wide summary files. These run group summary files are discussed in Section 6.2. The Risk Summary Reports are discussed in Section 7.

6.1 Facility-Specific Outputs

A standard HEM4 run produces the following facility-specific output files:

- 6 risk and HI files (maximum individual risk [MIR], maximum offsite impacts, risk breakdown, block summary chronic, ring summary chronic, and source risk KMZ);
- 3 incidence and population exposure files (incidence, cancer risk exposure, noncancer risk exposure);
- 3 concentration files (all inner receptors, all outer receptors, all polar receptors);
- dispersion model output file(s) from AERMOD (the number depends on the type run);
- 1 file cataloging modeling options used (input selection options); and
- 1 quality assurance (QA) file showing receptors discarded (overlapping source receptors).

In addition, depending on the modeling options chosen, a HEM4 run may produce 3 other non-standard/optional files, including the following 3 acute files:

- acute breakdown,
- acute chem populated, and
- acute chem max.

These facility-specific standard and optional files are described below in this section.

6.1.1 Maximum Individual Risk

The Maximum Individual Risk output file provides the MIR value for cancer and the max TOSHI value for noncancer chronic health effects predicted for any populated receptor that does not overlap facility property, such as census blocks, alternate receptors, and user-defined receptors that are designated as “populated”. (Note: user-defined receptors are considered populated receptors but are assigned a population of zero.) This file also indicates the population and exact location of the receptors where these maxima occur. Note that the MIR and max TOSHIs may or may not occur at the same receptors/locations, depending on what pollutants are being emitted from one source versus another source (indicated in the HAP Emissions input file) and the locations and parameters of the sources (indicated in the Emissions Location input file).

Table 33 below describes the fields of information provided in the Maximum Individual Risk file. A sample Maximum Individual Risk output file is provided in Appendix A.

Table 33. Fields Included in the Maximum Individual Risk & Maximum Offsite Impacts Files

Field	Description
Parameter	Maximum individual cancer risk (MIR) or maximum TOSHI including maximum respiratory HI, maximum liver HI, maximum neurological HI, etc. for 14 TOSHIs
Value of MIR or TOSHI	MIR value or maximum TOSHI value, including a rounded value and a value in scientific notation
Population	Population at the location of the MIR or maximum HI, if it is a census block or alternate receptor
Distance	Distance from the center of the modeling domain, in meters
Angle	Angle from north
Elevation	Elevation in meters above sea level
Hill Height	Controlling hill height of receptor, in meters above sea level, as described in Section 2.3.1 .
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. (Note: For alternate receptor run, there is a field called "Receptor ID")
Block ID	10-digit census block ID for linking to census demographic data, if the receptor is a census block. (Note: For alternate receptor run, there is a field called "Receptor ID")
UTM east coordinate	In meters
UTM north coordinate	In meters
Latitude	Decimal
Longitude	Decimal
Receptor type	Census block receptor, polar grid receptor, alternate receptor, user-defined receptor, boundary receptor, monitor location
Notes	This field indicates whether the receptor was modeled discretely or interpolated and also indicates if the original maximum receptor was overlapped (and therefore not used). In the case of interpolation or an overlap, you may wish to re-model the facility.

Relevant to the Maximum Individual Risk file, it should be noted that 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, this is indicated in the Notes field/column and the calculated results for the overlapping receptor are not used. Instead, the maximum cancer risk and TOSHIs are assumed equal to the maximum (next highest) impacts for any receptor that does not overlap facility property. This could include both populated (census, alternate, 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. In this

situation, check the source coordinates in the [emissions location](#) input file, and define a set of facility boundary receptors in the [user-defined receptors](#) file.

6.1.2 Maximum Offsite Impacts

The Maximum Offsite Impacts output file provides similar information to the Maximum Individual Risk output file, but the receptors of maximum impact in this file include any receptors, not only populated receptors. This file lists the highest cancer risks and TOSHI 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 discretely modeled census blocks (aka “inner receptors”), all user-defined receptors (including populated user receptors, boundary sites and ambient monitor sites), and all points in the polar receptor network, except for those receptors overlapping emission sources. Table 33 above describes the fields of information provided in the Maximum Offsite Impacts file. A sample Maximum Offsite Impacts output file is provided in Appendix A.

6.1.3 Risk Breakdown

The Risk Breakdown output file provides the breakdown of risk and TOSHI by pollutant and source, including a listing of pollutant concentrations and unit risk estimates (URE) and reference concentration (RfC) values. This file includes information about the MIR and HI (for populated census block, user, and alternate receptors), as well as the maximum offsite impacts (for any receptor, including non-populated receptors such as polar grid receptors, boundary receptors, and monitors), as discussed in Section 5.2.

This file also shows the contributions of gaseous and particulate emissions for any pollutants that are emitted in both forms, if you opted to model deposition/depletion or if you merely elected to show the particulate/gaseous breakdown, as explained in [Section 3.2.6](#). Table 34 below describes the fields of information provided in the Risk Breakdown file. A sample Risk Breakdown output file is provided in Appendix A.

As previously noted, HEM4 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 over a 70-year lifetime. Noncancer health effects are quantified using HQ and HI for various target organs. The HQ for a given pollutant and receptor site is the ratio of the ambient concentration of the pollutant to the 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.

Table 34. Fields Included in the Risk Breakdown File

Field	Description
Site type	MIR (for max populated receptor) or maximum offsite impact (for max of any receptor, populated or not)
Parameter	Cancer risk, all 14 TOSHLs (e.g., respiratory HI, liver HI, neurological HI)
Source ID	Individual source identification code, "Total by pollutant all sources", or "Total" for all pollutants and all sources combined
Pollutant	Pollutant name, "all modeled pollutants" for all pollutants combined for each source, or "all pollutants all sources" for all pollutants and all sources combined
Emission (Pollutant) type	P = particulate, V = vapor (gas), C = combined, NA = not applicable
Value	Cancer risk or noncancer HQ
Value_rnd	Cancer risk or noncancer HQ rounded to one significant figure
Conc_ugm3	Pollutant concentration ($\mu\text{g}/\text{m}^3$)
Conc_rnd	Pollutant concentration ($\mu\text{g}/\text{m}^3$) rounded to two significant figures
Emissions_tpy	Modeled tons per year (tpy) emitted of pollutant
URE	Unit risk estimate used to compute cancer risks for the pollutant [1 / ($\mu\text{g}/\text{m}^3$)]
RfC	Reference concentration used to compute HQs for the pollutant (mg/m^3); Note that HEM4 converts this to $\mu\text{g}/\text{m}^3$ to compute TOSHLs

6.1.4 Block Summary Chronic

The Block Summary Chronic file provides the total cancer risk and all 14 TOSHLs for every populated census block receptor, populated alternate receptor, and all user receptors, and also indicates whether the receptor is an overlap location. As noted above, 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. (For example, 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 block, populated user-defined, or alternate) receptors and unpopulated (polar, boundary, or monitor) receptors, as long as they do not overlap facility property. In the case of an overlap, you may wish to check the coordinates in your Emissions Location input file, and define a set of facility boundary receptors in the [user-defined receptors](#) file.

To facilitate detailed geographic information system (GIS) analyses of HEM4 results, the file gives the latitude and longitude, and the UTM coordinates of each receptor, in addition to cancer risk estimates and HI. This output file also gives the county FIPS code and block identification number for U.S. Census-based runs or alternate Receptor ID for non-census runs,

as well as the population of each receptor. This information is intended to facilitate studies linking HEM4 results with census information, such as demographic or economic data. Table 35 below describes the fields of information provided in the Block Summary Chronic file. A sample Block Summary Chronic output file is provided in Appendix A.

6.1.5 Ring Summary Chronic

The Ring Summary Chronic file provides the same information provided by the Block Summary Chronic File, but for points in the polar receptor network. However, because these are polar receptors, the FIPS, Block, and population fields are not included in the Ring Summary Chronic File, while three additional fields are provided: distance from center of polar network, angle from north, and sector number. Table 35 describes the fields of information in the Ring Summary Chronic file, and a sample file is provided in Appendix A.

Note: For both the Block Summary Chronic and Ring Summary Chronic files, in the case of an overlapped receptor, the risk and TOSHI values for that receptor displayed in these files will not be the originally modeled values. Instead, the maximum cancer risk and TOSHIs are assumed equal to the maximum (next highest) impacts for any receptor that does not overlap facility property. This could include both populated (census, alternate, 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. The originally modeled values that occurred in the location of the overlap are available in the All Inner Receptor, All Outer Receptor, and/or All Polar Receptor files described in Sections 6.1.10, 6.1.11, and 6.1.12, respectively.

Table 35. Fields Included in the Block Summary and Ring Summary Chronic Files

Field	Description
Latitude	Decimal
Longitude	Decimal
Overlap	N for No, Y for Yes. If Yes, the values shown for the receptor in that row are the next highest receptor (whether populated or non-populated), not overlapped. See also the Overlapping Source Receptors file .
Elevation	Elevation in meters above sea level
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. (Not part of Ring Summary Chronic File) Note: For alternate receptor run, there is a field called "Receptor ID".
Block ID	10-digit census block ID for linking to census demographic data, if the receptor is a census block. (Not part of Ring Summary Chronic File) Note: For an alternate receptor run, there is a field called "Receptor ID".
X	UTM Easting Coordinate
Y	UTM Northing Coordinate
Hill Height	Controlling hill height of receptor, in meters above sea level, as described in Section 2.3.1
Population	Population at the location of the MIR or maximum HI, if it is a census block, or has user-provided population in the case of an alternate receptor. (Not part of Ring Summary Chronic File)
Parameter	Cancer risk, all 14 TOSHIs (e.g., respiratory HI, liver HI, neurological HI)
Discrete/ Interpolated	D for Discretely modeled receptor (within the modeling distance , aka "inner receptors"), I for Interpolated receptor (outside the modeling distance, aka "outer receptors") (Not part of Ring Summary Chronic File)
Distance	Distance in meters from the center of the polar network of the polar receptor's location on polar ring (Not part of Block Summary Chronic File)
Angle (from north)	Angle from north of the polar radial on which the polar receptor is located (0 to 360 degrees) (Not part of Block Summary Chronic File)
Sector	Sector number within the polar network (the number depends on number of radials indicated in your Facility List Options file; default is 1-16) (Not part of Block Summary Chronic File)

6.1.6 Source Risk KMZ Image

The Source Risk KMZ file is a Google Earth™ map centered on the facility, as shown in Figure 19. 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 or alternate receptors (displayed as squares) and polar grid receptors (displayed as circles). The MIR receptor is marked with a red “X”.

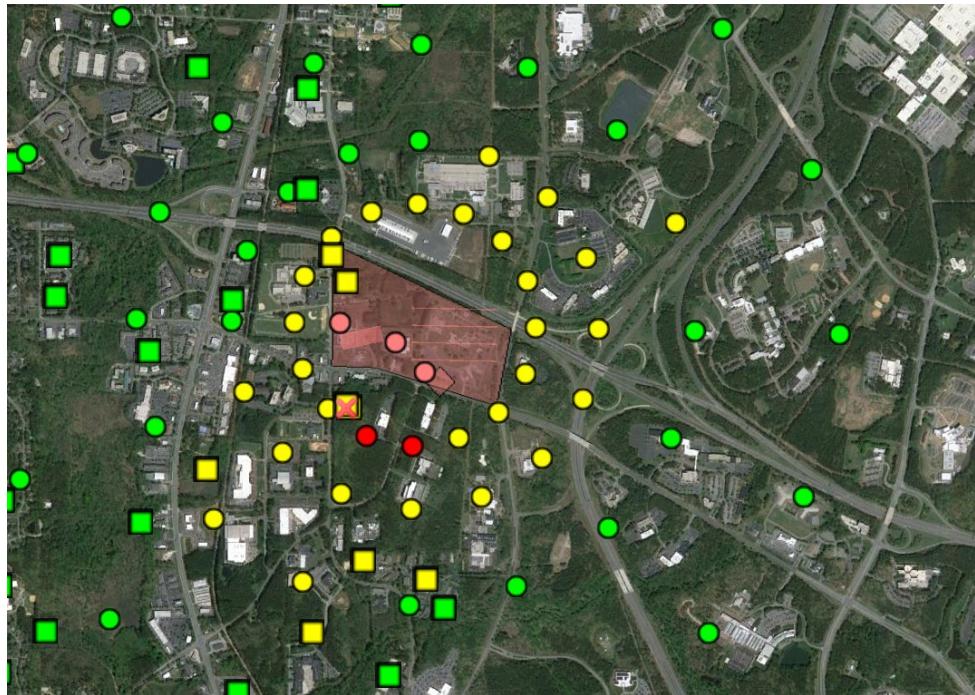


Figure 19. Sample Google Earth™ Map of Results

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 (for census blocks), 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 19 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).

6.1.7 Incidence

The facility-specific Incidence file provides the overall total incidence for all modeled pollutants from all sources in the given facility, the pollutant-specific total incidence for all sources combined, and the individual incidence per source for each pollutant. As explained in Section 5.3, the incidence is calculated as the cancer risk of each populated receptor (e.g., census block or alternate receptor) times the receptor population, divided by a 70-year average lifespan. This individual populated receptor incidence is then summed over all populated receptors in the modeling domain of the facility. Table 36 below describes the fields of information provided in the facility-specific Incidence file. A sample Incidence output file is provided in Appendix A.

Table 36. Fields Included in the Incidence File

Field	Description
Source ID	Individual source identification code, or “Total” for all sources combined
Pollutant	Pollutant name, or “All modeled pollutants” for all pollutants combined for each source and for the Total
Emission (Pollutant) type	P = particulate, V = vapor (gas), C = combined
Incidence	Cancer risk or noncancer HQ
Incidence, rounded	Cancer risk or noncancer HQ rounded to one significant figure

6.1.8 Cancer Risk Exposure

The Cancer Risk Exposure file is a simple two column (two field) file that provides the population numbers exposed to various cancer risk levels in the modeling domain surrounding the facility. Population numbers are provided for the following cancer risk levels:

- Greater than or equal to 1 in 1,000 ($\geq 1,000$ -in-a-million risk);
- Greater than or equal to 1 in 10,000 (≥ 100 -in-a-million risk);
- Greater than or equal to 1 in 20,000 (≥ 50 -in-a-million risk);
- Greater than or equal to 1 in 100,000 (≥ 10 -in-a-million risk);
- Greater than or equal to 1 in 1,000,000 (≥ 1 -in-a-million risk); and
- Greater than or equal to 1 in 10,000,000 (≥ 0.1 -in-a-million risk).

A sample Cancer Risk Exposure output file is provided in Appendix A.

6.1.9 Noncancer Risk Exposure

The Noncancer Risk Exposure file, like the Cancer Risk Exposure file described above, is a simple file that provides the population numbers exposed to various HI levels for all 14 TOSHIs, in the modeling domain surrounding the facility. Population numbers are provided for the following noncancer HI levels:

- Greater than 100;
- Greater than 50;
- Greater than 10;
- Greater than 1.0;
- Greater than 0.5; and
- Greater than 0.2.

Population numbers at each of the above noncancer HI levels are provided for the following TOSHIs:

- 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.

A sample Noncancer Risk Exposure output file is provided in Appendix A.

6.1.10 All Inner Receptors

The All Inner Receptors file provides the chronic concentration (in $\mu\text{g}/\text{m}^3$) and (if optionally modeled) the acute concentration of every populated (census block or alternate) receptor inside the [modeling distance](#), as well as every [user-defined receptor](#). **Note:** All concentrations in this file are discretely (explicitly) modeled, not interpolated. This file will also contain the deposition flux (in $\text{g}/\text{m}^2/\text{y}$) if you opted to calculate deposition with or without depletion. Columns for both dry and wet deposition flux results are provided and will be populated with non-zero results depending on the type of deposition modeling (wet, dry or both) you selected in the [Facility List Option fields](#). Table 37 below describes the fields of information provided in the All Inner Receptors file. A sample All Inner Receptors file output file is provided in Appendix A.

