Residual Risk Assessment for the Ferroalloys Source Category in Support of the September Supplemental Proposal

by
EPA's Office of Air Quality Planning and Standards
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Table of Contents

Index of Tables

Residual Risk Assessment for the Ferroalloys Source Category
in Support of the September Supplemental Proposal –
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Appendices

Appendix 1	Emissions Inventory Support Memorandum
Appendix 2	Technical Support Document for HEM3 Modeling
Appendix 3	Meteorological Data for HEM3 Modeling
Appendix 4	Technical Support Document for TRIM-Based Multipathway Screening Scenario for RTR: Summary of Approach and Evaluation
Appendix 5	Analysis of short-term emission rates relative to long-term emission rates
Appendix 6	Draft Detailed Risk Modeling Results
Appendix 7	Acute Impacts Refined Analysis
Appendix 8	Dispersion Model Receptor Revisions and Additions for Ferroalloys
Appendix 9	Protocol for Developing a TRIM.FaTE Model Scenario
Appendix 10	Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Ferroalloys Production Source Category

Index of Acronyms

AERMOD	American Meteorological Society/EPA Regulatory Model
AEGL	Acute exposure guideline level
ASTDR	US Agency for Toxic Substances and Disease Registry
CalEPA	California Environmental Agency
ERPG	Emergency Response Planning Guideline
HAP	Hazardous Air Pollutant
HEM	Human Exposure Model
HI	Hazard index
HQ	Hazard quotient
IRIS	Integrated Risk Information System
MACT	Maximum Achievable Control Technology
MIR	Maximum Individual Risk
MOA	Mode of action
NAC	National Advisory Committee
NAAQS	National Ambient Air Quality Standards
NATA	National Air Toxics Assessment
NEI	National Emissions Inventory
NPRM	Notice of Proposed Rulemaking
PAH	Polynuclear Aromatic Hydrocarbon
PB-HAP	Persistent and Bioaccumulative - HAP
POM	Polycyclic organic matter
REL	Reference exposure level
RfC	Reference concentration
RfD	Reference dose
RTR	Risk and Technology
TOSHI	Target-organ-specific hazard index
URE	Unit risk estimate

1 Introduction

Section 112 of the Clean Air Act (CAA) establishes a two-stage regulatory process for addressing emissions of hazardous air pollutants (HAP) from stationary sources. In the first stage, section 112(d) requires the Environmental Protection Agency (EPA, or the Agency) to develop technology-based standards for categories of sources (e.g., petroleum refineries, pulp and paper mills, etc.) [*1*]. EPA has largely completed the initial Maximum Achievable Control Technology (MACT) standards as required under this provision. Under section 112(d)(6), EPA must review each of these technology-based standards at least every eight years and revise a standard, as necessary, "taking into account developments in practices, processes and control technologies." In the second stage, EPA is required under section 112(f)(2) to assess the health and environmental risks that remain after implementation of the MACT standards. If additional risk reductions are necessary to protect public health with an ample margin of safety or to prevent an adverse environmental effect, EPA must develop standards to address these remaining risks. This second stage of the regulatory process is known as the residual risk stage. For each source category for which EPA issued MACT standards, the residual risk stage must be completed within eight years of promulgation of the initial technology-based standard.

In December of 2006 we consulted with a panel from the EPA's Science Advisory Board (SAB) on the "Risk and Technology Review (RTR) Assessment Plan," and in June of 2007, we received a letter with the results of that consultation. Subsequent to the consultation, in June of 2009, a meeting was held with an SAB panel for a formal peer review of the "Risk and Technology Review (RTR) Assessment Methodologies" [*2*]. We received the final SAB report on this review in May of 2010 [*3*]. Where appropriate, we have responded to the key messages from this review in developing our current risk assessments and we will be continuing our efforts to improve our assessments by incorporating updates based on the SAB recommendations as they are developed and become available. Our responses to the key recommendations of the SAB are outlined in a memo entitled, "EPA's Actions in Response to the Key Recommendations of Science Advisory Board Review of Risk and Technology Review Risk Assessment Methodologies" [*4*].

This document contains the methods and the results of baseline risk assessments (i.e., after the implementation of the MACT standard) and the results of the post-control scenario risk assessment performed for the ferroalloys source category. The methods discussion includes descriptions of the methods used to develop refined estimates of chronic inhalation exposures and human health risks for cancer and noncancer endpoints, as well as descriptions of the methods used to screen for acute health risks, chronic non-inhalation health risks, and adverse environmental effects.

2 Methods

2.1 Emissions and source data

Data from several CAA section 114 information collection requests (ICR) were used for this assessment. In 2010 and 2012 we sent ICRs to the two companies which own the two facilities in the U.S. which we are aware are covered by the Ferroalloys Production MACT standard. The ICRs requested available information regarding process equipment, control devices, point and fugitive emissions, practices used to control fugitive emissions, and other aspects of facility operations, including stack parameters and locations. Additionally, we requested that the two facilities conduct emissions tests for certain HAP from specific processes that were considered representative of the industry. Pollutants tested included metal HAP (e.g., manganese, nickel compounds) hydrochloric acid (HCl), hydrogen fluoride (HF),[1] formaldehyde, mercury compounds, polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and chlorodibenzodioxins and chlorodibenzofurans (CDD/CDF). The results of these tests and data collection efforts are described in more detail in the memo *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*, available in the docket (EPA-HQ-OAR-2010-0895) and as Appendix 1 to this document. Section 3 below provides a summary of the emissions.

2.2 Dispersion modeling for inhalation exposure assessment

Both long- and short-term inhalation exposure concentrations and associated health risks from each facility in the source category were estimated using the Human Exposure Model (HEM) in combination with the American Meteorological Society/EPA Regulatory Model (AERMOD) dispersion modeling system (HEM3). The approach used in applying this modeling system is outlined below, and further details are provided in Appendix 2 of this document (*Technical Support Document for HEM3 Modeling*). The HEM3 performs three main operations: atmospheric dispersion modeling, estimation of individual human exposures and health risks, and estimation of population risks. This section focuses on the dispersion modeling component. The exposure and risk characterization components are discussed in other subsections of Sections 2 and 3.

The dispersion model in the HEM3 system, AERMOD version 12345, is a state-of-the-science Gaussian plume dispersion model that is preferred by EPA for modeling point, area, and volume sources of continuous air emissions from facility applications [*5*]. Further details on AERMOD can be found in the AERMOD Users Guide [*6*]. The model is used to develop annual average ambient concentrations through the simulation of hour-by-hour dispersion from the emission sources into the surrounding atmosphere. Hourly emission rates used for this simulation are generated by evenly dividing the total annual emission rate from the inventory into the 8,760 hours of the year.

The first step in the application of the HEM3 modeling system is to predict ambient concentrations at locations of interest. The AERMOD model options employed are summarized in Table 2.2-1 and are discussed further below.

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[1] As explained in the memo *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*, test data were received from 4 furnaces for HF. All test results were below the detection limit of the test method. While we initially calculated numerical estimates based on the assumption that non-detects were equal to one-half of the detection limit and included these estimates in the inputs to the risk assessment, we have no evidence that HF is emitted from these sources.

Table 2.2-1 AERMOD version 12345 model options for RTR modeling

Modeling Option	*Selected Parameter for chronic exposure*
Type of calculations	Hourly Ambient Concentration
Source type	Point and area
Receptor orientation	Polar (13 rings and 16 radials) Discrete (census block centroids) and user-supplied receptors
Terrain characterization	Actual from USGS 1-degree DEM data
Building downwash	Not Included
Plume deposition/depletion	Not Included
Urban source option	Included if source in urbanized area
Meteorology	1 year representative NWS from nearest site (over 800 stations)

In HEM3, meteorological data are ordinarily selected from a list of over 800 National Weather Service (NWS) surface observation stations across the continental United States, Alaska, Hawaii, and Puerto Rico. In most cases the nearest station is selected as representative of the conditions at the subject facility. Ideally, when considering off-site meteorological data most site specific dispersion modeling efforts will employ up to five years of data to capture variability in weather patterns from year to year. However, because we had an insufficient number of appropriately formatted model input files derived from available meteorological data, we modeled only a single year, typically 2011. While the selection of a single year may result in under-prediction of long-term ambient levels at some locations, likewise it may result in over-prediction at others. For each facility identified by its characteristic latitude and longitude coordinates, the closest meteorological station was used in the dispersion modeling. The average distance between a modeled facility and the applicable meteorological station was approximately 30 miles (50 km). Appendix 3 of this document (*Meteorological Data Processing Using AERMET for HEM3*) provides a complete listing of stations and assumptions along with further details used in processing the data through AERMET (the AERMOD meteorological data pre-processing program). The sensitivity of model results to the selection of the nearest weather station and the use of one year of meteorological data is discussed in "Risk and Technology Review (RTR) Risk Assessment Methodologies" [*2*].

Beginning with version 12345, AERMET allows for a minimum wind speed of 0.5 m/s to be utilized when processing monitoring stations that are equipped with sonic anemometers and for an adjustment to the surface velocity (u*). The public version of AERMET available at the time we conducted the modeling for this source category did not include the surface friction velocity adjustment. Also at that time, an updated version of AERMET (and AERMOD) was under development that incorporated further surface friction velocity adjustments to AERMET version 12345. In anticipation of the update, EPA processed meteorological data using a pre-public release version of AERMET and incorporated the updated surface friction velocity adjustment in the output. It was EPA's judgment that the pre-public release version of AERMET would generate AERMOD-ready meteorological data very close to that generated with the final public release version.

EPA has posted the AERMET meteorological data used in the ferroalloys analysis on the EPA's FERA (Fate, Exposure, and Risk Analysis) website[2] under the HEM model page. AERMET and AERMOD (version 13350) were released to the public in late December 2013 on the EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website.[3]

The HEM3 system estimates ambient concentrations at the geographic centroids of census blocks (using the 2010 Census) and at other receptor locations that can be specified by the user. See Appendix 8 to this document (*Dispersion Model Receptor Revisions and Additions for the Ferroalloys Source Category*) for a discussion of user receptors and centroid location changes specific to this source category. The model accounts for the effects of multiple facilities when estimating concentration impacts at each block centroid. Typically we combined only the impacts of facilities within the same source category, and assessed chronic exposure and risk only for census blocks with at least one resident (i.e., locations where people may reasonably be assumed to reside rather than receptor points at the fenceline of a facility). Chronic ambient concentrations were calculated as the annual average of all estimated short-term (one-hour) concentrations at each block centroid. Possible future residential use of currently uninhabited areas was not considered. Census blocks, the finest resolution available in the census data, are typically comprised of approximately 40 people or about ten households.

In contrast to the development of ambient concentrations for evaluating long-term exposures, which was performed only for occupied census blocks, worst-case short-term (one-hour) concentrations were estimated both at the census block centroids and at points nearer the facility that represent locations where people may be present for short periods, but generally no nearer than 100 meters from the center of the facility (note that for large facilities, this 100-meter ring could still contain locations inside the facility property). Since short-term emission rates were needed to screen for the potential for hazard via acute exposures, and since the ICR data contains only annual emission totals, we generally apply the assumption to all source categories that the maximum one-hour emission rate from any source is ten times the average annual hourly emission rate for that source. More description of our short-term assessment can be found in Section 2.4 of this document - *Acute Risk Screening and Refined Assessments*.

Census block elevations for HEM3 modeling were determined nationally from the US Geological Service 1/3 Arc Second National Elevation Dataset, which have a spatial resolution of about 10 meters. Elevations of polar grid points used in estimating short- and long-term ambient concentrations were assumed to be equal to the highest elevation of any census block falling within the polar grid sector corresponding to the grid point. If a sector does not contain any blocks, the model defaults the elevation to that of the nearest block. If

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[2] The FERA webpage is http://www2.epa.gov/fera and the HEM3 webpage is http://www2.epa.gov/fera/risk-assessment-and-modeling-human-exposure-model-hem

[3] The SCRAM webpage is http://www.epa.gov/ttn/scram/.

an elevation is not provided for the emission source, the model uses the average elevation of all sectors within the innermost model ring. AERMOD adjusts the plume's flow if nearby elevated hills are expected to influence the wind patterns. For details on how hill heights were estimated and used in the AERMOD modeling, see Appendix 2 of this document, *Technical Support Document for HEM3 Modeling*.

2.3 Estimating chronic human inhalation exposure

We used the estimated annual average ambient air concentration of each HAP at each census block centroid as a surrogate for the lifetime inhalation exposure concentration of all the people who reside in the census block. That is, the risk analysis did not consider either the short-term or long-term behavior (mobility) of the exposed populations and its potential influence on their exposure.

We did not address short-term human activity for two reasons. First, our experience with the NATA assessments (which modeled daily activity using EPA's HAPEM model) suggests that, given our current understanding of microenvironment concentrations and daily activities, modeling short-term activity would, on average, reduce risk estimates about 25 percent for particulate HAP; it will also reduce risk estimates for gaseous HAP, but typically by much less. Second, basing exposure estimates on average ambient concentrations at census block centroids may underestimate or overestimate actual exposure concentrations at some residences. Further reducing exposure estimates for the most highly exposed residents by modeling their short-term behavior could add a systematic low bias to these results.