6.1.11 All Outer Receptors

The All Outer Receptors file includes nearly the same information provided in the All Inner Receptor file (described above) for every receptor located between the [modeling distance](#) (often specified as 3 km) and the [outer edge of the modeling domain](#) (the “maximum distance” often specified as 50 km). The dry and wet deposition fluxes provided in the All Inner Receptors file, however, are not provided in this file, for the outer receptors. **Note:** All concentrations in this file are interpolated using the polar grid receptors, not discretely (explicitly) modeled. Table 37 below describes the fields of information provided in the All Outer Receptors file. A sample All Outer Receptors file output file is provided in Appendix A.

Table 37. Fields Included in the All Inner and All Outer Receptor Files

Field	Description
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. (Note: For alternate receptor run, there is a field called "Receptor ID")
Block ID	10-digit census block ID for linking to census demographic data, if the receptor is a census block. (Note: For alternate receptor run, there is a field called "Receptor ID")
Latitude	Decimal
Longitude	Decimal
Source ID	Individual source identification code affiliated with given concentrations
Emission (Pollutant) type	P = particulate, V = vapor (gas), C = combined
Pollutant	Pollutant name affiliated with given concentrations
Conc	Chronic air concentration in $\mu\text{g}/\text{m}^3$
Acute Conc	Acute (short-term) air concentration in $\mu\text{g}/\text{m}^3$, if modeled
Elevation	Elevation in meters above sea level
Dry deposition	Dry deposition flux in $\text{g}/\text{m}^2/\text{year}$, if modeled (not included in All Outer Receptor file)
Wet deposition	Wet deposition flux in $\text{g}/\text{m}^2/\text{year}$, if modeled (not included in All Outer Receptor file)
Population	Population of receptor
Overlap	N for No, Y for Yes. Note: the value shown is the originally modeled value, even if overlapped (and therefore not used in other files such as the Maximum Individual Risk, Risk Breakdown, and Block Summary Chronic files)

6.1.12 All Polar Receptors

The All Polar Receptors file provides similar information to the All Inner Receptors and All Outer Receptors for the nodes of the [polar receptor grid](#), including the chronic concentration (in $\mu\text{g}/\text{m}^3$) and (if optionally modeled) the acute concentration of every polar receptor. **Note:** Like the All Inner Receptors file, all concentrations in the All Polar Receptors file are discretely (explicitly) modeled, not interpolated. Likewise, this file will also contain the deposition flux (in $\text{g}/\text{m}^2/\text{y}$) if you opted to calculate deposition with or without depletion. Columns for both dry and wet deposition flux results are provided and will be populated with non-zero results depending on the type of deposition modeling (wet, dry or both) you selected in the [Facility List Option fields](#). In addition, this file will contain the distance from the center of the polar network, the angle, sector, and ring number that describes the location of each polar receptor. Table 38 below describes the fields of information provided in the All Polar Receptors file. A sample All Polar Receptors file output file is provided in Appendix A.

Table 38. Fields included in the All Polar Receptors File

Field	Description
Source ID	Individual source identification code
Emission (Pollutant) type	P = particulate, V = vapor (gas), C = combined
Pollutant	Pollutant name affiliated with given concentrations
Conc	Chronic air concentration in $\mu\text{g}/\text{m}^3$
Acute Conc	Acute air concentration in $\mu\text{g}/\text{m}^3$
Distance	Distance in meters from the center of the polar network of the polar receptor's location on polar ring
Angle (from north)	Angle from north of the polar radial on which the polar receptor is located (0 to 360 degrees)
Sector	Sector number within the polar network (the number depends on number of radials indicated in your Facility List Options file; default is 1-16)
Ring number	The number of the ring ("circle") in the polar network on which the receptor is located, beginning with number 1 closest to facility center
Elevation	Elevation in meters above sea level
Latitude	Decimal
Longitude	Decimal
Overlap	N for No, Y for Yes. Note: the value shown is the originally modeled value, even if overlapped (and therefore not used in other files such as the Maximum Individual Risk, Risk Breakdown, and Ring Summary Chronic files).
Wet deposition	Wet deposition flux in $\text{g}/\text{m}^2/\text{year}$, if modeled (not included in All Outer Receptor files)
Dry deposition	Dry deposition flux in $\text{g}/\text{m}^2/\text{year}$, if modeled (not included in All Outer Receptor files)

6.1.13 AERMOD Outputs

With each run, HEM4 automatically provides a set of AERMOD text files that track the inputs and keywords (modeling commands) passed to AERMOD, including the receptor network and meteorological files, as well as the AERMOD outputs. The outputs produced by AERMOD are then passed back to HEM4 and used to produce the other outputs described in this guide. You should review these AERMOD text files (especially the aermod.out file described below) to confirm that AERMOD completed its modeling without error. These text files are described below:

- **aermod.inp** – a text file for combined particle and vapor phase emissions listing the inputs passed to AERMOD for modeling, including modeling control options (see AERMOD User's Guide), rural or urban dispersion environment, averaging time, specific input file parameters (e.g., from the Emissions Location file), the network of discrete receptor coordinates (block or alternate receptors in UTM), elevations and hill heights, meteorological data, and designated text formatted output files. Note: If particle and vapor phase emissions are modeled separately, then the above information will be provided for particle phase emissions in an **aermod_P.inp** file and for vapor phase emissions in an **aermod_V.inp** file.
- **aermod.out** – a text file for combined particle and vapor phase emissions listing the inputs received by AERMOD in the aermod.inp file (noted above), any fatal error messages, warning messages, informational messages, indication of successful AERMOD set-up or not, AERMOD version number used for modeling, type of deposition and depletion modeled if any, modeling options employed, whether short-term (acute) concentrations were modeled along with their period, number and type of sources, number of receptors, vintage of meteorological data used, emission rates modeled for each source (in grams per second), elevations and hill heights of every discrete (census block or alternate) receptor and every polar grid receptor, UTM coordinates and unit HAP chronic concentration at every receptor for each source, UTM coordinates and unit HAP short-term/acute concentration (if modeled) based on the acute high value selected, the number of hours processed, the number of calm (very low wind) hours identified, the number of missing hours in the meteorological data used for modeling, and an indication whether AERMOD finished the modeling run successfully or not. Note: If particle and vapor phase emissions are modeled separately, then the above information will be provided based on particle phase emissions in an **aermod_P.out** file and for vapor phase emissions in an **aermod_V.out** file. Deposition fluxes (wet/dry) will be provided with depletion applied to concentrations, if modeled.
- **plotfile.plt** – a text file for combined particle and vapor phase emissions listing the average modeled chronic concentration at every UTM receptor location and each modeled source. Note: If particle and vapor phase emissions are modeled separately, then these concentrations will be provided based on particle phase emissions in a **plotfile_p.plt** file and in a **plotfile_v.plt** file for vapor phase emissions. Deposition fluxes (wet/dry) will be provided with depletion applied to concentrations, if modeled.
- **maxhour.plt** – a text file for combined particle and vapor phase emissions listing the modeled short-term/acute concentration (based on the acute high value indicated in your Facility List Options file) at every UTM receptor location and each modeled source. Note: If particle and vapor phase emissions are modeled separately, then these acute concentrations will be provided based on particle phase emissions in a **maxhour_p.plt** file and for vapor phase emissions in an **maxhour_v.plt** file.

Note: Concentration results provided by AERMOD in the above files should not be interpreted as predicted concentrations of any pollutant listed in the HEM4 input files. Rather, these AERMOD results reflect concentrations attributable to a unit-emission rate (1 kg/s), which HEM4 converts to specific modeled pollutant emissions, as explained in Section 5 above. To fully understand the AERMOD processing and output files, refer to the AERMOD documentation for further guidance ([EPA 2019a](#), [EPA 2019b](#)).

6.1.14 Input Selection Options

The Input Selection Options output file is a useful QA file to refer to because it provides a record of the modeling options you chose for the run, as well as the names and location of the input files you indicated. The following information is provided in this file:

- Facility ID;
- AERMOD control options used;
- Phase of emissions;
- Dispersion environment (rural or urban or blank for default);
- Whether deposition was modeled;
- Whether depletion was modeled;
- Type of deposition modeled for particle and vapor;
- Type of depletion modeled for particle and vapor;
- Whether elevations were modeled (or flat terrain used);
- Acute averaging period (e.g., 1 hour);
- Acute multiplier (factor applied to annual average emissions, if any);
- Whether building downwash was modeled;
- Whether user receptors were modeled;
- Maximum domain distance used (in meters);
- Modeling distance used (in meters);
- Overlap distance used (in meters);
- Number of polar rings used;
- Number of polar radials used;
- Whether acute was modeled;
- Distance to first ring (meter);
- Whether FASTALL was used;
- Run group name;
- Facility List Options file – name/location;
- Emissions Location file – name/location;
- HAP Emissions file – name/location;
- User Receptor file – name/location (if used);
- Particle Size file – name/location (if used);
- Building downwash file – name/location (if used);
- Buoyant line file – name/location (if used);
- Landuse file – name/location (if used);
- Month-to-Seasons file – name/location (if used);
- Polygon vertex file – name/location (if used);
- Whether Alternate Receptors were used; and
- Whether any of the Alternate Receptors were missing population values. Note: To compute incidence, population values are needed at every populated alternate receptor. Even if only one Alternate Receptor is missing a value in its population field, incidence is not computed by HEM4.

6.1.15 Acute Maximum Concentrations (Optional)

If you optionally chose to model acute impacts for a given facility, HEM4 will produce an Acute Chem Max output file. The Acute Chem Max output provides the maximum acute (short-term) pollutant concentration at any receptor for all sources combined. The “maximum” reported in this file refers to the [acute high value](#) you identified (e.g., the absolute maximum, the 99th percentile, the 98th percentile) and is based on the [acute multiplier](#) you provided (e.g., 10 times the average annual emission rate), as well as the [acute averaging period](#) (generally 1-hour) you indicated in the respective acute fields of your Facility List Options file. The maxima provided in the Acute Chem Max output may occur at any receptor—populated or unpopulated—including census blocks, alternate receptors, polar grid receptors, and user-defined receptors. This file also provides the specific location of the receptor with highest modeled concentration for each pollutant – including UTM and latitude/longitude coordinates, FIPS, Block, distance from facility center, and angle from north – as well as the elevation and hill height of the receptor. It should be noted that each pollutant may cause a different receptor to be the maximum (based on emissions of that specific pollutant). Finally, this output file also lists the acute reference concentrations for 11 different acute benchmarks, above which adverse short-term health impacts can be expected. For example, the file provides:

- the California Acute Reference Exposure Level (REL) benchmark;
- the Acute Exposure Guideline Level (AEGL1) for transient, reversible effects and AEGL2 for long-lasting, irreversible effects, based on one and eight hours of exposure;
- the Emergency Response Planning Guideline (ERPG-1) for mild or transient effects and the ERPG-2 for irreversible or serious effects, based on one hour of exposure; and
- several other acute benchmark concentrations, as described in Table 41.

The EPA’s Air Toxics Risk Assessment Library ([EPA 2017](#)) 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>). Table 39 below describes the fields of information provided in the Acute Chem Max file, and a sample file output file is provided in Appendix A.

Note: the concentrations reported in Table 39 are in $\mu\text{g}/\text{m}^3$, while the acute benchmark values (reference concentrations) are in mg/m^3 , and should therefore be multiplied by 1,000 for comparison to the modeled concentrations.

6.1.16 Acute Populated Concentrations (Optional)

If you optionally chose to model acute impacts for a given facility, HEM4 will also produce an Acute Chem Pop output file. The Acute Chem Pop file provides the same information described above in the Acute Chem Max file, but for only populated receptors (census blocks, alternate receptors and user-defined receptors), not unpopulated receptors. Therefore, the concentrations shown in this file may or may not be the acute maxima/high values for all receptors; but they are the acute high values for the populated receptors. See discussion in Section 6.1.16. Table 39 below describes the fields of information provided in the Acute Chem Max file, and a sample file output file is provided in Appendix A. **Note:** the concentrations reported in Table 39 are in $\mu\text{g}/\text{m}^3$, while the acute benchmark values (reference concentrations) are in mg/m^3 , and should therefore be multiplied by 1,000 for comparison to the modeled concentrations.

Table 39. Fields included in the Acute Chem Max and Acute Chem Pop Files

Field	Description
Pollutant	Pollutant name
Conc	High value maximum Acute Concentration in $\mu\text{g}/\text{m}^3$
Conc sci	High value maximum Acute Concentration, scientific notation, in $\mu\text{g}/\text{m}^3$
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
Population	If the receptor is a census block or alternate receptor
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. (Note: For alternate receptor run, there is a field called "Receptor ID")
Census block ID	For linking to demographic data (if the receptor is a census block). (Note: For an alternate receptor run, there is a field called "Receptor ID")
UTM east coordinate	In meters
UTM north coordinate	In meters
Latitude	Decimal
Longitude	Decimal
Receptor type	C = census block or alternate receptor, P = populated receptor user-defined receptor, PG = polar grid receptor, B = boundary receptor, M = monitor
Notes	Indicates whether the receptor was discretely (explicitly) modeled or interpolated

6.1.17 Acute Breakdown (Optional)

If you chose to optionally model acute impacts for a given facility, HEM4 also produces a third acute output file entitled Acute Bkdn, which provides the contribution (“breakdown”) of each emission source to the receptor of maximum acute impact for each pollutant (i.e., the acute concentration of pollutant at the maximum receptor for that pollutant, caused by each source). This information is provided for both the maximum/high value receptor (whether populated or nonpopulated) and for the highest populated receptor.

The acute breakdown file includes the following fields:

- pollutant;
- Source ID;
- emission type (P for particle, V for vapor, C for combined);
- the maximum pollutant concentration ($\mu\text{g}/\text{m}^3$) at a populated receptor;
- the maximum pollutant concentration ($\mu\text{g}/\text{m}^3$) at all receptors (both populated and unpopulated); and
- columns indicating whether the pollutant’s concentration at each receptor was interpolated or not.

Note: Concentration values are interpolated outside the [modeling distance](#) (e.g., between 3 km and 50 km).

6.2 Run Group Outputs

In addition to the facility-specific outputs listed in Section 6.1, HEM4 produces three summary output files, based on the results for the entire run group of modeled facilities. These multi-facility outputs are updated after the output files for the individual facilities have been created and essentially concatenate the individual facility results into group-wide summary files. In each of these three xlsx files, HEM4 writes one row of information for each facility upon completion of that facility's individual modeling run. The three group-wide output files created by HEM4 in the following sections and sample files are provided in Appendix A. Note: These files will be produced even if you are modeling only one facility.

6.2.1 Facility Max Risk and HI

The Facility Max Risk and HI output file provides the maximum modeled risk and hazard index results for every facility as well as additional facility-specific modeling results, including:

- a listing of all Facility IDs modeled;
- the cancer risk at the receptor that experiences the highest risk in the modeled radius around each facility (i.e., facility-specific MIR);
- whether or not the MIR (max cancer risk) is interpolated from nearby receptors⁹;
- the type of receptor where the MIR (max cancer risk) occurs (e.g., census block, alternate receptor, polar grid, user-defined receptor);
- the latitude and longitude of the MIR (cancer) receptor;
- the census block ID, alternate receptor ID or user receptor ID of the MIR receptor;
- the 14 TOSHLs at the receptors that experience the maximum TOSHI for each facility including: whether or not the TOSHI value is interpolated, the receptor type(s) where the max TOSHLs occur, the latitude and longitude for certain max TOSHI receptors (e.g., respiratory, neurological), and the census block ID, alternate receptor ID or user receptor ID of each max TOSHI receptor;
- the population, if any, excluded from the modeling run because of any census block centroid(s) located within the overlap distance around each emission source (and therefore considered on facility property)¹⁰;
- the cancer incidence (predicted excess cancers per year due to modeled emissions) at each facility;
- the file name of the meteorological station used in the modeling of each facility;
- the distance (in kilometers) from the facility center to the meteorological station used in the modeling run;
- the latitude and longitude location of the facility center; and
- the dispersion environment used by HEM4 for modeling each facility – rural or urban.

The TOSHLs modeled by HEM4 can impact the following organs and organ systems: respiratory; liver; neurological; developmental; reproductive; kidney; ocular; endocrine; hematological; immunological; skeletal; spleen; thyroid; and whole body. In the sample abbreviated Facility Max Risk and HI provided in Appendix A, only respiratory HI is shown,

⁹ An interpolated MIR generally suggests that the modeling distance should be increased and the facility remodeled.