We did not address long-term migration nor population growth or decrease over 70 years, instead basing the assessment on the assumption that each person's predicted exposure is constant over the course of their lifetime which is assumed to be 70 years. In assessing cancer risk, we generally estimated three metrics; the maximum individual risk (MIR), which is defined as the risk associated with a lifetime of exposure at the highest concentration; the population risk distribution; and the cancer incidence. The assumption of not considering short or long-term population mobility does not bias the estimate of the theoretical MIR nor does it affect the estimate of cancer incidence since the total population number remains the same. It does, however, affect the shape of the distribution of individual risks across the affected population, shifting it toward higher estimated individual risks at the upper end and reducing the number of people estimated to be at lower risks, thereby increasing the estimated number of people at specific risk levels.

2.4 Acute Risk Screening and Refined Assessments

In establishing a scientifically defensible approach for the assessment of potential health risks due to acute exposures to HAP, we followed the same general approach that has been used for developing chronic health risk assessments under the residual risk program. That is, we developed a tiered, iterative approach. This approach to risk assessment was endorsed by the National Academy of Sciences in its 1993 publication "Science and Judgment in Risk Assessment" and subsequently was adopted in the EPA's "Residual Risk Report to Congress" in 1999.

The assessment methodology is designed to eliminate from further consideration those facilities for which we have confidence that no acute adverse health effects of concern will occur. To do so, we use what is called a tiered, iterative approach to the assessment. This means that we began with a screening assessment, which relies on readily available data and uses conservative assumptions that in combination approximate a worst-case exposure. The result of this screening process is that either the facility being assessed poses no potential acute health risks (i.e., it “screens out”), or that it requires further, more refined assessment. A more refined acute assessment could use industry- or site-specific data on the temporal pattern of emissions, the layout of emission points at the facility, the boundaries of the facility, and/or the local meteorology. In some cases, all of these site-specific data are used to refine the assessment; in others, lesser amounts of site-specific data can be used to determine that acute exposures are not a concern, and significant additional data collection is not necessary.

Acute health risk screening was performed for each facility as the first step. When we identify acute impacts which exceed their relevant benchmarks, we pursue refining our acute screening estimates to the extent possible. In some cases, this may include the use of a facility-specific emissions multiplier to estimate the peak hourly emission rates from the average rates (rather than the default factor of 10). In other cases, this may entail determining the actual physical layout and boundaries of a facility to more accurately gauge where people might reasonably be exposed for an hour.

When screening for potentially significant acute exposures, we used an estimate of the highest hourly ambient concentration at any off-site location as the surrogate for the maximum potential acute exposure concentration for any individual. These hourly concentrations are based on hourly emissions, as described above. Since information is not usually available on short-term emission rates, we generally apply the assumption that the maximum one-hour emission rate from any source is ten times the average annual hourly emission rate for that source. (The average hourly emissions rate is defined as the total emissions for a year divided by the total number of operating hours in the year.) This choice of a factor of ten for acute screening was originally based on engineering judgment.

To develop a more robust peak-to-mean emissions factor, and in response to one of the key messages from the SAB consultation on our RTR Assessment Plan, we performed an analysis using a short-term emissions dataset from a number of sources located in Texas (originally reported on by Allen *et al.* 2004) [7]. In that report, the Texas Environmental Research Consortium Project compared hourly and annual emissions data for volatile organic compounds for all facilities in a heavily-industrialized 4-county area (Harris, Galveston, Chambers, and Brazoria Counties) over an eleven-month time period in 2001. We obtained the dataset and performed our own analysis, focusing on sources which reported emitting high quantities of HAP over short periods of time (see Appendix 5 of this document, *Analysis of data on short-term emission rates relative to long-term emission rates*). Most peak emission events were less than twice the annual average, and the highest was a factor of 74 times the annual average, and the 99th percentile ratio of peak hourly emission rate to the annual hourly emission rate was 9. Based on these results, we generally chose the factor of ten for all initial screening. This factor is intended to cover all possible hourly peaks associated with routinely-variable emissions. While there have been some documented emission excursions above this level, our analysis of the data from the Texas Environmental Research Consortium suggests that this factor should cover more than 99 percent of the short-term peak gaseous or volatile HAP emissions from typical industrial sources. We have no data relating specifically to peak short-term emissions of particulate HAP. In the absence of source category-specific data, we use this same default approach for particulate emissions as well.

For the ferroalloys source category, however, maximum hourly emissions estimates were available, so we did not use the default emissions multiplier of 10. See Appendix 1 to this document, *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*, which is also available separately in the docket, for the detailed description of how the maximum hourly emissions were developed for the ferroalloys source category. In general, some processes operate continuously so there are no peak emissions and these processes received a factor of 1 (i.e., maximum hourly emissions equal annual average hourly emissions). Other processes, for example tapping and casting, have specific cycles, with peak emissions occurring for a part of that cycle (e.g., 30 minutes during a 2-hour period). For these processes, we used a factor of 4 in the acute assessment.

As mentioned above, when we identify acute impacts which exceed their relevant benchmarks, we pursue refining our acute screening estimates to the extent possible. For the ferroalloys production source category, we conducted a review of the layout of the polar receptors around the facilities compared to the facility boundaries to determine the maximum off-site acute impact for the facilities that did not screen out during the initial run. Appendix 6 to this document (*Draft Detailed Risk Modeling Results*) contains the initial acute results for the source category, while Appendix 7 to this document (*Acute Impacts Refined Analysis*), contains the refined acute results.

In summary, we used conservative assumptions for emission rates, meteorology, and exposure location, and refined data where available. We used the following assumptions in our acute assessment approach:

- Peak 1-hour emissions were obtained from the emissions memo and based on the operating characteristics of ferroalloys production emission sources as described in Appendix 1.
- For facilities with multiple emission points, peak 1-hour emissions were assumed to occur at all emission points at the same time.
- We assumed that the peak emissions occur at all emission points at the same time.
- For facilities with multiple emission points, 1-hour concentrations at each receptor were assumed to be the sum of the maximum concentrations due to each emission point, regardless of whether those maximum concentrations occurred during the same hour.
- Worst-case meteorology (from one year of local meteorology) was assumed to occur at the same time the peak emission rates occur. The recommended EPA local-scale dispersion model, AERMOD, is used for simulating atmospheric dispersion.