¹⁰ A value in the population overlap field generally indicates that the facility should be remodeled (e.g., with a smaller overlap distance specified) to ensure that the population associated with the census block centroid(s) is accounted for.

which is commonly the highest TOSHI level based on the dispersion and inhalation modeling performed by AERMOD and HEM4.

6.2.2 Facility Cancer Risk Exposure

The Facility Cancer Risk Exposure output file lists the facilities by ID, their corresponding latitudes and longitudes (of the calculated facility centers), and the population exposed to different cancer risk levels surrounding each facility, including:

- the number of people from each facility exposed to a cancer risk level greater than or equal to 1 in 1,000 (or 1,000 in a million);
- the number of people from each facility exposed to a cancer risk level greater than or equal to 1 in 10,000 (or 100 in a million);
- the number of people from each facility exposed to a cancer risk level greater than or equal to 1 in 100,000 (or 10 in a million);
- the number of people from each facility exposed to a cancer risk level greater than or equal to 1 in 1,000,000 (or 1 in a million); and
- the number of people from each facility exposed to a cancer risk level greater than or equal to 1 in 10,000,000 (or 0.1 in a million).

Note that each row of this output file is facility-specific and does not reflect the impacts of multiple facilities with overlapping modeling domains (which may impact the same receptor and increase population numbers at various risk levels beyond what each single facility causes). A sample Cancer Risk Exposure file is provided in Appendix A.

6.2.3 Facility TOSHI Exposure

The Facility TOSHI Exposure output file lists the facilities by ID and the number of people with a TOSHI greater than 1 for each facility and for each of the 14 TOSHIs currently modeled by HEM4. Note: Because the convention of one significant figure is employed, an HI greater than 1 equates mathematically to an HI greater than or equal to 1.5. A Facility TOSHI Exposure file is provided in Appendix A.

6.2.4 Additional Run Group Outputs

HEM4 will also produce several other group output files with each run, including:

- An **Inputs folder** containing every input file used by HEM4 (that you provided) for your modeling run - a useful QA feature to ensure the inputs you intended to be modeled were indeed the ones modeled
- A Google Earth™ map showing the source locations at every facility in your modeling run - named **AllFacility_source_locations.kmz**

- A **hem4.log** text file, as described in Section 4.4, which provides a permanent record of your model run – includes the files uploaded, the output files produced, whether the run was successful and/or any errors that occurred
- If HEM4 could not model all facilities listed in your inputs, a **Skipped Facilities** file (*Skipped_Facilities.xlsx*) will be produced which simply lists the IDs of those skipped facilities. You may use this to remodel those facilities, after correcting or amending the issues that caused the facilities to be skipped. This is discussed further in Section 9.

Note: **Do not change the names of the facility-level or HEM4 output files** (discussed above), as several of these files are referenced by their specific names in the code of the Risk Summary Report programs, described next in Section 7.

7. Risk Summary Reports

You may choose to run nine different Risk Summary Reports, as described in the step-by-step HEM4 instructions in [Section 4.5](#). These reports, like the Run Group outputs described in Section 6.2, are based on risk results from all facilities modeled in your run group. However, the Risk Summary Reports have the added benefit of taking into account multiple impacts on the same receptor from nearby facilities. The nine Risk Summary Reports are described in this section.

7.1 Max Risk Summary

The Max Risk Summary output (*max_risk.xlsx*) provides the maximum cancer risk and maximum noncancer risk for all 14 TOSHI's at any populated receptor in the run group, accounting for multiple impacts on receptors from neighboring facilities. This summary also provides the FIPS and block ID for census blocks, the alternate receptor ID, or the user receptor ID of each of the maxima, as well as the receptor's population. The Max Risk Summary also lists the Facility ID(s) of the facility or facilities that impact these max receptors (i.e., contribute to the max risk and max TOSHI's at these receptors). Note: The maxima reported in this summary will equal the highest facility-specific risk and HI listed in the Facility Max Risk and HI output (discussed in Section 6.2.1), except when more than one facility's impacts on the same receptor cause the max risk and HI to be greater than the highest facility-specific risk and HI. A sample Max Risk Summary file is shown in Figure 20.

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

Figure 20. Sample Max Risk Summary Output

7.2 Cancer Drivers Summary

The Cancer Drivers output (*cancer_drivers.xlsx*) provides the pollutants and sources that are driving the maximum risk at each modeled facility (i.e., those pollutant-source combinations driving the risk at the receptor with the highest risk, for each facility). This file lists the facilities by ID; the MIR modeled at each facility from all pollutants and emission sources acting on the receptor; the predominant pollutant(s) and emission source(s) contributing to at least 90% of that facility's MIR; the cancer risk associated with each of those pollutant-source combinations; and the percentage risk contribution to the MIR for each. Figure 21 shows a sample output.

Note: The Risk Contribution column for each facility will not sum to 100%, because only the pollutant-source combinations that add to at least 90% are displayed.

A	B	C	D	E	F	
1	Facility ID	MIR	Pollutant	Cancer Risk	Risk Contribution	Source ID
2	270536222111	1.13E-06	Arsenic compounds	8.90885E-07	78.84	CEPM0005
3	270536222111	1.13E-06	Nickel compounds	2.35101E-07	20.81	CEPM0005
4	3605517127011	1.02585E-06	Arsenic compounds	9.7294E-07	94.84	CEPM0002
5	484535678711	3.45674E-07	Arsenic compounds	4.61526E-08	13.35	CEPM0006
6	484535678711	3.45674E-07	Arsenic compounds	4.25802E-08	12.32	CEPM0026
7	484535678711	3.45674E-07	Arsenic compounds	3.81743E-08	11.04	CEPM0024
8	484535678711	3.45674E-07	Arsenic compounds	3.30016E-08	9.55	CEPM0007
9	484535678711	3.45674E-07	Arsenic compounds	3.27424E-08	9.47	CEPM0001
10	484535678711	3.45674E-07	Arsenic compounds	3.24023E-08	9.37	CEPM0004
11	484535678711	3.45674E-07	Arsenic compounds	2.62015E-08	7.58	CEPM0029
12	484535678711	3.45674E-07	Arsenic compounds	2.52855E-08	7.31	CEPM0005
13	484535678711	3.45674E-07	Arsenic compounds	2.46037E-08	7.12	CEPM0003
14	484535678711	3.45674E-07	Arsenic compounds	2.29875E-08	6.65	CEPM0002
15	480292859911	2.67013E-07	Arsenic compounds	3.40035E-08	12.73	CEIT0017
16	480292859911	2.67013E-07	Arsenic compounds	3.35951E-08	12.58	CEIT0024
17	480292859911	2.67013E-07	Arsenic compounds	3.35095E-08	12.55	CEIT0019
18	480292859911	2.67013E-07	Arsenic compounds	3.3506E-08	12.55	CEIT0018
19	480292859911	2.67013E-07	Arsenic compounds	3.34516E-08	12.53	CEIT0023
20	480292859911	2.67013E-07	Arsenic compounds	3.31681E-08	12.42	CEIT0020
21	480292859911	2.67013E-07	Arsenic compounds	3.29414E-08	12.34	CEIT0022
22	480292859911	2.67013E-07	Arsenic compounds	3.28125E-08	12.29	CEIT0021

Figure 21. Sample Cancer Drivers Summary Output

7.3 Hazard Index Drivers Summary

The Hazard Index Drivers output (*hazard_index_drivers.xlsx*) provides the sources and pollutants that are driving the maximum TOSHI at each modeled facility (i.e., those source-pollutant combinations driving the HI at each receptor with the highest TOSHI, for each facility). This file lists the facilities by ID; the “HI type” (respiratory, neurological, liver, etc., for all non-zero TOSHI values); the maximum TOSHI (“HI Total”) modeled at each facility from all pollutants and emission sources acting on the receptor, the predominant sources and pollutants contributing to at least 90% of each maximum TOSHI; the TOSHI (“Hazard Index”) value associated with each of these source-pollutant combinations; and the percentage each source-pollutant combination contributes to each maximum TOSHI (for all nonzero TOSHIs at each

facility). Figure 22 shows a sample output. **Note:** The Percentage column for each facility will not sum to 100%, because only the source-pollutant combinations that add to at least 90% are displayed.

	A	B	C	D	E	F	G
1	Facility ID	HI Type	HI Total	Source ID	Pollutant	Hazard Index	Percentage
2	Fac1-NC	Developmental HI	8.9969812	SR000001	arsenic compounds	8.964020301	99.63
3	Fac1-NC	Kidney HI	1.4796741	SR000001	cadmium compounds	1.445809726	97.71
4	Fac1-NC	Respiratory HI	0.6770494	RW000001	acrolein	0.557883699	82.4
5	Fac1-NC	Respiratory HI	0.6770494	FU000001	bis(2-ethylhexyl)phthalate	0.1113999602	16.84
6	Fac1-NC	Liver HI	0.1816668	FU000001	bis(2-ethylhexyl)phthalate	0.1113999602	62.75
7	Fac1-NC	Liver HI	0.1816668	RW000001	trichloroethylene	0.066946044	36.85
8	Fac1-NC	Neurological HI	0.0882496	RW000001	trichloroethylene	0.066946044	75.86
9	Fac1-NC	Neurological HI	0.0882496	FU000001	mercury (elemental)	0.020602338	23.35
10	Fac1-NC	Reproductive HI	0.0746997	RW000001	trichloroethylene	0.066946044	89.62
11	Fac1-NC	Reproductive HI	0.0746997	RV000001	1,3-butadiene	0.007751977	10.38
12	Fac1-NC	Immunological HI	0.0671872	RW000001	trichloroethylene	0.066946044	99.64
13	Fac2-IL	Liver HI	0.0405107	FU000001	bis(2-ethylhexyl)phthalate	0.037081163	91.53
14	Fac2-IL	Respiratory HI	0.039644	FU000001	bis(2-ethylhexyl)phthalate	0.037081163	93.54
15	Fac2-IL	Neurological HI	0.0266972	FU000001	mercury (elemental)	0.023278107	87.19
16	Fac2-IL	Neurological HI	0.0266972	FU000001	mercury (elemental)	0.00256432	9.61
17	Fac1-NC	Hematological HI	0.0009175	FU000001	selenium compounds	0.000910023	99.18
18	Fac2-IL	Hematological HI	0.0008619	FU000001	selenium compounds	0.000854773	99.18
19	Fac1-NC	Skeletal HI	0.000797	RW000001	hydrofluoric acid	0.000796977	100
20	Fac1-NC	Endocrine HI	2.296E-06	RV000001	cumene	2.29579E-06	100
21	Fac2-IL	Reproductive HI	2.124E-06	FU000001	benzo[a]pyrene	1.60048E-06	75.34
22	Fac2-IL	Developmental HI	2.124E-06	FU000001	benzo[a]pyrene	1.60048E-06	75.34
23	Fac2-IL	Reproductive HI	2.124E-06	FU000001	benzo[a]pyrene	5.23844E-07	24.66
24	Fac2-IL	Developmental HI	2.124E-06	FU000001	benzo[a]pyrene	5.23844E-07	24.66

Figure 22. Sample Hazard Index Drivers Summary Output

7.4 Risk Histogram Summary

The Risk Histogram output (*histogram_risk.xlsx*) provides the population and facility counts at various risk levels. This file lists the number of people and facilities in the modeled run group in the following risk bins:

- less than 1 in 1 million risk (displayed as “<1e-6”);
- greater than or equal to 1 in 1 million risk (displayed as “>= 1e-6”);
- greater than or equal to 10 in 1 million risk (displayed at “>=1e-5”);
- greater than or equal to 100 in 1 million risk (displayed as “>=1e-4”); and
- greater than or equal to 1,000 in 1 million risk (displayed as “>=1e-3”).

Note: This program assigns populations and facilities to cancer risk bins based on their risk level after rounding to one significant figure, per EPA convention. Also, note that the Risk Histogram Summary takes into account multiple impacts on the same receptor (from facilities located close to one another). This may cause the population numbers from this file to differ from the population numbers provided by the Facility Cancer Risk Exposure file. Figure 23 shows a sample output. Finally, it should also be noted that the total population modeled in the

run group can be determined by summing cells B2 and B3; and the total number of facilities modeled can be determined by summing cells C2 and C3.

	A	B	C
1	Risk level	Population	Facility count
2	<1e-6	3088984	0
3	≥1e-6	835305	2
4	≥1e-5	45866	1
5	≥1e-4	435	1
6	≥1e-3	0	0

Figure 23. Sample Risk Histogram Summary Output

7.5 Hazard Index Histogram Summary

The Hazard Index Histogram output (hi_histogram.xlsx) provides the population and facility counts at various noncancer HI levels, for all 14 TOSHLs. This file lists the number of people and facilities in the modeled run group in the following noncancer HI bins:

- > 1,000;
- > 100;
- > 10;
- > 1; and
- ≤ 1.

Note: This program assigns populations and facilities to noncancer HI bins based on their HI level after rounding to one significant figure, per EPA convention. Also, note that the Hazard Index Histogram Summary takes into account multiple impacts on the same receptor (from facilities located close to one another). This may cause the population numbers from this file to differ from the population numbers provided by the Facility TOSHI Exposure file. Figure 24 shows an abbreviated sample output for 3 TOSHLs; the actual file shows results for 14 TOSHLs.

	A	B	C	D	E	F	G
1	HI Level	Respiratory Pop	Respiratory Facilities	Liver Pop	Liver Facilities	Neurological Pop	Neurological Facilities
2	> 1000	0	0	0	0	0	0
3	> 100	0	0	0	0	0	0
4	> 10	0	0	0	0	0	0
5	> 1	167	1	0	0	22	1
6	≤ 1	3924289	1	3924289	2	3924434	1

Figure 24. Sample Hazard Index Histogram Summary Output (Partial)

7.6 Incidence Drivers Summary

The Incidence Drivers output (*incidence_drivers.xlsx*) provides the pollutants driving the incidence across the entire run group of modeled facilities. (As noted in previous sections, the incidence is equal to the cancer risk of each block times the population of that block, divided by a 70-year lifetime, and summed over all blocks in the modeling domain.) In this file, the total incidence and individual incidence attributable to each pollutant are provided, as well as the percentage that pollutant-specific incidence is of total incidence. The pollutants are listed in descending order of contribution to the total incidence. Figure 25 shows a sample output.

	A	B	C
1	Pollutant	Incidence	% of Total Incidence
2	arsenic compounds	0.039060199	81.83%
3	1,3-butadiene	0.003666767	7.68%
4	cadmium compounds	0.003205572	6.72%
5	naphthalene	0.00105277	2.21%
6	benzene	0.000444901	0.93%
7	bis(2-ethylhexyl)phthalate	0.000219206	0.46%
8	chromium (vi) compounds	5.6644E-05	0.12%
9	trichloroethylene	1.01883E-05	0.02%
10	Total incidence	0.04773414	100%

Figure 25. Sample Incidence Drivers Summary Output

7.7 Acute Impacts Summary

The Acute Impacts output (*acute_impacts.xlsx*) provides the maximum acute concentration for every modeled pollutant, six acute benchmark values (REL, AEGL1, AEGL2, ERPG1, ERPG2 and IDLH, as defined above in Table 41), and the hazard quotient (HQ) based on the ratio of the pollutant's max acute concentration to the dose-response values for those six benchmarks. It should be noted that the max acute concentration is based on the [acute high value](#) you chose in your Facility List Options file. The file also provides the receptor ID at which this max acute concentration occurs, including the FIPS and block ID for a census block receptor, the alternate receptor ID, the user receptor ID, or the distance and angle for a polar receptor.

The Acute Impacts Summary is available only if you entered Y in the [acute column](#) of the Facility List Options input file prior to modeling, for one or more facilities in your run group. Note: The pollutant concentration is provided in mg/m³ in this output (not µg/m³ as provided by HEM4 at receptor locations in other output files) because the benchmark values are based on mg not µg). Figure 26 shows an abbreviated sample screenshot of the Acute Impacts Summary file.

7.8 Multipathway Summary

The Multipathway Summary output (*multi_pathway.xlsx*) provides arsenic, polycyclic aromatic hydrocarbon (PAH) and dioxin/furan (D/F) concentrations and risk at MIR receptors and within directional octants around each facility, which are useful for a post-HEM4 multipathway analysis.