- A person was assumed to be located downwind at the point of maximum modeled impact during this same worst-case 1-hour period, but no nearer to the source than 100 meters.
- The maximum impact was compared to multiple short-term health benchmarks for the HAP being assessed to determine if a possible acute health risk might exist. These benchmarks are described in section 2.6 of this report.

2.5 Multipathway human health and environmental risk screening

The potential for significant human health risks due to exposures via routes other than inhalation (i.e., multipathway exposures) was screened by first determining whether any sources emitted any hazardous air pollutants known to be persistent and bioaccumulative in the environment (PB-HAP)[4]. The PB-HAP compounds or compound classes are identified for the screening from the EPA's Air Toxics Risk Assessment Library [*8*]. Examples of PB-HAP are cadmium compounds, chlordane, chlorinated dibenzodioxins and furans, DDE, heptachlor, hexachlorobenzene, hexachlorocyclohexane, lead compounds, mercury compounds, methoxychlor, polychlorinated biphenyls (PCB), polycyclic organic matter (POM), toxaphene, and trifluralin. Emissions of cadmium compounds, chlorinated dibenzodioxins and furans, lead compounds, mercury compounds, PCBs, and POM (of which PAH are a subset) were identified in the emissions inventory for the ferroalloys source category.

With respect to PB-HAP emissions other than lead, emissions were evaluated for potential non-inhalation risks using a tiered screening approach which was developed for use with the EPA's peer-reviewed Total Risk Integrated Methodology – Fate, Transport, and Ecological Exposure (TRIM.FaTE[5]) model. With this approach, we first determine whether the facility-specific emission rates of each of the emitted PB-HAP are large enough to create the potential for significant non-inhalation human health risks under reasonable worst-case conditions. To facilitate this step, we developed emission rate screening levels for each PB-HAP using a hypothetical upper-end screening exposure scenario developed for use in conjunction with TRIM.FaTE. The exposure scenario includes a generic farming/fishing exposure scenario that simulates a subsistence environment. We conducted a sensitivity analysis on the screening scenario to ensure that its key design parameters would represent the upper end of the range of possible values, such that it would represent a conservative but not impossible scenario. The PB-HAP emissions from each facility in the source category were compared to the emission rate screening levels for each of the PB-HAP identified to assess the potential for significant human health risks via non-inhalation pathways. For the purpose of developing emission rates for the multipathway screen, we derived emission levels for each PB-HAP (other than lead) at which the maximum human health risk would be 1 in a million for lifetime cancer risk or a hazard quotient of 1.0 for noncancer impacts. We call this application of the

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[4] Although the two-letter chemical symbol for lead is Pb, in this assessment PB-HAP refers to the many air pollutants known to be persistent and bioaccumulative in the environment. In instances where the report is specifically referring to lead, it is spelled out (i.e., the two-letter chemical symbol for lead is not used in this document).

[5] EPA's Total Risk Integrated Methodology (General Information) http://www2.epa.gov/fera/total-risk-integrated-methodology-trim-general

TRIM.FaTE model the Tier I Screen. See Appendix 4 of this document (*Technical Support Document for TRIM-Based Multipathway Screening Scenario for RTR: Summary of Approach and Evaluation*) for a complete discussion of the development and testing of the screening scenario, as well as for the values of facility-level emission rates developed for screening potentially significant multipathway impacts.

If the PB-HAP emissions for a facility exceed the Tier I screening emission rate, we conduct a Tier II multipathway screen. In the Tier II screen, the location of each facility that exceeded the Tier I emission rate is used to refine some of the assumptions associated with the environmental scenario while maintaining the exposure scenario assumptions. We then adjust the risk-based Tier I screening level for each PB-HAP for each facility based on an understanding of how exposure concentrations estimated for the screening scenario change with meteorology and environmental assumptions. This step creates a facility-specific emission rate screening level for each PB-HAP (i.e., the level for cadmium could be different for every facility), unlike the Tier I emission rate screening level which was constant for the same PB-HAP at different facilities (i.e., the level for cadmium was the same for every facility). Facility emissions of PB-HAP that do not exceed these new Tier II screening levels are considered to pose no significant risks. When facilities exceed the Tier II screening levels, it does not mean that multipathway impacts are significant, only that we cannot rule out that possibility based on the results of the screen. See Appendix 4 of this document (*Technical Support Document for TRIM-Based Multipathway Screening Scenario for RTR: Summary of Approach and Evaluation*) for a complete discussion of the Tier II screen.

If the PB-HAP emissions for a facility exceed the Tier II screening emissions rate, and data are available, we may decide to conduct a more refined multipathway assessment. A refined assessment replaces some of the assumptions made in the Tier II screen, with site specific data. The refined assessment also uses the TRIM.FaTE model and facility-specific emission rate levels that are created for each PB-HAP. There are many variables to consider in a refined multipathway assessment and we have developed a protocol to maintain consistency across source categories. This protocol can be found in Appendix 9 of this document (*Protocol for Developing a TRIM.FaTE Model Scenario to Support a Site-Specific Risk Assessment in the RTR Program*). For the ferroalloys production source category, we did conduct a refined multipathway assessment for one facility in the category. A detailed discussion of the approach for this assessment can be found in Appendix 10 of this document (*Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Ferroalloys Production Source Category*).

In evaluating the potential multipathway risks from emissions of lead compounds, rather than developing a screening emission rate for them, we compared maximum estimated chronic atmospheric concentrations with the current National Ambient Air Quality Standard (NAAQS) for lead. Values below the NAAQS were considered to have a low potential for multipathway risks.

The NAAQS value, a public health policy judgment, incorporated the Agency's most recent health evaluation of air effects of lead exposure for the purposes of setting a national ambient air quality standard. In setting this value, the Administrator promulgated a standard that was requisite to protect public health with an adequate margin of safety. We consider values below the level of the primary NAAQS to protect against multipathway risks because as mentioned above, the primary NAAQS is set as to protect public health with an adequate margin of safety. However, ambient air lead concentrations above the NAAQS are considered to pose the potential for increased risk to public health. We consider this NAAQS assessment to be a refined analysis given: 1) the numerous health studies, detailed risk and exposure analyses, and level of external peer and public review that went into the development of the primary NAAQS for lead, combined with: 2) the site-specific dispersion modeling used in this assessment to estimated ambient lead concentrations due to ferroalloys emissions. It should be noted, however, that this comparison does not account for possible population exposures to lead from sources other than the one being modeled; for example, via consumption of water from untreated local sources or ingestion of locally grown food. Nevertheless, the Administrator judged that such a standard would protect, with an adequate margin of safety, the health of children and other at-risk populations against an array of adverse health effects, most notably including neurological effects, particularly neurobehavioral and neurocognitive effects, in children (73 FR 67007). The Administrator, in setting the standard, also recognized that no evidence-or risk based bright line indicated a single appropriate level. Instead a collection of scientific evidence and other information was used to select the standard from a range of reasonable values (73 FR 67006).

We further note that comparing ambient lead concentrations to the NAAQS for lead, considering the level, averaging time, form and indicator, also informs whether there is the potential for adverse environmental effects. This is because the secondary lead NAAQS, set to protect against adverse welfare effects (including adverse environmental effects), has the same averaging time, form, and level as the primary standard. Thus, ambient lead concentrations above the NAAQS for lead also indicate the potential for adverse environmental effects.

The EPA has developed a screening approach to examine the potential for adverse environmental effects as required under section 112(f)(2)(A) of the CAA. The environmental screen focuses on the following seven environmental HAP:

- Five persistent bioaccumulative HAP (PB-HAP) – cadmium, dioxins/furans, POM, mercury (both inorganic mercury and methyl mercury), and lead,
- Two acid gases – hydrogen chloride (HCl) and hydrogen fluoride (HF).

HAP that persist and bioaccumulate are of particular environmental concern because they accumulate in the soil, sediment, and water. The acid gases – HCl and HF – were included due to their well-documented potential to cause direct damage to terrestrial plants.

For the environmental risk screening analysis, EPA first determined whether any facilities in the source category emitted any of the seven environmental HAP. If one or more of the seven environmental HAP evaluated are emitted by at least one facility in the source category we proceed to the second step of the evaluation.

For cadmium, mercury, POM, and dioxins/furans, the environmental screening analysis consists of two tiers. In the first tier, TRIM.FaTE modeling was conducted under worst-case environmental conditions to determine whether the facility-specific off-site emission rates of each of the emitted environmental HAP exceeded ecological benchmarks represented as emissions screening levels. If off-site emissions from a facility do not exceed the Tier I screening levels the facility "passes" the screen, and therefore, is not evaluated further under the screening approach. If off-site emissions from a facility exceed the Tier I screening levels, we evaluate the facility further in Tier II.

In Tier II of the environmental screening analysis, the screening emission levels are adjusted to account for local meteorology and the actual location of lakes in the vicinity of facilities that did not pass the Tier I screen. If off-site emissions from a facility do not exceed the Tier II screening levels, the facility passes the screen, and is typically not evaluated further. If off-site emissions from a facility exceed the Tier II screening levels, the facility does not pass the screen, and, therefore, may have the potential to cause adverse environmental effects. Such facilities are evaluated further to investigate factors such as the magnitude and characteristics of the area of exceedance.

For acid gases, the environmental screening analysis evaluates the potential phytotoxicity and reduced productivity of plants due to chronic exposure to acid gases. The environmental risk screening methodology for acid gases is a single-tier screen that compares the average off-site ambient air concentration over the modeling domain to ecological benchmarks for each of the acid gases. For purposes of ecological risk screening, EPA identifies a potential for adverse environmental effects to plant communities from exposure to acid gases when the average concentration of the HAP around a facility exceeds the LOAEL ecological benchmark. In such cases, we further investigate factors such as the magnitude and characteristics of the area of exceedance (e.g., land use of exceedance area, size of exceedance area) to determine if there is an adverse environmental effect.

For lead compounds, we currently do not have the ability to calculate media concentrations using the TRIM.FaTE model. However, air concentrations of lead are already calculated as part of the human health exposure and risk analysis using the HEM3-AERMOD air dispersion model. To evaluate the potential for adverse environmental effects from lead, we compare the average modeled air emission concentrations of lead from each facility in the source category emissions to the level of the secondary National Ambient Air Quality Standard (NAAQS) for lead. The secondary lead NAAQS is a reasonable means of evaluating environmental risk because it is set to provide substantial protection against adverse welfare effects which can include "effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being." [6]

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[6] A secondary standard, as defined in Section 109(b)(2), must "specify a level of air quality the attainment and maintenance of which, in the judgment of the Administrator, based on criteria, is requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air." Welfare effects as defined in section 302(h) (42 U.S.C. 7602(h)) include, but are not limited to, "effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility and climate,

2.6 Dose-response assessment

2.6.1 Sources of chronic dose-response information

Dose-response assessment (carcinogenic and non-carcinogenic) for chronic exposure (either by inhalation or ingestion) for the HAP reported in the emissions inventory for the ferroalloys source category were based on the EPA Office of Air Quality Planning and Standards' (OAQPS) existing recommendations for HAP [*9*], which were also used for NATA [*10*]. This information has been obtained from various sources and prioritized according to (1) conceptual consistency with EPA risk assessment guidelines and (2) level of peer review received. The prioritization process was aimed at incorporating into our assessments the best available science with respect to dose-response information. The recommendations are based on the following sources, in order of priority:

1) US Environmental Protection Agency (EPA). EPA has developed dose-response assessments for chronic exposure for many of the pollutants in this study. These assessments typically provide a qualitative statement regarding the strength of scientific data and specify a reference concentration (RfC, for inhalation) or reference dose (RfD, for ingestion) to protect against effects other than cancer and/or a unit risk estimate (URE, for inhalation) or slope factor (SF, for ingestion) to estimate the probability of developing cancer. The RfC is defined as an "estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." The RfD is "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." The URE is defined as "the upper-bound excess cancer risk estimated to result from continuous lifetime exposure to an agent at a concentration of 1 $\mu g/m^3$ in air." The SF is "an upper bound, approximating a 95 percent confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, [is] usually expressed in units of proportion (of a population) affected per mg/kg-day…" EPA disseminates dose-response assessment information in several forms, based on the level of review. The Integrated Risk Information System (IRIS) [*11*] is an EPA database that contains scientific health assessment information, including dose-response information. All IRIS assessments since 1996 have also undergone independent external peer review. The current IRIS process includes review by EPA scientists, interagency reviewers from other federal agencies, and the public, and peer review by independent scientists external to EPA. New IRIS values are developed and old IRIS values are updated as new health effects data become available. Refer to the "IRIS Track" website[7] for detailed information on status and scheduling of current individual IRIS assessments and updates. EPA's science policy approach, under the current carcinogen guidelines, is to use linear low-dose extrapolation

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damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

[7] http://cfpub.epa.gov/ncea/iristrac/

as a default option for carcinogens for which the mode of action (MOA) has not been identified. We expect future EPA dose-response assessments to identify nonlinear MOAs where appropriate, and we will use those analyses (once they are peer reviewed) in our risk assessments. At this time, however, there are no available carcinogen dose-response assessments for inhalation exposure that are based on a nonlinear MOA.