This file lists the following information:

- the Run Group's label;
- the Facility ID;
- whether the facility was modeled using an urban or rural dispersion environment;
- whether the receptor in a given output row is an MIR or the closest receptor to the facility center in a specific octant direction (E, N, NE, NW, S, SE, SW, W);
- the pollutants the MIR is attributable to (All HAP, As for Arsenic, PAH, or D/F for Dioxins/Furans);
- whether the closest octant receptor is at a census block centroid, alternate receptor, or a discrete user receptor;
- the FIPS plus Block ID of the census receptor, or the ID of alternate and user receptor;
- the latitude and longitude location of the receptor;
- the population of the receptor;
- the total inhalation risk of that receptor (for all HAP);
- the total inhalation risk of that receptor attributable to Arsenic compounds;
- the total inhalation risk of that receptor attributable to PAHs; and
- the total inhalation risk of that receptor attributable to Dioxins/Furans.

Figure 27 shows a screenshot of a sample Multipathway Summary file. Note that blank cells indicate that emissions from this sample facility do not include arsenic, PAH, or D/F.

Facility ID	Pollutant	CONC_MG/M3	REL	AEGL_1_1H	[4 other benchmark columns]		HQ_REL	HQ_AEGL1	[4 other HQ columns based on 4 other benchmarks]	[4 columns indicating Receptor ID or distance and angle for polar receptor]
								
Fac1-NC	acetaldehyde	0.014339116	0.47	81	...	0.03050876	0.00017703
Fac1-NC	acrolein	0.100373815	0.0025	0.069	...	40.149526	1.45469297
Fac1-NC	arsenic compounds	0.069242032	0.0002	0	...	346.210161	0
Fac1-NC	benz[a]anthracene	1.61754E-06	0	0	...	0	0
Fac1-NC	benzene	0.029947323	0	170	...	0	0.00017616

Figure 26. Sample Acute Impacts Summary Output (abbreviated)

Run Group	Facility ID	Rural/Urban	Octant or MIR	Chem, Centroid, or Discrete	Fips + Block	Lat	Lon	Population	Total Inhalation Cancer Risk	Total Inhalation As Cancer Risk	Total Inhalation PAH Cancer Risk	Total Inhalation D/F Cancer Risk
test_8-8-2020	Fac1-NC	U	MIR	All HAP	370639801001074	35.89908	-78.888	3	0.000610761	0	0	0
test_8-8-2020	Fac1-NC	U	MIR	As						0	0	0
test_8-8-2020	Fac1-NC	U	MIR	PAH						0	0	0
test_8-8-2020	Fac1-NC	U	MIR	DF						0	0	0
test_8-8-2020	Fac1-NC	U	E	Centroid	370630020283011	35.89548	-78.8494	1	1.28285E-05	0	0	0
test_8-8-2020	Fac1-NC	U	N	Centroid	370630020271050	35.91643	-78.8859	55	7.45249E-05	0	0	0
test_8-8-2020	Fac1-NC	U	NE	Centroid	370630020281025	35.92024	-78.8455	3	2.99575E-05	0	0	0
test_8-8-2020	Fac1-NC	U	NW	Centroid	370630020272047	35.90438	-78.8882	7	0.000248176	0	0	0
test_8-8-2020	Fac1-NC	U	S	Centroid	370630020272057	35.89265	-78.8873	219	0.00017255	0	0	0
test_8-8-2020	Fac1-NC	U	SE	Centroid	370630020283042	35.88258	-78.864	41	1.48092E-05	0	0	0
test_8-8-2020	Fac1-NC	U	SW	Discrete	U000000000URCPT1	35.90016	-78.8888	0	0.000518777	0	0	0
test_8-8-2020	Fac1-NC	U	W	Discrete	U000000000URCPT2	35.90434	-78.8909	0	0.00018499	0	0	0

Figure 27. Sample Multipathway Summary Output

7.9 Source Type Risk Histogram Summary

The Source Type Risk Histogram Summary (*source_type_risk.xlsx*) output provides a table showing the maximum cancer risk overall for the run group, as well as individually by emission source type. For the maximum overall risk and for the source type-specific risk, the file also provides the number of people estimated at three risk levels: ≥ 1 in 1 million, ≥ 10 in 1 million, and ≥ 100 in 1 million. The overall incidence and the incidence attributable to each emission source type is also provided. Figure 28 shows a screenshot of a sample Source Type Risk Histogram Summary file.

	Maximum Overall	SR	RV	FU	MS	RW	CV	HV	CT
Cancer Risk									
Maximum (in 1 million)	600	600	5	4	0.5	0.4	0.009	0.007	0.002
Number of people									
≥ 100 in 1 million	435	435	0	0	0	0	0	0	0
≥ 10 in 1 million	48,998	37,478	0	0	0	0	0	0	0
≥ 1 in 1 million	800,229	528,652	214,494	239	0	0	0	0	0
Incidence									
	0.047	0.035	0.012	0.00022	5.9E-06	0.000011	3.3E-06	3.8E-06	2.1E-06
Run Group MIR (in a million) = 600.0									

Figure 28. Sample Sourcetype_Histogram_Sorted RTR Summary Output

Note: The Maximum Overall column lists the population at various risk levels attributable to all source types/emission process groups combined, while the other columns list the population at various risk levels attributable to each individual source type in isolation. The sum of the population tallies across the individual source types may not necessarily equal the corresponding value in the maximum overall column, at a given risk level, because: (a) two or more source types' impact in combination may be required to cause a census block population to exceed a given risk level; or conversely (b) an individual source type's impact in isolation may be enough to cause a census block population to exceed a given risk level, while other source types may similarly impact the same census block population and also (in isolation) cause that population to exceed the given risk level.

8. Understanding the Risk Results

This section contains an overview on using some of the HEM4 outputs and Risk Summary Reports to ascertain the cancer risks, noncancer hazards and acute impacts posed by a group of modeled facilities.

Step 1: Open the ***Max_Risk.xlsx*** summary report output to obtain the highest cancer risk and noncancer TOSHI_s for all the modeled facilities in your run group, as well as the max receptor IDs and population at each max receptor. You can also view the number of facilities impacting each maximum receptor (in the case of nearby facilities impacting the same receptor).

Step 2: Open the ***Facility_max_risk_and_HI.xlsx*** output to obtain the facility-specific MIR in column B (mx_can_rsk), as well as the facility-specific maximum TOSHI values in each of their respective columns. Note: the highest facility-specific maximum is not necessarily the run group maximum based on concurrent emissions from the entire group of modeled facilities. Multi-facility impacts on the same receptor (from facilities located close to one another) are not accounted for in the ***Facility_max_risk_and_HI.xlsx*** output file, because each row of this output file is specific to each individual facility. Therefore, the run group maximum reported in the ***Max_Risk.xlsx*** summary report (which, as mentioned in Step 1, accounts for multiple impacts on the same receptor from more than one facility) will either be equal to or greater than the highest facility-specific MIR in the ***Facility_max_risk_and_HI.xlsx*** output.

Step 3: Open the ***Cancer_drivers.xlsx*** output to obtain the pollutant and emission source type driving the modeled risk. To report the top cancer drivers for a run group, use the Pollutant from column C and the Source ID from column F for all rows associated with the facility showing the highest risk. The MIR value from this highest facility will equal that listed in the ***Facility_max_risk_and_HI.xlsx*** file from Step 2. Note: This output does not account for 100% of the modeled risk, but rather provides those pollutant-emission source combinations that contribute at least 90% to the facility's MIR (from one or more pollutant-emission source combinations, depending on how many combinations are needed to describe 90% of the modeled risk at each facility).

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

Step 5: Open the ***Hazard_Index_Drivers.xlsx*** output to obtain the pollutant and emission source driving all (non-zero) TOSHI_s at each modeled facility. To report the top HI drivers for a run group, use the Pollutant from column E and the Source ID from column D for all rows associated with the facility showing the highest total TOSHI in column C ("HI Total"). The TOSHI value from this highest facility should equal the TOSHI value listed in the ***Facility_max_risk_and_HI.xlsx*** file from Step 2. Note: This output

does not account for 100% of the modeled TOSHI, but rather provides those pollutant-emission source combinations that contribute at least 90% to the facility's total TOSHI.

Step 6: Open the ***Hi_histogram.xlsx*** output to obtain the number of people and facilities at various HI levels for each of the 14 TOSHIs. These numbers are based on the one significant figure rounding convention (e.g., an HI of 1.4 rounds to 1 and so is considered ≤ 1).

Step 7: Open the ***Incidence_drivers.xlsx*** output to obtain the run group-wide incidence attributable to each pollutant. This file is sorted in descending order of incidence and column C provides the percentage each pollutant drives the total incidence for all of your modeled facilities.

Step 8: Open the ***Source_type_risk.xlsx*** output to obtain the number of people at various risk levels caused by each emission source type, and the incidence attributable to each source type. This output also shows the run group MIR and the number of people at various risk levels attributable to all source types combined ("Maximum Overall" which accounts for impacts on the same receptor by different source types), as well as the overall incidence.

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

Step 10: Open the ***AllFacility_source_locations.kmz*** output to see all modeled sources at each facility in your run group on a Google Earth™ map. This map provides a ready view of the distance between your modeled facilities, and it allows you to perform QA to determine whether the modeled locations of your sources are reasonable.

For additional details regarding the modeling results for each of the facilities in the run group, open the individual facility subfolders in the output folder. Section 6 discusses these facility-specific output files. Each facility folder also contains a ***source_risk.kmz*** output file which displays the detailed modeled risk results for that facility on a Google Earth™ map.

Finally, HEM4 provides numerous graphical ways to review and understand your outputs, as discussed further in [Section 4.6](#) regarding the *Analyze Outputs* buttons on the HEM4 interface.

9. Quality Assurance Remodeling

There are several quality assurance (QA) checks that you should perform after HEM4 has completed modeling each of your facilities. These QA checks should be made before you run the Risk Summary Reports (described in [Section 4.5](#)), to determine if any of the facilities need to be revised and remodeled.

Ensuring the Maximum Individual Risk (MIR) and Max Target Organ-Specific Hazard Index (TOSHIs) are Located at Populated Receptors

First, open and review the ***Facility_max_risk_and_HI.xlsx*** file to ensure that:

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

The cancer risk and noncancer TOSHI QA checks described above are especially important for facilities of interest, such as those facilities with relatively high cancer risk or TOSHI values in the modeled set. Remodel those facilities (as described below) that failed one or more of the QA checks before running the Risk Summary Reports. Rerunning HEM4 for such facilities will ensure that all facilities in the run group are modeled and that the modeled maximum risk and TOSHI values occur at populated receptors.

Follow these steps to rerun a facility when the MIR or the maximum TOSHI occurs at an unpopulated receptor (such as a polar grid receptor)¹¹. First, review the ***Source_risk.kmz*** file located in the individual facility subfolder. Opening this file will start Google Earth™ if it is installed on your computer. [Figure 29](#) shows a sample Google Earth™ kmz output file.

Zoom in on the facility center and turn on the polar grid (by checking the box next to “Polar receptor cancer risk” in the Places key) to make visible the polar grid receptor at which the MIR or TOSHI value occurs. Next, find the census block centroid closest to the MIR polar receptor. Use the ‘ruler’ tool to measure the distance (in meters) from the census block centroid to the approximate facility center. Increase this distance enough to ensure that a census block centroid near the current polar MIR receptor will be closer to the facility center than this revised first polar ring when the facility is rerun, as explained further below. Follow these steps for all facilities of interest requiring remodeling due to an overlapped populated receptor.

¹¹ The MIR or maximum TOSHI can occur at a polar grid receptor if there is a census block or alternate receptor located within the overlap distance of the facility boundary. In this case, HEM4 will select the closest receptor to the facility boundary (i.e., census block, alternate, user-defined, or polar) to estimate the MIR at a location nearest to the population inside the overlap distance that has been excluded.



Figure 29. Sample Source_risk.kmz HEM4 Output

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

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

Re-start HEM4 using the new **QA1_Facility_list_options.xlsx** file as an input. (Note: There may be extra facilities in the *HAP Emissions* and *Emissions Location* files from your original run, because HEM4 will only use data for the facilities listed in the Facility List Options file you specify for the QA run.) HEM4 will then remodel the facilities with revised first ring distances. This “bumping out” of the first polar ring will allow HEM4 to choose a populated census block or alternate receptor as the MIR or TOSHI receptor, because the first polar ring of polar receptors will be more distant from the facility center than the closest populated receptor. When re-running HEM4, it is advisable to name the ‘output’ folder using “QA1” in case additional QA runs are necessary.

Once you have rerun the facility or facilities, check the outputs to determine if the relevant MIR or TOSHI is now at a populated receptor by opening the **QA1_Facility_max_risk_and_HI.xlsx** file. If the MIR or TOSHI is still at a polar grid receptor, repeat the above steps (starting with opening the **Source_risk.kmz** file) using the identifier QA2 for the naming convention. Make the first ring of the polar grid more distant from the facility center than in the first adjustment.

After you have successfully adjusted the distance so that the MIR and maximum TOSHIs occur at populated receptors, copy the most recent facility rows from all **QA_Facility_max_risk_and_HI.xlsx** files (e.g., QA1, QA2, QA3) into the original **Facility_max_risk_and_HI.xlsx** file.

Perform this row replacement for each remodeled facility, using the most recent QA run applicable to that facility. In addition, replace the original subfolder for each remodeled facility by copying the most recent facility output subfolder (including all its revised contents) from the QA run to the location of the original facility output. Move or delete the original subfolder.

Ensuring Maxima are Discretely Modeled, not Interpolated:

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

Open the **Source_risk.kmz** file located in the individual facility subfolder to determine if a facility with an interpolated MIR and/or TOSHI should be remodeled with an increased modeling distance. This Google Earth™ kmz file will show where the closest populated receptors are located. The modeling distance should be increased to include the populated receptor(s). Use Google Earth's™ ruler tool to determine the new modeling distance. Remember to increase this distance slightly before remodeling the facility in a QA run, as discussed above. Note: If the risk and all TOSHIs are considered low—and if the reason for the low values is that the facility is located in a sparsely populated area—you may decide that revising the modeling distance and remodeling is not necessary.

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

In general, the image of each facility's emission sources and receptors on a Google Earth™ satellite map (i.e., the **Source_risk.kmz** file) is a powerful tool for QA checks of the inputs and modeling parameters that HEM4 uses (see [Figure 29](#) above as an example). It is best practice to review each **Source_risk.kmz** file, even if all MIR and TOSHI values listed in the **Facility_max_risk_and_HI.xlsx** output occur at populated receptors and no values are interpolated. Reviewing these map images allows you to determine if sources are mislocated and require remodeling and if the surrounding populations are represented well enough by the populated receptors. (If surrounding populations are not represented sufficiently by the receptors, you can remodel with the addition of user-defined receptors placed near residences.)

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

Once you have performed all QA checks and remodeled any facilities, you are ready to run the Risk Summary Reports, as described in [Section 4.5](#). The Risk Summary Report programs need as inputs the final *Facility_max_risk_and_HI.xlsx* and several facility-specific outputs (depending on the HEM4 options you selected and which Risk Summary Reports you run). **Therefore, do not rename the HEM4 output files.**

Modeling Skipped Facilities:

As noted in [Section 4.8](#), if HEM4 is unable to model a facility or facilities due to errors in the inputs, HEM4 will produce an Excel file entitled “Skipped Facilities” (*Skipped_facilities.xlsx*) in the run group’s output subfolder. After you fix the errors in the inputs, you can use the list of skipped facilities in column A of this output file to create a new Facility List Options file. Use the new Facility List Options file to model the facilities as a group. Then copy the resulting skipped facility output folders back into the directory/folder containing the original group’s modeled outputs. Next, append the resulting Facility Mask Risk and HI rows into the original Facility Max Risk and HI file (described in Section 6.2.1). Do the same appending for the Facility Cancer Risk Exposure file (described in Section 6.2.2) and the Facility TOSHI Exposure file (described in Section 6.2.3). Finally, run the Risk Summary Reports on the full set of HEM4 outputs (as described in Section 4.5 and Section 7).

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11. Appendix A: Sample HEM4 Output Files

This appendix contains examples (some abbreviated to fit) of the facility-specific and run group HEM4 output files. Sample Risk Summary Reports are provided in Section 7.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Parameter	Value	Value rounded	Value scientific notation	Population	Distance (m)	Angle (from north)	Elevation (m)	Hill height (m)	FIPS	Block	UTM easting	UTM northing	Latitude	Longitude	Receptor type	Notes	
Cancer risk	0.00061	0.0006	6.1e-04	3	491.8557	217.7	89.7	89.7	37063	9801001074	690605	3974816	35.89908	-78.888	Census block	Discrete	
Respiratory HI	0.67705	0.7	6.8e-01	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Liver HI	0.18167	0.2	1.8e-01	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Neurological HI	0.08825	0.09	8.8e-02	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Developmental HI	8.99698	9	9.0e+00	3	491.8557	217.7	89.7	89.7	37063	9801001074	690605	3974816	35.89908	-78.888	Census block	Discrete	
Reproductive HI	0.0747	0.07	7.5e-02	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Kidney HI	1.47967	1	1.5e+00	3	491.8557	217.7	89.7	89.7	37063	9801001074	690605	3974816	35.89908	-78.888	Census block	Discrete	
Ocular HI	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Endocrine HI	2.3E-06	2E-06	2.3e-06	219	1124.139	191.4	85.8	85.8	37063	0020272057	690684	3974103	35.89265	-78.8873	Census block	Discrete	
Hematological HI	0.00092	0.0009	9.2e-04	3	491.8557	217.7	89.7	89.7	37063	9801001074	690605	3974816	35.89908	-78.888	Census block	Discrete	
Immunological HI	0.06719	0.07	6.7e-02	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Skeletal HI	0.0008	0.0008	8.0e-04	0	459.4366	233.9	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	Discrete	
Spleen HI	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Thyroid HI	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Whole body HI	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	

Figure 30. Sample Maximum Individual Risk HEM4 Output (facility-specific)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Parameter	Value	Value_rnd	Value_sci	Population	Distance (in meters)	Angle (from north)	Elevation (in meters)	Hill Height (in meters)	Fips	Block	Utm_east	Utm_north	Latitude	Longitude	Rec_type	
Cancer risk	0.000783	0.0008	7.8e-04	0	565	67.5	92	92			691428	3975421	35.90438	-78.878745	Polar grid	
Respiratory HI	0.677049	0.7	6.8e-01	0	459.436612	233.85	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	
Liver HI	0.277505	0.3	2.8e-01	0	565	90	92	92			691471	3975205	35.90242	-78.878321	Polar grid	
Neurological HI	0.08825	0.09	8.8e-02	0	459.436612	233.85	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	
Developmental HI	11.47101	10	1.1e+01	0	565	67.5	92	92			691428	3975421	35.90438	-78.878745	Polar grid	
Reproductive HI	0.0747	0.07	7.5e-02	0	459.436612	233.85	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	
Kidney HI	1.974576	2	2.0e+00	0	565	67.5	92	92			691428	3975421	35.90438	-78.878745	Polar grid	
Ocular HI	0	0	0	0	0	0	0	0			0	0	0	0	0	
Endocrine HI	4.2E-06	4E-06	4.2e-06	0	565	90	92	92			691471	3975205	35.90242	-78.878321	Polar grid	
Hematological HI	0.001641	0.002	1.6e-03	0	565	90	92	92			691471	3975205	35.90242	-78.878321	Polar grid	
Immunological HI	0.067187	0.07	6.7e-02	0	459.436612	233.85	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	
Skeletal HI	0.000797	0.0008	8.0e-04	0	459.436612	233.85	90.5	90.5	U0000	0000URCPT1	690535	3974934	35.90016	-78.88875	User receptor	
Spleen HI	0	0	0	0	0	0	0	0			0	0	0	0	0	
Thyroid HI	0	0	0	0	0	0	0	0			0	0	0	0	0	
Whole body HI	0	0	0	0	0	0	0	0			0	0	0	0	0	

Figure 31. Sample Maximum Offsite Risk HEM4 Output (facility-specific)

A	B	C	D	E	F	G	H	I	J	K	L
Site type	Parameter	Source ID	Pollutant	Emission type	Value	Value rounded	Conc (ug/m3)	Conc rounded (ug/m3)	Emissions (tpy)	URE 1/(ug/m3)	RFc (mg/m3)
Max indiv risk	Cancer risk	CT000001	All modeled pollutants	NA	1.88E-09	2E-09	6.95E-10	7E-10	2.456E-07	0	0
Max indiv risk	Cancer risk	CT000001	2,3,4,7,8-pentachlorodibenzofuran	C	1.04E-09	1E-09	1.05E-10	1E-10	3.7E-08	9.9	1.3E-07
Max indiv risk	Cancer risk	CT000001	1,2,3,7,8-pentachlorodibenzo-p-dioxin	C	2.25E-10	2E-10	6.82E-12	7E-12	2.41E-09	33	4E-08
...
Max indiv risk	Cancer risk	Total	All pollutants all sources	NA	0.000611	0.0006	1.964495	2	39.355593	0	0
Max indiv risk	Cancer risk	Total by pollutant all sources	arsenic compounds	NA	0.000579	0.0006	0.134549	0.1	1.06	0	0
Max indiv risk	Cancer risk	Total by pollutant all sources	cadmium compounds	NA	2.61E-05	0.00003	0.014526	0.01	0.2	0	0
...
Max offsite impact	Cancer risk	CT000001	All modeled pollutants	NA	6.26E-09	6E-09	2.31E-09	2E-09	2.456E-07	0	0
Max offsite impact	Cancer risk	CT000001	2,3,4,7,8-pentachlorodibenzofuran	C	3.44E-09	3E-09	3.48E-10	3E-10	3.7E-08	9.9	1.3E-07
...
Max offsite impact	Cancer risk	Total	All pollutants all sources	NA	0.000783	0.0008	2.157177	2	39.355593	0	0
Max offsite impact	Cancer risk	Total by pollutant all sources	arsenic compounds	NA	0.000739	0.0007	0.171925	0.2	1.06	0	0
Max offsite impact	Cancer risk	Total by pollutant all sources	cadmium compounds	NA	3.54E-05	0.00004	0.019652	0.02	0.2	0	0
...
Max indiv risk	Developmental HI	CT000001	2,3,4,7,8-pentachlorodibenzofuran	C	0	0	1.05E-10	1E-10	3.7E-08	9.9	1.3E-07
Max indiv risk	Developmental HI	CT000001	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	C	0	0	5.15E-12	5E-12	1.82E-09	3.3	4E-07
...
Max indiv risk	Developmental HI	CT000001	All modeled pollutants	NA	0	0	6.95E-10	7E-10	2.456E-07	0	0
...
Max indiv risk	Developmental HI	Total	All pollutants all sources	NA	8.996981	9	1.964495	2	39.355593	0	0
Max indiv risk	Developmental HI	Total by pollutant all sources	arsenic compounds	NA	8.969901	9	0.134549	0.1	1.06	0	0
Max indiv risk	Developmental HI	Total by pollutant all sources	trichloroethylene	NA	0.027078	0.03	0.054157	0.05	0.24	0	0
...
Max offsite impact	Developmental HI	CT000001	2,3,4,7,8-pentachlorodibenzofuran	C	0	0	3.48E-10	3E-10	3.7E-08	9.9	1.3E-07
Max offsite impact	Developmental HI	CT000001	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	C	0	0	1.71E-11	2E-11	1.82E-09	3.3	4E-07
...
Max offsite impact	Developmental HI	CT000001	All modeled pollutants	NA	0	0	2.31E-09	2E-09	2.456E-07	0	0
...
Max offsite impact	Developmental HI	Total	All pollutants all sources	NA	11.47101	10	2.157177	2	39.355593	0	0
Max offsite impact	Developmental HI	Total by pollutant all sources	arsenic compounds	NA	11.46165	10	0.171925	0.2	1.06	0	0
Max offsite impact	Developmental HI	Total by pollutant all sources	trichloroethylene	NA	0.009358	0.009	0.018716	0.02	0.24	0	0
...

Figure 32. Sample Risk Breakdown HEM4 Output (facility-specific, abbreviated)

Note: To capture the full extent of the kind of information provided in this output, the above sample Risk Breakdown file includes missing rows as indicated by the ellipses (...) for risk by individual source and pollutant, for risk by individual source and all pollutants combined, and for risk by individual pollutant and all sources combined. The above sample file also depicts only one of the 14 TOSHLIs (Developmental HI) included in the actual file. The file includes the above breakdown for cancer risk and for all 14 (noncancer) TOSHLIs, for both populated receptors ("Max indiv risk") and for any receptor whether populated or unpopulated ("Max offsite impact").

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Latitude	Longitude	Overlap	Elevation	FIPS	Block	X	Y	Hill	Population	MIR	Respiratory HI	Liver HI	Neurological HI	...
36.09438	-79.38606	N	181.3	37001	203004018	645293	3995623	181.3	66	3.86E-07	0.000246666	3.85E-05	1.43E-05	...
36.09624	-79.37883	N	173.5	37001	203005002	645941	3995840	173.5	3	3.89E-07	0.000248244	3.87E-05	1.43E-05	...
36.09475	-79.38259	N	178.3	37001	203005005	645605	3995669	178.3	3	3.88E-07	0.000247772	3.86E-05	1.43E-05	...
36.09726	-79.38345	N	173.7	37001	203005007	645523	3995946	173.7	55	3.85E-07	0.000245794	3.83E-05	1.42E-05	...
36.09843	-79.3833	N	171.2	37001	203005008	645534	3996075	171.2	35	3.84E-07	0.00024509	3.82E-05	1.42E-05	...
36.08863	-79.3819	N	174.5	37001	203005010	645678	3994991	174.5	57	3.94E-07	0.0002521	3.93E-05	1.46E-05	...
36.092	-79.38435	N	185.3	37001	203005011	645452	3995361	185.3	2	3.89E-07	0.000248895	3.88E-05	1.44E-05	...
36.09427	-79.38459	N	179.3	37001	203005012	645426	3995613	179.3	13	3.87E-07	0.000247309	3.86E-05	1.43E-05	...
36.09397	-79.38536	N	183.4	37001	203005013	645357	3995577	183.4	2	3.87E-07	0.000247214	3.86E-05	1.43E-05	...
36.09193	-79.38555	N	185.4	37001	203005014	645343	3995351	185.4	13	3.88E-07	0.000248466	3.88E-05	1.44E-05	...
36.09238	-79.38517	N	184.4	37001	203005015	645377	3995402	184.4	10	3.88E-07	0.000248321	3.87E-05	1.44E-05	...
36.09002	-79.38582	N	181	37001	203005017	645323	3995140	181	14	3.90E-07	0.000249604	3.90E-05	1.44E-05	...
36.08975	-79.38621	N	178	37001	203005018	645288	3995109	178	11	3.90E-07	0.000249626	3.90E-05	1.44E-05	...
36.08996	-79.3878	N	183.5	37001	203005019	645144	3995129	183.5	19	3.89E-07	0.000248859	3.89E-05	1.44E-05	...
36.0873	-79.38689	N	183.1	37001	203005039	645232	3994836	183.1	36	3.91E-07	0.000250958	3.92E-05	1.45E-05	...
36.08769	-79.3852	N	181.4	37001	203005040	645383	3994881	181.4	37	3.92E-07	0.00025139	3.93E-05	1.46E-05	...
36.08671	-79.3833	N	174.7	37001	203005042	645556	3994776	174.7	24	3.94E-07	0.000252807	3.95E-05	1.46E-05	...
36.08729	-79.38956	N	189.6	37001	203005046	644991	3994831	189.6	82	3.90E-07	0.000249883	3.90E-05	1.45E-05	...
36.08615	-79.38586	N	181.1	37001	203005048	645326	3994709	181.1	26	3.93E-07	0.000252133	3.94E-05	1.46E-05	...
36.08476	-79.38295	N	171.2	37001	203005050	645591	3994560	171.2	12	3.96E-07	0.000254249	3.97E-05	1.47E-05	...
36.08756	-79.37782	N	169.4	37001	203005052	646047	3994878	169.4	24	3.97E-07	0.000254489	3.97E-05	1.47E-05	...
36.0909	-79.37605	N	166.8	37001	203005053	646200	3995251	166.8	99	3.95E-07	0.000252943	3.94E-05	1.46E-05	...
36.0907	-79.37304	N	156.3	37001	203005054	646472	3995234	156.3	19	3.98E-07	0.000254301	3.96E-05	1.47E-05	...
36.09164	-79.37145	N	157.3	37001	203005056	646614	3995340	157.3	8	3.98E-07	0.000254305	3.96E-05	1.47E-05	...
36.09327	-79.37612	N	166	37001	203005057	646190	3995514	166	24	3.93E-07	0.000251308	3.92E-05	1.45E-05	...
36.0889	-79.37362	N	154.5	37001	203005061	646424	3995033	154.5	46	3.99E-07	0.00025531	3.98E-05	1.48E-05	...
36.08887	-79.371	N	157	37001	203005062	646659	3995034	157	16	4.01E-07	0.000256407	4.00E-05	1.48E-05	...
36.08803	-79.37061	N	159.1	37001	203005063	646696	3994941	159.1	17	4.02E-07	0.000257159	4.01E-05	1.49E-05	...
...

Figure 33. Sample Block Summary Chronic HEM4 Output (facility-specific, abbreviated)

Note: The Block Summary Chronic file is large because it includes the cancer risk ("MIR") and all 14 TOSHLIs for every modeled block or alternate receptor. The above sample file includes ellipses (...) because it shows only a partial list of rows and only 3 of the 14 TOSHI's (Respiratory HI, Liver HI and Neurological HI). In addition, the actual file includes a final column indicating whether the concentration (and therefore risk and TOSHLIs) at each receptor were discretely modeled or interpolated.

Latitude	Longitude	Overlap (m)	Elevation			Hill	MIR	Respiratory HI	Liver HI	Neurological HI	Developmental HI	...	Distance (m)	Angle (from north)	Sector	
				X	Y											
35.90762	-78.88444	N		92	690906	3975770	92	0.000276	0.16267133	0.06719334	0.022959781	4.061680358	...	565	0	1
35.91028	-78.88437	N		85	690906	3976065	85	0.000163	0.08834714	0.03991907	0.012732447	2.405209191	...	860	0	1
35.91433	-78.88426	N		86	690906	3976515	86	9.86E-05	0.05006334	0.02351642	0.007284751	1.449323028	...	1310	0	1
35.92046	-78.8841	N		86	690906	3977195	86	5.67E-05	0.02748919	0.01321489	0.004022705	0.830353561	...	1990	0	1
35.92956	-78.88386	N		98	690906	3978205	98	3.29E-05	0.01497071	0.00728229	0.002192643	0.476986257	...	3000	0	1
35.94127	-78.88355	N		108	690906	3979505	108	1.98E-05	0.00851103	0.00414235	0.001235919	0.283698446	...	4300	0	1
35.95749	-78.88311	N		128	690906	3981305	128	1.19E-05	0.00487219	0.00221982	0.000669144	0.164677271	...	6100	0	1
35.98092	-78.88249	N		128	690906	3983905	128	7.18E-06	0.00297086	0.00127924	0.000389865	0.098200187	...	8700	0	1
36.01425	-78.88159	N		126	690906	3987605	126	4.30E-06	0.00182397	0.00072968	0.000225519	0.057813435	...	12400	0	1
36.0611	-78.88034	N		134	690906	3992805	134	2.61E-06	0.0011715	0.00040331	0.000128775	0.03383493	...	17600	0	1
36.12777	-78.87855	N		174	690906	4000205	174	1.60E-06	0.00087183	0.00020231	7.08E-05	0.018804954	...	25000	0	1
36.22237	-78.87599	N		234	690906	4010705	234	9.40E-07	0.00061899	9.59E-05	3.64E-05	0.00985544	...	35500	0	1
36.35301	-78.87245	N		207	690906	4025205	207	6.14E-07	0.00039616	6.43E-05	2.42E-05	0.00651898	...	50000	0	1
35.90719	-78.88206	N		92	691122	3975727	92	0.000317	0.20423035	0.08411586	0.028758088	4.672317905	...	565	22.5	2
35.90963	-78.88074	N		92	691235	3976000	92	0.000192	0.10610333	0.04725769	0.015216162	2.82876806	...	860	22.5	2
35.91334	-78.87874	N		86	691407	3976415	86	0.000106	0.05416447	0.02491204	0.007832226	1.5593033	...	1310	22.5	2
35.91895	-78.8757	N		86	691668	3977044	86	5.91E-05	0.02814812	0.01306979	0.004078483	0.86713832	...	1990	22.5	2
35.92728	-78.8712	N		98	692054	3977977	98	3.20E-05	0.01471825	0.00679289	0.002115014	0.466186678	...	3000	22.5	2
35.938	-78.86539	N		115	692552	3979178	115	1.81E-05	0.00825512	0.00360303	0.001123976	0.256202648	...	4300	22.5	2
35.95285	-78.85736	N		126	693240	3980841	126	1.10E-05	0.00516917	0.00198365	0.000625377	0.149211565	...	6100	22.5	2
35.9743	-78.84575	N		126	694235	3983243	126	6.79E-06	0.00327005	0.00114822	0.000363808	0.089533991	...	8700	22.5	2
36.00481	-78.82921	N		122	695651	3986661	122	4.11E-06	0.00201365	0.00066383	0.000211097	0.053338866	...	12400	22.5	2
36.04769	-78.80594	N		119	697641	3991465	119	2.48E-06	0.00123679	0.00037985	0.000121813	0.031601403	...	17600	22.5	2
36.1087	-78.77729	N		128	700473	3998302	128	1.51E-06	0.00079302	0.00020903	6.91E-05	0.018536631	...	25000	22.5	2
36.19526	-78.72566	N		185	704491	4008003	185	9.14E-07	0.00055697	0.00010008	3.60E-05	0.010134297	...	35500	22.5	2
36.31474	-78.66039	N		161	710040	4021399	161	5.74E-07	0.0003369	6.18E-05	2.22E-05	0.006426578	...	50000	22.5	2
35.90606	-78.88005	N		92	691306	3975605	92	0.000421	0.26615504	0.10388434	0.036941868	6.177728359	...	565	45	3
35.90789	-78.8777	N		92	691514	3975813	92	0.000272	0.16583271	0.06683816	0.023219576	3.998420365	...	860	45	3
...