2) US Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR, which is part of the US Department of Health and Human Services, develops and publishes Minimum Risk Levels (MRLs) [*12*] for inhalation and oral exposure to many toxic substances. As stated on the ATSDR web site: "Following discussions with scientists within the Department of Health and Human Services (HHS) and the EPA, ATSDR chose to adopt a practice similar to that of the EPA's Reference Dose (RfD) and Reference Concentration (RfC) for deriving substance specific health guidance levels for non-neoplastic endpoints." The MRL is defined as "an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure." ATSDR describes MRLs as substance-specific estimates to be used by health assessors to select environmental contaminants for further evaluation. Exposures above an MRL do not necessarily represent a threat, and MRLs are therefore not intended for use as predictors of adverse health effects or for setting cleanup levels.

3) California Environmental Protection Agency (CalEPA). The CalEPA Office of Environmental Health Hazard Assessment has developed dose-response assessments for many substances, based both on carcinogenicity and health effects other than cancer. The process for developing these assessments is similar to that used by EPA to develop IRIS values and incorporates significant external scientific peer review. As cited in the CalEPA Technical Support Document for developing their chronic assessments[8]: "The guidelines for developing chronic inhalation exposure levels incorporate many recommendations of the U.S. EPA [*13*] and NAS [*14*]." The non-cancer information includes available inhalation health risk guidance values expressed as chronic inhalation reference exposure levels (RELs) [*15*]. CalEPA defines the REL as "the concentration level at or below which no health effects are anticipated in the general human population." CalEPA's quantitative dose-response information on carcinogenicity by inhalation exposure is expressed in terms of the URE [*16*], defined similarly to EPA's URE.

In developing chronic risk estimates, we adjusted dose-response values for some HAP based on professional judgment, as follows:

1) Consistent with Agency policy (as mentioned above), which was supported by the SAB,[9] the EPA has chosen in this instance to rely on the ATSDR MRL for manganese in the

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[8] Air Toxics Hot Spots Program, Risk Assessment Guidelines, Part III - Technical Support Document for the Determination of Non-cancer Chronic Reference Exposure Levels. Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. February 2000 (http://www.oehha.ca.gov/air/chronic_rels/pdf/relsP32k.pdf)

[9] The SAB peer review of RTR Risk Assessment Methodologies is available at: http://yosemite.epa.gov/sab/sabproduct.nsf/4AB3966E263D943A8525771F00668381/$File/EPA-SAB-10-007-unsigned.pdf

current ferroalloys supplemental proposal. There is an existing IRIS RfC for manganese (Mn) published in 1993[10]. This value was in the RTR risk assessment supporting the 2011 Ferroalloys Notice of Proposed Rulemaking. However, since the 2011 proposal ATSDR has published an assessment of Mn toxicity (2012) which includes a chronic inhalation reference value (i.e., an ATSDR Minimal Risk Level or MRL)[11]. Both the 1993 IRIS RfC and the 2012 ATSDR MRL were based on the same study (Roels et al., 1993). In developing their assessment, ATSDR used updated dose-response modeling methodology (benchmark dose approach) and considered recent pharmacokinetic findings to support their MRL derivation. Consistent with Agency policy, which was supported by SAB, the EPA has chosen to rely on the ATSDR MRL for Mn in the current ferroalloys supplemental proposal.

2) In the case of nickel compounds, to provide a conservative estimate of potential cancer risks, we used the IRIS URE value for nickel subsulfide (which is considered the most potent carcinogen among all nickel compounds) in the assessment for the 2011 proposed rule for ferroalloys production. In the 2011 proposal rule, the determination of the percent of nickel subsulfide was considered a major factor for estimating the risks of cancer due to nickel-containing emissions. Nickel speciation information for some of the largest nickel-emitting sources (including oil combustion, coal combustion, and others) suggested that at least 35 percent of total nickel emissions may be soluble compounds and that the cancer risk for the mixture of inhaled nickel compounds (based on nickel subsulfide, and representative of pure insoluble crystalline nickel) was derived to reflect the assumption that 65 percent of the total mass of nickel may be carcinogenic.

   Based on consistent views of major scientific bodies (i.e., National Toxicology Program (NTP) in their 12th Report of the Carcinogens (ROC)[12], International Agency for Research on Cancer (IARC)[13], and other international agencies)[14] that consider all nickel compounds to be carcinogenic, we currently consider all nickel compounds to have the potential of being carcinogenic to humans. The *12th Report of the Carcinogens* states that the "combined results of epidemiological studies, mechanistic studies, and carcinogenic studies in rodents support the concept that nickel compounds generate nickel ions in target cells at sites critical for carcinogenesis, thus allowing consideration and evaluation of these compounds as a single group." Although the precise nickel compound (or compounds) responsible for carcinogenic effects in humans is not always clear, studies indicate that nickel sulfate and the combinations of nickel sulfides and oxides encountered

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[10] USEPA Integrated Risk Information System Review of Manganese (1993) available at http://www.epa.gov/iris/subst/0373.htm

[11] Agency for Toxic Substances & Disease Registry Toxicological Profile for Manganese (2012) available at http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=102&tid=23

[12] National Toxicology Program (NTP), 2011. Report on carcinogens. 12th ed. Research Triangle Park, NC: US Department of Health and Human Services (DHHS), Public Health Service. Available online at http://ntp.niehs.nih.gov/ntp/roc/twelfth/roc12.pdf

[13] International Agency for Research on Cancer (IARC), 1990. IARC monographs on the evaluation of carcinogenic risks to humans. Chromium, nickel, and welding. Vol. 49. Lyons, France: International Agency for Research on Cancer, World Health Organization Vol. 49:256.

[14] World Health Organization (WHO, 1991) and the European Union's Scientific Committee on Health and Environmental Risks (SCHER, 2006).

in the nickel refining industries cause cancer in humans (these studies are summarized in a review by Grimsrud et al., 2010[15]). The major scientific bodies mentioned above have also recognized that there are differences in toxicity and/or carcinogenic potential across the different nickel compounds.

In the inhalation risk assessment for the 2011 proposal, to take a conservative approach, we considered all nickel compounds to have the same carcinogenic potential as nickel subsulfide and used the IRIS URE for nickel subsulfide to estimate risks due to all nickel emissions from the source category. However, given that there are two additional URE values[16] derived for exposure to mixtures of nickel compounds, as a group, that are 2-3 fold lower than the IRIS URE for nickel subsulfide, the EPA also considers it reasonable to use a value that is 50 percent of the IRIS URE for nickel subsulfide for providing an estimate of the lower end of the plausible range of cancer potency values for different mixtures of nickel compounds. In the public comments provided in response to the proposal and available in the docket, one facility provided additional data in the form of a laboratory test report that indicated it would be unlikely that 100 percent of the nickel from the furnace would be in the form of nickel subsulfide. Given our current knowledge of the carcinogenic potential of all nickel compounds, and the potential differences in carcinogenic potential across nickel compounds, we consider it reasonable to use a value that is 50 percent of the IRIS URE for nickel subsulfide for providing an estimate of the cancer potency for different mixtures of nickel compounds in the revised dataset for the current supplemental proposal.