Figure 34. Sample Ring Summary Chronic HEM4 Output (facility-specific, abbreviated)

Note: The Ring Summary Chronic file includes the cancer risk ("MIR") and all 14 TOSHI's for every modeled polar receptor. The above sample file includes ellipses (...) because it shows only a partial list of rows and only 4 of the 14 TOSHI's (Respiratory HI, Liver HI, Neurological HI, and Developmental HI). The final 3 columns shown (above) cycle through polar receptor ring distances over each angle from north (or sector) for a total of 16 angles/sectors by default, unless you indicate a different number of radials in your Facility List Options file.

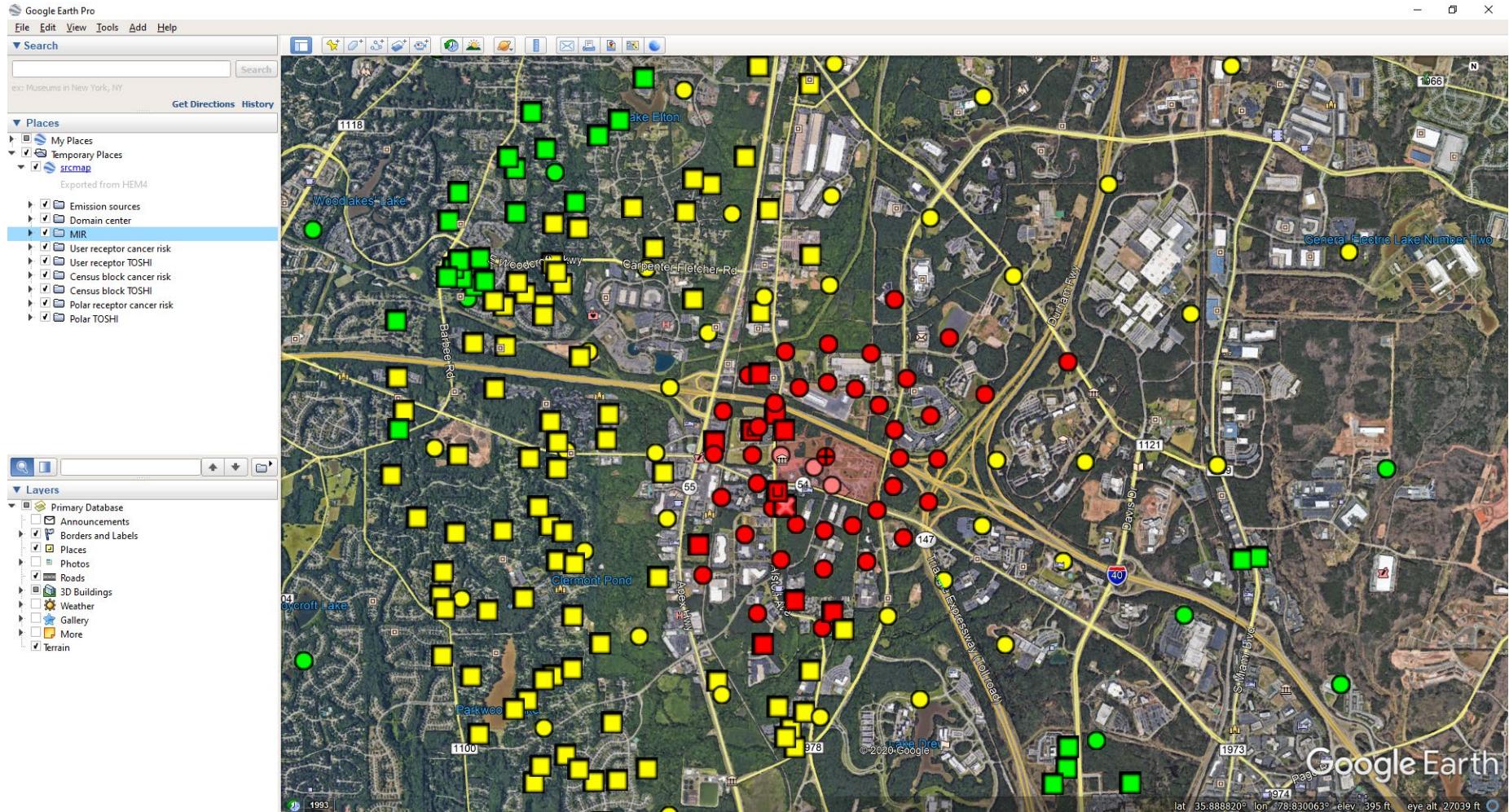


Figure 35. Sample Source Risk KMZ Google Earth™ Image (facility-specific)

A	B	C	D	E
Source ID	Pollutant	Emission type	Incidence	Incidence rounded
Total	All modeled pollutants	C	0.047682	0.048
CT000001	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	C	1.513E-09	1.5E-09
CT000001	1,2,3,4,6,7,8-heptachlorodibenzofuran	C	6.008E-09	6E-09
CT000001	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	C	1.238E-08	1.2E-08
CT000001	1,2,3,4,7,8-hexachlorodibenzofuran	C	1.44E-07	1.4E-07
CT000001	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	C	1.317E-08	1.3E-08
CT000001	1,2,3,6,7,8-hexachlorodibenzofuran	C	1.296E-07	1.3E-07
CT000001	1,2,3,7,8,9-hexachlorodibenzofuran	C	2.316E-08	2.3E-08
CT000001	1,2,3,7,8-pentachlorodibenzo-p-dioxin	C	1.744E-07	1.7E-07
...
Total	1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	C	5.041E-10	5E-10
Total	1,2,3,4,6,7,8,9-octachlorodibenzofuran	C	5.209E-11	5.2E-11
Total	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	C	8.953E-09	9E-09
Total	1,2,3,4,6,7,8-heptachlorodibenzofuran	C	3.556E-08	3.6E-08
CT000001	All modeled pollutants	C	1.462E-06	0.0000015
CV000001	All modeled pollutants	C	3.309E-06	0.0000033
FU000001	All modeled pollutants	C	0.0001703	0.00017
HV000001	All modeled pollutants	C	3.88E-06	0.0000039
MS000001	All modeled pollutants	C	5.983E-06	0.000006
RV000001	All modeled pollutants	C	0.0051644	0.0052
RV000002	All modeled pollutants	C	3.079E-06	0.0000031
RV000003	All modeled pollutants	C	1.772E-06	0.0000018
RV000004	All modeled pollutants	C	0.0069082	0.0069
RW000001	All modeled pollutants	C	1.116E-05	0.000011
SR000001	All modeled pollutants	C	0.0354084	0.035

Figure 36. Sample Incidence HEM4 Output (facility-specific, abbreviated)

Note: The sample Incidence file above includes ellipses (...) for some rows because the file is too long to depict fully. The above rows indicate the kinds of information provided in this file.

A	B
1 Level	Population
2 Greater than or equal to 1 in 1,000	0
3 Greater than or equal to 1 in 10,000	435
4 Greater than or equal to 1 in 20,000	2119
5 Greater than or equal to 1 in 100,000	48998
6 Greater than or equal to 1 in 1,000,000	800221
7 Greater than or equal to 1 in 10,000,000	1545731

Figure 37. Sample Cancer Risk Exposure HEM4 Output (facility-specific)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Level	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	Whole body HI
Greater than 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater than 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater than 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater than 1.0	0	0	0	435	0	0	0	0	0	0	0	0	0	0
Greater than 0.5	0	0	0	3065	0	12	0	0	0	0	0	0	0	0
Greater than 0.2	12	0	0	19289	0	432	0	0	0	0	0	0	0	0

Figure 38. Sample Noncancer Risk Exposure HEM4 Output (facility-specific)

A	B	C	D	E	F	G	H	I	J	K	L	M
FIPS	Block	Latitude	Longitude	Source ID	Emission type	Pollutant	Conc	Elevation	Dry deposition	Wet deposition	Population	Overlap
							(ug/m3)	(m)	(g/m2/yr)	(g/m2/yr)		
17063	1022007	41.459428	-88.264967	CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	1.00E-11	189.2	2.15E-12	2.46E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	6.50E-13	189.2	1.40E-13	1.60E-13	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	6.93E-13	189.2	1.49E-13	1.70E-13	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	6.25E-12	189.2	1.34E-12	1.53E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	6.97E-12	189.2	1.49E-12	1.71E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	1.11E-12	189.2	2.38E-13	2.72E-13	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	4.56E-12	189.2	9.78E-13	1.12E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	2.95E-12	189.2	6.32E-13	7.24E-13	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	5.92E-13	189.2	1.27E-13	1.45E-13	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	6.37E-12	189.2	1.37E-12	1.56E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	indeno[1,2,3-c,d]pyrene	4.06E-11	189.2	8.70E-12	9.96E-12	11	N
17063	1022007	41.459428	-88.264967	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	7.57E-13	189.2	1.62E-13	1.86E-13	11	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	9.21E-12	189.1	2.00E-12	2.27E-12	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	5.97E-13	189.1	1.29E-13	1.47E-13	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	6.36E-13	189.1	1.38E-13	1.57E-13	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	5.73E-12	189.1	1.24E-12	1.41E-12	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	6.39E-12	189.1	1.39E-12	1.58E-12	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	1.02E-12	189.1	2.21E-13	2.51E-13	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	4.18E-12	189.1	9.07E-13	1.03E-12	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	2.71E-12	189.1	5.87E-13	6.68E-13	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	5.43E-13	189.1	1.18E-13	1.34E-13	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	5.84E-12	189.1	1.27E-12	1.44E-12	16	N
17063	1022008	41.4587614	-88.2642443	CT000001	P	indeno[1,2,3-c,d]pyrene	3.72E-11	189.1	8.08E-12	9.19E-12	16	N
...

Figure 39. Sample All Inner Receptors HEM4 Output (facility-specific, abbreviated)

Note: The Dry deposition and Wet deposition flux columns will be blank if you did not choose to model deposition in your Facility List Options file.

A	B	C	D	E	F	G	H	I	J	K
FIPs	Block	Latitude	Longitude	Source ID	Emission type	Pollutant	Conc ($\mu\text{g}/\text{m}^3$)	Elevation (m)	Population	Overlap
17093	8907002213	41.5097585	-88.271948	CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	8.50E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	5.51E-13	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	5.87E-13	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	5.29E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	5.90E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	9.40E-13	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	3.86E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	2.50E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	5.01E-13	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	5.39E-12	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	indeno[1,2,3-c,d]pyrene	3.44E-11	177.7	5	N
17093	8907002213	41.5097585	-88.271948	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	6.41E-13	177.7	5	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	5.56E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	3.61E-13	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	3.84E-13	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	3.46E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	3.86E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	6.15E-13	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	2.53E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	1.63E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	3.28E-13	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	3.53E-12	173.3	11	N
17093	8907002186	41.4973643	-88.294909	CT000001	P	indeno[1,2,3-c,d]pyrene	2.25E-11	173.3	11	N
...

Figure 40. Sample All Outer Receptors HEM4 Output file (facility-specific, abbreviated)

Note: The All Outer Receptor file tends to be a very large file, especially if you chose to model with the default maximum distance for your modeling domain of 50 kilometers and a default (discrete / inner) modeling distance of 3 kilometers. Deposition flux is not calculated for the outer modeling domain represented by the All Outer Receptor file, so these columns will not appear in this file even if you chose to model deposition.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Source ID	Emission type	Pollutant	Conc	Distance	Angle	Sector	Ring number	Elevation (m)	Latitude	Longitude	Overlap	Wet deposition	Dry deposition
			(ug/m3)	(m)	(from north)							(g/m2/yr)	(g/m2/yr)
CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	1.61E-11	100	0	1	1	196	41.49089612	-88.27001629	N	2.21E-12	3.69E-12
CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	1.04E-12	100	0	1	1	196	41.49089612	-88.27001629	N	1.43E-13	2.39E-13
CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	1.11E-12	100	0	1	1	196	41.49089612	-88.27001629	N	1.52E-13	2.55E-13
CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	1.00E-11	100	0	1	1	196	41.49089612	-88.27001629	N	1.37E-12	2.30E-12
CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	1.12E-11	100	0	1	1	196	41.49089612	-88.27001629	N	1.53E-12	2.56E-12
CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	1.78E-12	100	0	1	1	196	41.49089612	-88.27001629	N	2.44E-13	4.08E-13
CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	7.31E-12	100	0	1	1	196	41.49089612	-88.27001629	N	1.00E-12	1.68E-12
CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	4.73E-12	100	0	1	1	196	41.49089612	-88.27001629	N	6.48E-13	1.08E-12
CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	9.49E-13	100	0	1	1	196	41.49089612	-88.27001629	N	1.30E-13	2.18E-13
CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	1.02E-11	100	0	1	1	196	41.49089612	-88.27001629	N	1.40E-12	2.34E-12
CT000001	P	indeno[1,2,3-c,d]pyrene	6.51E-11	100	0	1	1	196	41.49089612	-88.27001629	N	8.91E-12	1.49E-11
CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1.21E-12	100	0	1	1	196	41.49089612	-88.27001629	N	1.66E-13	2.79E-13
CT000001	P	2,3,4,7,8-pentachlorodibenzofuran	1.41E-11	500	0	1	2	196	41.49449822	-88.27008666	N	4.31E-12	3.08E-12
CT000001	P	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	9.17E-13	500	0	1	2	196	41.49449822	-88.27008666	N	2.79E-13	2.00E-13
CT000001	P	1,2,3,7,8-pentachlorodibenzo-p-dioxin	9.76E-13	500	0	1	2	196	41.49449822	-88.27008666	N	2.97E-13	2.13E-13
CT000001	P	1,2,3,6,7,8-hexachlorodibenzofuran	8.80E-12	500	0	1	2	196	41.49449822	-88.27008666	N	2.68E-12	1.92E-12
CT000001	P	1,2,3,4,7,8-hexachlorodibenzofuran	9.81E-12	500	0	1	2	196	41.49449822	-88.27008666	N	2.99E-12	2.14E-12
CT000001	P	1,2,3,7,8,9-hexachlorodibenzofuran	1.56E-12	500	0	1	2	196	41.49449822	-88.27008666	N	4.76E-13	3.41E-13
CT000001	P	2,3,4,6,7,8-hexachlorodibenzofuran	6.42E-12	500	0	1	2	196	41.49449822	-88.27008666	N	1.96E-12	1.40E-12
CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzofuran	4.15E-12	500	0	1	2	196	41.49449822	-88.27008666	N	1.27E-12	9.06E-13
CT000001	P	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	8.34E-13	500	0	1	2	196	41.49449822	-88.27008666	N	2.54E-13	1.82E-13
CT000001	P	1,2,3,7,8-pentachlorodibenzofuran	8.97E-12	500	0	1	2	196	41.49449822	-88.27008666	N	2.73E-12	1.96E-12
CT000001	P	indeno[1,2,3-c,d]pyrene	5.72E-11	500	0	1	2	196	41.49449822	-88.27008666	N	1.74E-11	1.25E-11
CT000001	P	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1.07E-12	500	0	1	2	196	41.49449822	-88.27008666	N	3.25E-13	2.33E-13
...