3) Where possible for emissions of unspecified mixtures of HAP categories such as metal compounds and POM, we apply category-specific chemical speciation profiles appropriate to the source category to develop a composite dose-response value for the category.

4) Where POM emissions were not speciated into individual compounds, we applied the same simplifying assumptions to assessments that are used in NATA [*17*]. The NATA approach partitions POM into eight different non-overlapping "groups" that are modeled as separate pollutants. Each POM group comprises POM species of similar carcinogenic potency, for which we can apply the same URE.

5) In 2004, the EPA determined that the Chemical Industry Institute of Toxicology (CIIT) cancer dose-response value for formaldehyde (5.5×10^{-9} per µg/m^3) was based on better science than the IRIS cancer dose-response value (1.3×10^{-5} per µg/m^3), and we switched from using the IRIS value to the CIIT value in risk assessments supporting regulatory actions. Subsequent research published by EPA suggested that the CIIT model was not appropriate and, in 2010 EPA returned to using the 1991 IRIS value. The EPA has been working on revising the formaldehyde IRIS assessment and the National Academy of

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[15] Grimsrud TK and Andersen A. Evidence of carcinogenicity in humans of water-soluble nickel salts. J Occup Med Toxicol 2010, 5:1-7. Available online at http://www.occup-med.com/content/5/1/7

[16] Two UREs (other than the current IRIS values) have been derived for nickel compounds as a group: one developed by the California Department of Health Services (http://www.arb.ca.gov/toxics/id/summary/nickel_tech_b.pdf) and the other by the Texas Commission on Environmental Quality (http://www.epa.gov/ttn/atw/nata1999/99pdfs/healtheffectsinfo.pdf).

> Sciences (NAS) completed its review of the EPA's draft assessment in April of 2011.[17] The EPA will follow the NAS Report recommendations and will present results obtained by implementing the biologically-based dose-response (BBDR) model for formaldehyde. The EPA will compare these estimates with those currently presented in the External Review draft of the assessment and will discuss their strengths and weaknesses. As recommended by the NAS committee, appropriate sensitivity and uncertainty analyses will be an integral component of implementing the BBDR model. The draft IRIS assessment will be revised in response to the NAS peer review and public comments and the final assessment will be posted on the IRIS database. In the interim, we will present findings using the 1991 IRIS value as a primary estimate; EPA may also consider other information as the science evolves.

The emissions inventory for the ferroalloys source category includes emissions of HAP with available chronic quantitative inhalation dose-response values. Of these, 38 are classified as known, probably, or possible carcinogens, with quantitative cancer dose-response values available. These 38 HAP, their quantitative inhalation chronic cancer dose-response values, and the source of each value are listed in Table 2.6-1(A). The dioxin and POM compounds with chronic oral cancer dose-response values available (for which multipathway screening assessments were performed) are listed in Table 2.6-1(B). Thirty HAP have quantitative inhalation chronic noncancer threshold values available; two of these thirty HAP (cadmium and mercury), for which a multipathway assessment was performed, also have quantitative oral chronic noncancer threshold values available. These 30 HAP, their threshold values, and the source of the value are listed in Table 2.6-2(A) and Table 2.6-2(B).

Table 2.6-1 (A) Dose-Response Values for Chronic Inhalation Exposure to Carcinogens

URE (unit risk estimate for cancer)[18] = cancer risk per *µg/m³ of a*verage lifetime exposure.
Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Health Hazard Assessment, EPA/OAQPS = interim value recommended by the EPA Office of Air Quality Planning and Standards

Pollutant	**CAS Number[19]**	**URE[5] (1/µg/m³)**	**Source**
Arsenic compounds	7440382	4.3E-3	IRIS
Cadmium compounds	7440439	0.0018	IRIS
Chlorinated Dioxin/Furans			
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	3268879	0.0099	EPA ORD
1,2,3,4,6,7,8,9-Octochlorodibenzofuran	39001020	0.0099	EPA ORD

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[17] http://www.nap.edu/catalog.php?record_id=13142

[18] The URE is the upper-bound excess cancer risk estimated to result from continuous lifetime exposure to an agent at a concentration of 1 µg/m³ in air. URE's are considered upper bound estimates meaning they represent a plausible upper limit to the true value.

[19] Chemical Abstract Services identification number. For groups of compounds that lack a CAS number we have used a surrogate 3-digit identifier corresponding to the group's position on the CAA list of HAP.

Table 2.6-1 (A) Dose-Response Values for Chronic Inhalation Exposure to Carcinogens

URE (unit risk estimate for cancer)[18] = cancer risk per *µg/m³ of* average lifetime exposure. Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Health Hazard Assessment, EPA/OAQPS = interim value recommended by the EPA Office of Air Quality Planning and Standards

Pollutant	CAS Number[19]	URE[5] (1/µg/m³)	Source
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822469	0.33	EPA ORD
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562394	0.33	EPA ORD
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673897	0.33	EPA ORD
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227286	3.3	EPA ORD
1,2,3,4,7,8-Hexachlorodibenzofuran	70648269	3.3	EPA ORD
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653857	3.3	EPA ORD
1,2,3,6,7,8-Hexachlorodibenzofuran	57117449	3.3	EPA ORD
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408743	3.3	EPA ORD
1,2,3,7,8,9-Hexachlorodibenzofuran	72918219	3.3	EPA ORD
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321764	33	EPA ORD
1,2,3,7,8-Pentachlorodibenzofuran	57117416	0.99	EPA ORD
2,3,4,6,7,8-Hexachlorodibenzofuran	60851345	3.3	EPA ORD
2,3,4,7,8-Pentachlorodibenzofuran	57117314	9.9	EPA ORD
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	33	EPA ORD
2,3,7,8-Tetrachlorodibenzofuran	51207319	3.3	EPA ORD
Chromium (VI)	18540299	1.2E-2	IRIS
Formaldehyde[20]	50000	1.3E-5	IRIS
Naphthalene	91203	3.4E-5	CAL

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[20] The EPA has used the CIIT value (5.5×10^{-9} per mg/m³) to characterize formaldehyde cancer risks in some instances.