Figure 41. Sample All Polar Receptors HEM4 Output file (facility-specific, abbreviated)

Note: The Dry deposition and Wet deposition flux columns will be blank if you did not choose to model deposition in your Facility List Options file.

Figure 42. Sample AERMOD.inp file (facility-specific, abbreviated)

Note: If particle and vapor phase emissions are modeled separately (e.g., when modeling deposition/depletion), then two aermod.inp files will be provided in the facility folder: an aermod_P.inp file for particle phase emissions and an aermod_V.inp file for vapor phase emissions.

Figure 43. Sample AERMOD.out file (facility-specific, abbreviated)

Note: If particle and vapor phase emissions are modeled separately (e.g., when modeling deposition/depletion), then two aermod.out files will be provided in the facility folder: an aermod_P.out file for particle phase emissions and an aermod_V.out file for vapor phase emissions. Deposition fluxes (Dry Depo and Wet Depo) will be provided with depletion applied to concentrations, if modeled.

plotfile.plt - Notepad

File Edit Format View Help

* AERMOD (19191): Fac1-NC 08/25/20
 * AERMET (19191): 12:00:45

* MODELING OPTIONS USED: NonDEFAULT CONC ELEV ALPHA URBAN ADJ_U* BUOYLINE

* PLOT FILE OF PERIOD VALUES AVERAGED ACROSS 0 YEARS FOR SOURCE GROUP: CT000001

* FOR A TOTAL OF 329 RECEPTORS.

* FORMAT: (2(1X,F13.5),1X,E13.6,3(1X,F8.2),2X,A6,2X,A8,2X,I8.8,2X,A8)

X	Y	AVERAGE CONC	ZELEV	ZHILL	ZFLAG	AVE	GRP	NUM HRS	NET ID
688085.0000	3975161.0000	0.253092E+02	100.00	100.00	0.00	PERIOD	CT000001	00003326	
688431.0000	3974590.0000	0.297584E+02	89.00	89.00	0.00	PERIOD	CT000001	00003326	
688074.0000	3974564.0000	0.275790E+02	96.00	96.00	0.00	PERIOD	CT000001	00003326	
688329.0000	3973976.0000	0.301464E+02	87.00	87.00	0.00	PERIOD	CT000001	00003326	
688603.0000	3974075.0000	0.311166E+02	81.00	81.00	0.00	PERIOD	CT000001	00003326	
689200.0000	3973740.0000	0.356151E+02	84.00	84.00	0.00	PERIOD	CT000001	00003326	
688986.0000	3973544.0000	0.331389E+02	86.00	86.00	0.00	PERIOD	CT000001	00003326	
688843.0000	3975073.0000	0.302065E+02	87.00	87.00	0.00	PERIOD	CT000001	00003326	
688627.0000	3975147.0000	0.292191E+02	94.00	94.00	0.00	PERIOD	CT000001	00003326	
688703.0000	3974777.0000	0.307262E+02	87.00	87.00	0.00	PERIOD	CT000001	00003326	
688794.0000	3974637.0000	0.319091E+02	86.00	86.00	0.00	PERIOD	CT000001	00003326	
688857.0000	3974368.0000	0.336242E+02	88.00	88.00	0.00	PERIOD	CT000001	00003326	
688897.0000	3974590.0000	0.336846E+02	89.00	89.00	0.00	PERIOD	CT000001	00003326	
688987.0000	3974348.0000	0.358162E+02	91.00	91.00	0.00	PERIOD	CT000001	00003326	
688771.0000	3973458.0000	0.318658E+02	87.00	87.00	0.00	PERIOD	CT000001	00003326	
688844.0000	3973490.0000	0.327004E+02	89.00	89.00	0.00	PERIOD	CT000001	00003326	
688649.0000	3973298.0000	0.299506E+02	85.00	85.00	0.00	PERIOD	CT000001	00003326	
688548.0000	3973225.0000	0.288798E+02	83.00	83.00	0.00	PERIOD	CT000001	00003326	
688950.0000	3972883.0000	0.298544E+02	79.00	79.00	0.00	PERIOD	CT000001	00003326	
689303.0000	3973138.0000	0.338950E+02	81.00	81.00	0.00	PERIOD	CT000001	00003326	
689577.0000	3972790.0000	0.358756E+02	74.00	74.00	0.00	PERIOD	CT000001	00003326	
689172.0000	3972686.0000	0.330014E+02	84.00	84.00	0.00	PERIOD	CT000001	00003326	
689054.0000	3972778.0000	0.316748E+02	84.00	84.00	0.00	PERIOD	CT000001	00003326	
689351.0000	3972699.0000	0.339758E+02	77.00	77.00	0.00	PERIOD	CT000001	00003326	
688985.0000	3973950.0000	0.367440E+02	92.00	92.00	0.00	PERIOD	CT000001	00003326	
690232.0000	3977482.0000	0.245790E+02	82.00	82.00	0.00	PERIOD	CT000001	00003326	
689973.0000	3977269.0000	0.233639E+02	88.00	88.00	0.00	PERIOD	CT000001	00003326	

Figure 44. Sample plotfile.plt output file (facility-specific, abbreviated)

Note: If particle and vapor phase emissions are modeled separately (e.g., when modeling deposition/depletion), then these concentrations will be provided based on particle phase emissions in a plotfile_p.plt file and in a plotfile_v.plt file for vapor phase emissions. Deposition fluxes (Dry Depo and Wet Depo) will be provided with depletion applied to concentrations, if modeled.

X	Y	AVERAGE CONC	ZELEV	ZHILL	ZFLAG	AVE	GRP	RANK	NET ID	DATE(CONC)
688085.0000	3975161.00000	0.284562E+03	100.00	100.00	0.00	1-HR	CT000001	87TH		19032801
688431.0000	3974590.00000	0.316115E+03	89.00	89.00	0.00	1-HR	CT000001	87TH		19030220
688074.0000	3974564.00000	0.301197E+03	96.00	96.00	0.00	1-HR	CT000001	87TH		19021915
688329.0000	3973976.00000	0.329636E+03	87.00	87.00	0.00	1-HR	CT000001	87TH		19022215
688603.0000	3974075.00000	0.329503E+03	81.00	81.00	0.00	1-HR	CT000001	87TH		19060919
689200.0000	3973740.00000	0.406146E+03	84.00	84.00	0.00	1-HR	CT000001	87TH		19030908
688986.0000	3973544.00000	0.375320E+03	86.00	86.00	0.00	1-HR	CT000001	87TH		19060911
688843.0000	3975073.00000	0.336322E+03	87.00	87.00	0.00	1-HR	CT000001	87TH		19052105
688627.0000	3975147.00000	0.325032E+03	94.00	94.00	0.00	1-HR	CT000001	87TH		19060814
688703.0000	3974777.00000	0.314162E+03	87.00	87.00	0.00	1-HR	CT000001	87TH		19040119
688794.0000	3974637.00000	0.335495E+03	86.00	86.00	0.00	1-HR	CT000001	87TH		19021214
688857.0000	3974368.00000	0.370621E+03	88.00	88.00	0.00	1-HR	CT000001	87TH		19041011
688897.0000	3974590.00000	0.364171E+03	89.00	89.00	0.00	1-HR	CT000001	87TH		19021710
688987.0000	3974348.00000	0.385640E+03	91.00	91.00	0.00	1-HR	CT000001	87TH		19052724
688771.0000	3973458.00000	0.361640E+03	87.00	87.00	0.00	1-HR	CT000001	87TH		19022311
688844.0000	3973490.00000	0.364316E+03	89.00	89.00	0.00	1-HR	CT000001	87TH		19051506
688649.0000	3973298.00000	0.326036E+03	85.00	85.00	0.00	1-HR	CT000001	87TH		19042910
688548.0000	3973225.00000	0.315116E+03	83.00	83.00	0.00	1-HR	CT000001	87TH		19021121
688950.0000	3972883.00000	0.301050E+03	79.00	79.00	0.00	1-HR	CT000001	87TH		19052120
689303.0000	3973138.00000	0.344125E+03	81.00	81.00	0.00	1-HR	CT000001	87TH		19021622
689577.0000	3972790.00000	0.379355E+03	74.00	74.00	0.00	1-HR	CT000001	87TH		19021609
689172.0000	3972686.00000	0.330885E+03	84.00	84.00	0.00	1-HR	CT000001	87TH		19032014
689054.0000	3972778.00000	0.307257E+03	84.00	84.00	0.00	1-HR	CT000001	87TH		19051805
689351.0000	3972699.00000	0.353838E+03	77.00	77.00	0.00	1-HR	CT000001	87TH		19021619
688985.0000	3973950.00000	0.415687E+03	92.00	92.00	0.00	1-HR	CT000001	87TH		19032002
690232.0000	3977482.00000	0.241090E+03	82.00	82.00	0.00	1-HR	CT000001	87TH		19062313
689973.0000	3977269.00000	0.229380E+03	88.00	88.00	0.00	1-HR	CT000001	87TH		19040417

Figure 45. Sample maxhour.plt output file (optional facility-specific, abbreviated)

Note: The Maxhour plot file will be produced if you opted to model acute concentrations in your Facility List Options file. If particle and vapor phase emissions are modeled separately (e.g., when modeling deposition/depletion), then these acute concentrations will be provided based on particle phase emissions in a maxhour_p.plt file and for vapor phase emissions in an maxhour_v.plt file.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Facility ID	Aermod Title2	Emissions Phase	Rural/Urban	Deposition (YN)	Depletion (YN)	Deposition Type (particle/vapor)	Depletion Type (particle/vapor)	Elevation (YN)	Acute Hours	Acute Multiplier	Building Downwash (YN)	User Receptors (YN)	Max Modeling Distance	Discrete Modeling Distance	Overlap Distance	Number of Polar Rings	Number of Polar Radials	Acute (YN)	First Ring Distance ...	
Fac1-NC	CO TITLETWO Combined particle and vapor- phase emissions		N	N	NO/NO	NO/NO	Y	1	50	Y	Y	50000	3000	30	13	16	Y	565	...	

Figure 46. Sample Input Selection Options HEM4 Output file (facility-specific, abbreviated)

Note: The above Input Selection Options files does not show all information provided; the actual file contains 34 fields / columns providing chosen modeling run options.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Pollutant	Conc (ug/m3)	Conc sci (ug/m3)	Aegl_1 1hr (mg/m3)	Rel (mg/m3)	Population	Distance (in meters)	Angle (from north)	Elevation (in meters)	Height (in meters)	Fips	Block	Utm easting	Utm northing	Latitude	Longitude	Receptor type	Notes
1,3-butadiene	64.17283562	6.4e+01	1500	...	0	...	0	565	90	92	92	na	691471	3975205	35.90242	-78.87832	PG	Polar	
acetaldehyde	14.33911644	1.4e+01	81	...	0.47	...	0	459	233	90	90	U0000	0000URCPT1	35	3974934	35.90016	-78.88875	P	Discrete
acrolein	100.3738151	1.0e+02	0.069	...	0.0025	...	0	459	233	90	90	U0000	0000URCPT1	35	3974934	35.90016	-78.88875	P	Discrete
arsenic compounds	69.24203227	6.9e+01	0	...	0.0002	...	0	565	180	92	92	na	690906	3974640	35.89744	-78.88471	PG	Polar	
benzene	29.94732329	3.0e+01	170	...	0	...	0	565	90	92	92	na	691471	3975205	35.90242	-78.87832	PG	Polar	
bis(2-ethylhexyl)phthalate	1839.115705	1.8e+03	0	...	0	...	0	565	180	92	92	na	690906	3974640	35.89744	-78.88471	PG	Polar	
cadmium compounds	7.45282988	7.5e+00	0.1	...	0	...	0	565	180	92	92	na	690906	3974640	35.89744	-78.88471	PG	Polar	
chloroform	0.409275616	4.1e-01	0	...	0.15	...	0	565	67	92	92	na	691428	3975421	35.90438	-78.87874	PG	Polar	
chromium (iii) compounds	39.58179966	4.0e+01	0	...	0	...	0	565	180	92	92	na	690906	3974640	35.89744	-78.88471	PG	Polar	
chromium (vi) compounds	0.0395818	4.0e-02	0	...	0	...	0	565	180	92	92	na	690906	3974640	35.89744	-78.88471	PG	Polar	
cumene	1.02676537	1.0e+00	250	...	0	...	0	565	90	92	92	na	691471	3975205	35.90242	-78.87832	PG	Polar	
...	

Figure 47. Sample Acute Maximum Concentrations HEM4 Output file (optional facility specific, abbreviated)

Note: The Acute Maximum Concentrations (acute_chem_max) file will be produced if you opted to model acute concentrations in your Facility List Options file. The above sample file is abbreviated; the actual file contains 11 acute benchmark columns, not only the Aegl_1hr and Rel columns shown.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Pollutant	Conc (ug/m3)	Conc sci (ug/m3)	Aegl_1 1hr (mg/m3)	...	Rel (mg/m3)	...	Population	Distance (in meters)	Angle (from north)	Elevation (in meters)	Hill Height (in meters)	Fips	Block	Utm easting	Utm northing	Latitude	Longitude	Receptor type	Notes
	1,3-butadiene	10.2245116	1.0e+01	1500	...	0	...	219	1124	191	85	85 37063	0020272057	690684	3974103	35.89265	-78.8873	C	Discrete
acetaldehyde	9.996	1.0e+01	81	...	0.47	...	7	383	301	97	97 37063	0020272047	690578	3975403	35.90438	-78.88816	C	Discrete	
acrolein	69.972	7.0e+01	0.069	...	0.0025	...	7	383	301	97	97 37063	0020272047	690578	3975403	35.90438	-78.88816	C	Discrete	
arsenic compounds	60.7940659	6.1e+01	0	...	0.0002	...	2	492	220	90	90 37063	0020272056	690588	3974829	35.89921	-78.88819	C	Discrete	
benzene	4.77143877	4.8e+00	170	...	0	...	219	1124	191	85	85 37063	0020272057	690684	3974103	35.89265	-78.8873	C	Discrete	
bis(2-ethylhexyl)phthalate	942.976132	9.4e+02	0	...	0	...	2	492	220	90	90 37063	0020272056	690588	3974829	35.89921	-78.88819	C	Discrete	
cadmium compounds	6.54636892	6.5e+00	0.1	...	0	...	2	492	220	90	90 37063	0020272056	690588	3974829	35.89921	-78.88819	C	Discrete	
chloroform	0.05841962	5.8e-02	0	...	0.15	...	2	4329	48	117	117 37063	0018091060	694160	3978061	35.92762	-78.84785	C	Interpolated	
chromium (iii) compounds	35.8686185	3.6e+01	0	...	0	...	2	492	220	90	90 37063	0020272056	690588	3974829	35.89921	-78.88819	C	Discrete	
chromium (vi) compounds	0.03586862	3.6e-02	0	...	0	...	2	492	220	90	90 37063	0020272056	690588	3974829	35.89921	-78.88819	C	Discrete	
cumene	0.16359219	1.6e-01	250	...	0	...	219	1124	191	85	85 37063	0020272057	690684	3974103	35.89265	-78.8873	C	Discrete	
...	

Figure 48. Sample Acute Populated Concentrations HEM4 Output file (optional facility-specific, abbreviated)

Note: The Acute Populated Concentrations (acute_chem_pop) file will be produced if you opted to model acute concentrations in your Facility List Options file. The above sample file is abbreviated; the actual file contains 11 acute benchmark columns, not only the Aegl_1hr and Rel columns shown.

A	B	C	D	E	F	G
Pollutant	Source ID	Emission type	Max conc at populated receptor (ug/m3)	Is max conc at populated receptor interpolated? (Y/N)	Max conc at any receptor (ug/m3)	Is max conc at any receptor interpolated? (Y/N)
			6.81669E-07 N	1.3295E-06 N		
1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	FU000001	C	7.04392E-08 N	1.3738E-07 N		
1,2,3,4,6,7,8,9-octachlorodibenzofuran	FU000001	C	3.11291E-09 N	2.0383E-09 N		
1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	CT000001	C	1.87004E-08 N	1.1675E-08 N		
1,2,3,4,6,7,8-heptachlorodibenzofuran	CV000001	C	8.13071E-09 N	2.569E-08 N		
1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	HV000001	C	1.23623E-08 N	8.0945E-09 N		
1,2,3,4,6,7,8-heptachlorodibenzofuran	CV000001	C	7.42649E-08 N	4.6364E-08 N		
1,2,3,4,6,7,8-heptachlorodibenzofuran	HV000001	C	3.22894E-08 N	1.0202E-07 N		
1,2,3,4,7,8,9-heptachlorodibenzofuran	FU000001	C	9.42976E-08 N	1.8391E-07 N		
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	CT000001	C	2.54693E-09 N	1.6677E-09 N		
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	CV000001	C	1.53004E-08 N	9.552E-09 N		
1,2,3,4,7,8-hexachlorodibenzofuran	HV000001	C	6.6524E-09 N	2.1019E-08 N		
1,2,3,4,7,8-hexachlorodibenzofuran	CT000001	C	2.96397E-08 N	1.9407E-08 N		
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	CV000001	C	1.78057E-07 N	1.1116E-07 N		
1,2,3,4,7,8-hexachlorodibenzofuran	HV000001	C	7.74168E-08 N	2.446E-07 N		
1,2,3,4,7,8-hexachlorodibenzofuran	RV000003	C	3.94583E-09 N	1.2858E-09 N		
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	CT000001	C	2.71077E-09 N	1.7749E-09 N		
1,2,3,6,7,8-hexachlorodibenzofuran	CV000001	C	1.62846E-08 N	1.0166E-08 N		
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	HV000001	C	7.08033E-09 N	2.2371E-08 N		
1,2,3,6,7,8-hexachlorodibenzofuran	RV000002	C	5.67075E-10 N	5.9953E-11 N		
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	CT000001	C	2.66608E-08 N	1.7457E-08 N		
1,2,3,6,7,8-hexachlorodibenzofuran	CV000001	C	1.60162E-07 N	9.9989E-08 N		
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	HV000001	C	6.96362E-08 N	2.2002E-07 N		
1,2,3,6,7,8-hexachlorodibenzofuran	RV000003	C	3.54927E-09 N	1.1565E-09 N		
...

Figure 49. Sample Acute Breakdown HEM4 Output file (optional facility-specific)

Note: The Acute Breakdown file will be produced if you opted to model acute concentrations in your Facility List Options file.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Facil_id	mx_can_rsk	can_rsk_interpltd	can_rcpt_type	can_latitude	can_longitude	can_blk	respiratory_hi	[59 TOSHI columns]	pop_overlp	incidence	metname	km_to_metstation	fac_center_latitude	fac_center_longitude	rural_urban
Fac1-NC	0.000610761	N	Census block	35.8990848	-78.8880045	9801001074	0.6770494	...	0	0.047682	NC13722_2019.SFC	9.2712	35.9025311	-78.884577	U
Fac2-IL	9.00146E-07	N	Census block	41.4797356	-88.2618629	8907002218	0.03653	...	0	4.581E-06	IL04808_2019.SFC	35.6838	41.49	-88.27	R

Figure 50. Sample Facility Max Risk and HI HEM4 Output file (for run group, abbreviated)

Note: The Facility Max Risk and HI file covers the entire run group with one row of output per facility. The above sample file is abbreviated; there are 59 additional columns not shown pertaining to all 14 TOSHI values and locations.

A	B	C	D	E	F	G	H
Facil_id	latitude	longitude	Number people exposed to >= 1 in 1,000 risk	Number people exposed to >= 1 in 10,000 risk	Number people exposed to >= 1 in 100,000 risk	Number people exposed to >= 1 in 1,000,000 risk	Number people exposed to >= 1 in 10,000,000 risk
Fac1-NC	35.90253	-78.884577	0	435	48998	800221	1545731
Fac2-IL	41.49	-88.27	0	0	0	0	296

Figure 51. Sample Facility Cancer Risk Exposure HEM4 Output file (for run group)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Facility ID	Number people exposed to > 1 Respiratory HI	Number people exposed to > 1 Liver HI	Number people exposed to > 1 Neurological HI	Number people exposed to > 1 Developmental HI	Number people exposed to > 1 Reproductive HI	Number people exposed to > 1 Kidney HI	Number people exposed to > 1 Ocular HI	Number people exposed to > 1 Endocrinological HI	Number people exposed to > 1 Hematological HI	Number people exposed to > 1 Immunological HI	Number people exposed to > 1 Skeletal HI	Number people exposed to > 1 Spleen HI	Number people exposed to > 1 Thyroid HI	Number people exposed to > 1 Whole Body HI
Fac1-NC	0	0	0	435	0	0	0	0	0	0	0	0	0	0
Fac2-IL	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 52. Sample Facility TOSHI Exposure HEM4 Output file (for run group)

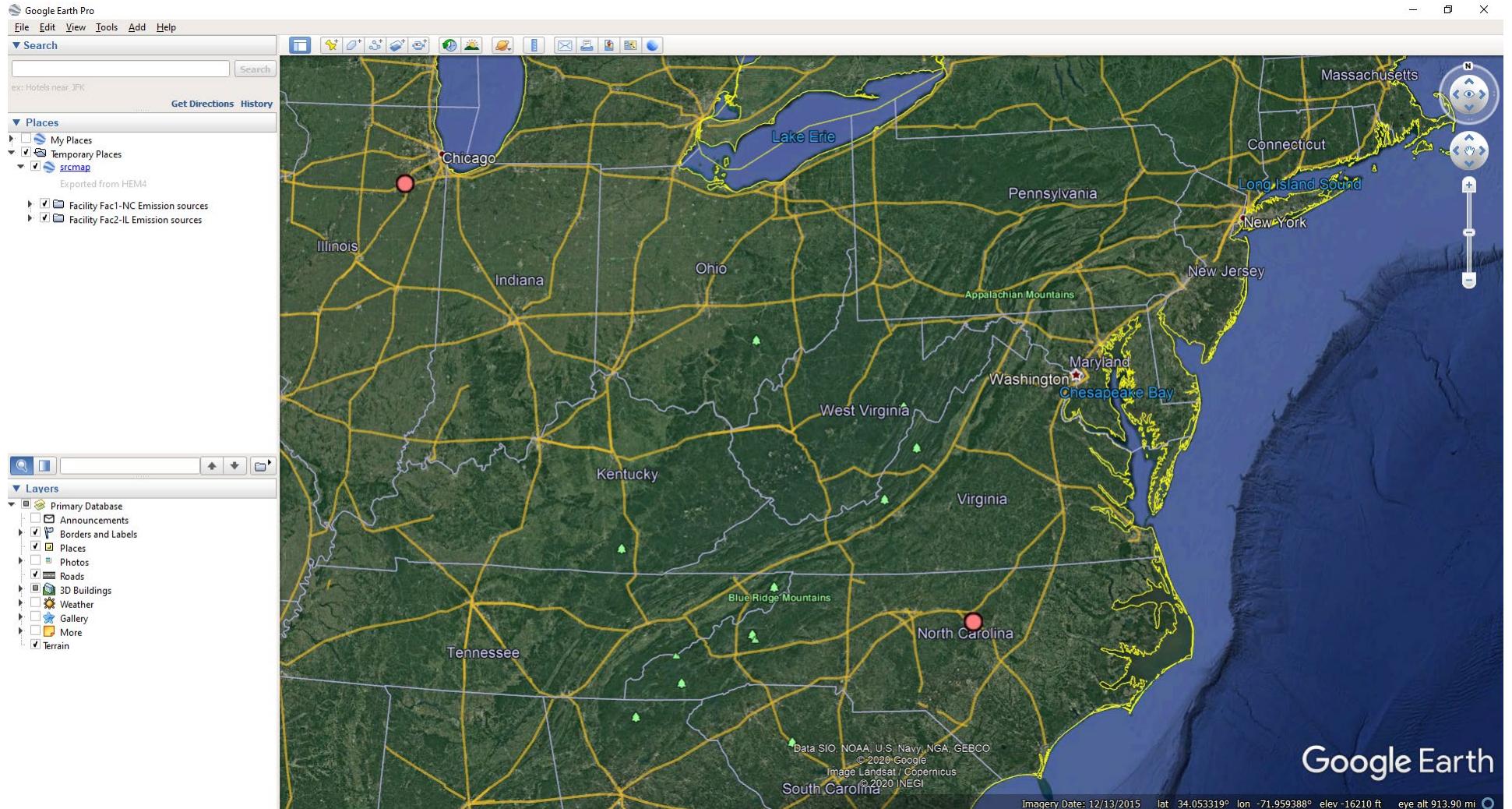
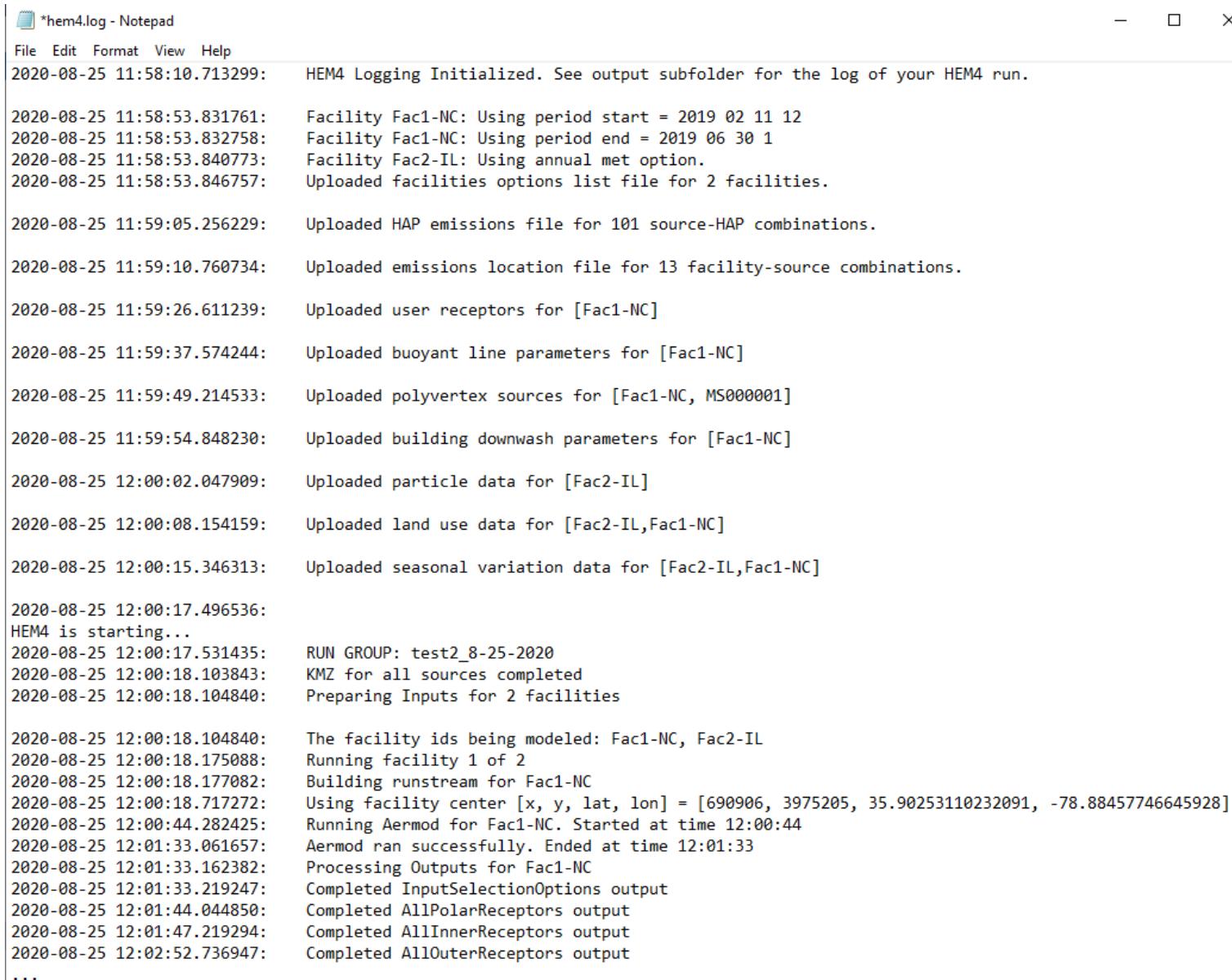


Figure 53. Sample All Facility Source Locations Google Earth™ Image (for run group)

Note: The All Facility Source Locations Google Earth™ image depicts the two sample facilities modeled in this run group – located in Illinois and North Carolina – on a map. On the actual map image, you can zoom in to see the individual sources at each facility in more detail.



The screenshot shows a Notepad window titled "*hem4.log - Notepad". The menu bar includes File, Edit, Format, View, and Help. The log file content is as follows:

```
File Edit Format View Help
2020-08-25 11:58:10.713299: HEM4 Logging Initialized. See output subfolder for the log of your HEM4 run.

2020-08-25 11:58:53.831761: Facility Fac1-NC: Using period start = 2019 02 11 12
2020-08-25 11:58:53.832758: Facility Fac1-NC: Using period end = 2019 06 30 1
2020-08-25 11:58:53.840773: Facility Fac2-IL: Using annual met option.
2020-08-25 11:58:53.846757: Uploaded facilities options list file for 2 facilities.

2020-08-25 11:59:05.256229: Uploaded HAP emissions file for 101 source-HAP combinations.

2020-08-25 11:59:10.760734: Uploaded emissions location file for 13 facility-source combinations.

2020-08-25 11:59:26.611239: Uploaded user receptors for [Fac1-NC]

2020-08-25 11:59:37.574244: Uploaded buoyant line parameters for [Fac1-NC]

2020-08-25 11:59:49.214533: Uploaded polyvertex sources for [Fac1-NC, MS000001]

2020-08-25 11:59:54.848230: Uploaded building downwash parameters for [Fac1-NC]

2020-08-25 12:00:02.047909: Uploaded particle data for [Fac2-IL]

2020-08-25 12:00:08.154159: Uploaded land use data for [Fac2-IL,Fac1-NC]

2020-08-25 12:00:15.346313: Uploaded seasonal variation data for [Fac2-IL,Fac1-NC]

2020-08-25 12:00:17.496536:
HEM4 is starting...
2020-08-25 12:00:17.531435: RUN GROUP: test2_8-25-2020
2020-08-25 12:00:18.103843: KMZ for all sources completed
2020-08-25 12:00:18.104840: Preparing Inputs for 2 facilities

2020-08-25 12:00:18.104840: The facility ids being modeled: Fac1-NC, Fac2-IL
2020-08-25 12:00:18.175088: Running facility 1 of 2
2020-08-25 12:00:18.177082: Building runstream for Fac1-NC
2020-08-25 12:00:18.717272: Using facility center [x, y, lat, lon] = [690906, 3975205, 35.90253110232091, -78.88457746645928]
2020-08-25 12:00:44.282425: Running Aermod for Fac1-NC. Started at time 12:00:44
2020-08-25 12:01:33.061657: Aermod ran successfully. Ended at time 12:01:33
2020-08-25 12:01:33.162382: Processing Outputs for Fac1-NC
2020-08-25 12:01:33.219247: Completed InputSelectionOptions output
2020-08-25 12:01:44.044850: Completed AllPolarReceptors output
2020-08-25 12:01:47.219294: Completed AllInnerReceptors output
2020-08-25 12:02:52.736947: Completed AllOuterReceptors output
...
```

Figure 54. Sample HEM4 Log Output file (for run group, abbreviated)

End

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