Table 2.6-1 (A) Dose-Response Values for Chronic Inhalation Exposure to Carcinogens

URE (unit risk estimate for cancer)[18] = cancer risk per *µg/m³ of a*verage lifetime exposure. Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Health Hazard Assessment, EPA/OAQPS = interim value recommended by the EPA Office of Air Quality Planning and Standards

Pollutant	CAS Number[19]	URE[5] $(1/\mu g/m^3)$	Source
Nickel compounds	7440020	2.4E-4[21]	IRIS
Polycyclic Organic Matter	246	[22]	
2-Methylnaphthalene	91576	8.8E-5	CAL
Acenaphthene	83329	8.8E-5	CAL
Acenaphthylene	206968	8.8E-5	CAL
Benz[a]anthracene	56553	1.76E-4	CAL
Benzo[a]pyrene	50328	1.76E-3	CAL
Benzo[b]fluoranthene	205992	1.76E-4	CAL
Benzo[e]pyrene	192972	8.8E-5	CAL
Benzo[g,h,i]perylene	191242	8.8E-5	CAL
Benzo[k]fluoranthene	207089	1.76E-4	CAL
Chrysene	218019	1.76E-5	CAL
Dibenzo[a,h]anthracene	53703	1.92E-3	CAL
Fluoranthene	206440	8.8E-5	CAL
Fluorene	86737	8.8E-5	CAL
Indeno[1,2,3-cd]pyrene	193395	1.76E-4	CAL
Perylene	198550	8.8E-5	CAL

Table 2.6-1 (B) Dose-Response Values for Chronic Oral Exposure to Carcinogens

SF (oral slope factor for cancer) = cancer risk per mg/kg/d of average lifetime exposure. Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Health Hazard Assessment

Pollutant	CAS Number[9]	SF (1/mg/kg/d)	Source
Dioxin/Furans			
Hexachlorodibenzo-p-dioxin	19408743	6200	IRIS
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	150000	EPA ORD

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[21] We typically use the value of 4.8E-4 $(1/\mu g/m^3)$ for nickel compounds, as explained earlier in this report. For this source category, we had information to indicate that a value of 2.4E-4 $(1/\mu g/m^3)$ was appropriate.

[22] Assigned the URE associated with a mixture of POM compounds having a similar potency. Details of this method, also used in the National Air Toxics Assessments, are available at http://www.epa.gov/ttn/atw/nata2005/methods.html#pom

Table 2.6-1 (B) Dose-Response Values for Chronic Oral Exposure to Carcinogens

SF (oral slope factor for cancer) = cancer risk per mg/kg/d of average lifetime exposure.
Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Health Hazard Assessment

Pollutant	CAS Number[9]	SF (1/mg/kg/d)	Source
Polycyclic Organic Matter	246		
Benz[a]anthracene	56553	1.2	CAL
Benzo[a]pyrene	50328	7.3	IRIS
Benzo[b]fluoranthene	205992	1.2	CAL
Benzo[k]fluoranthene	207089	1.2	CAL
Chrysene	218019	0.12	CAL
Dibenzo[a,h]anthracene	53703	4.1	CAL
Indeno[1,2,3-cd]pyrene	193395	1.2	CAL

Table 2.6-2 (A) Dose-Response Values for Chronic Inhalation Exposure to Noncarcinogens

RfC (reference inhalation concentration) = an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Human Health Assessment, ATSDR = US Agency for Toxic Substances Disease Registry, EPA/OAQPS = interim value recommended by the EPA Office of Air Quality Planning and Standards

Pollutant	CAS Number[6]	RfC (mg/m^3)	Source[23]
Arsenic compounds	7440382	0.000015	CAL
Cadmium compounds	7440439	0.00001	ATSDR
Chlorinated dioxins and furans			
1,2,3,4,6,7,8,9-Octochlorodibenzofuran	39001020	0.00013	CAL
1,2,3,4,6,7,8,9-Octochlorodibenzo-p-dioxin	3268879	0.00013	CAL
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562394	0.000004	CAL
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822469	0.000004	CAL
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673897	0.000004	CAL
1,2,3,4,7,8-Hexachlorodibenzofuran	70648269	0.0000004	CAL
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227286	0.0000004	CAL
1,2,3,6,7,8-Hexachlorodibenzofuran	57117449	0.0000004	CAL
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653857	0.0000004	CAL
1,2,3,7,8,9-Hexachlorodibenzofuran	72918219	0.0000004	CAL

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[23] The descriptors L (low), M (medium), and H (high) have been added for IRIS RfC values to indicate the overall level of confidence in the RfC value, as reported in the IRIS file.

Table 2.6-2 (A) Dose-Response Values for Chronic Inhalation Exposure to Noncarcinogens

RfC (reference inhalation concentration) = an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Sources: IRIS = EPA Integrated Risk Information System, CAL = California EPA Office of Environmental Human Health Assessment, ATSDR = US Agency for Toxic Substances Disease Registry, EPA/OAQPS = interim value recommended by the EPA Office of Air Quality Planning and Standards

Pollutant	**CAS Number**[6]	**RfC (mg/m^3)**	**Source**[23]
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408743	0.0000004	CAL
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321764	0.00000004	CAL
1,2,3,7,8-Pentachlorodibenzofuran	57117416	0.0000013	CAL
2,3,4,6,7,8-Hexachlorodibenzofuran	60851345	0.0000004	CAL
2,3,4,7,8-Pentachlorodibenzofuran	57117314	0.00000013	CAL
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	0.00000004	CAL
2,3,7,8-Tetrachlorodibenzofuran	51207319	0.0000004	CAL
Chromium (VI) compounds	18540299	0.0001	IRIS - M
Formaldehyde	50000	0.0098	ATSDR
Hydrochloric acid	7647010	0.02	IRIS - L
Hydrofluoric acid	7664393	0.014	CAL
Lead compounds	7439921	0.00015	EPA OAQPS
Manganese compounds	7439965	0.0003	ATSDR
Mercury (elemental)	7439976	0.0003	IRIS - M
Gaseous divalent mercury	201	0.0003	IRIS - M
Particulate divalent mercury	184	0.0003	IRIS - M
Naphthalene	91203	0.003	IRIS - M
Nickel compounds	7440020	0.00009	ATSDR

Table 2.6-1 (B) Dose-Response Values for Chronic Oral Exposure to Noncarcinogens

RfD (reference dose) = an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
Sources: IRIS = EPA Integrated Risk Information System

Pollutant	**CAS Number**	**RfD (mg/kg/d)**	**Source**[24]
Cadmium compounds	7440439	0.0005	IRIS - H
Mercuric chloride[25]	7439976	0.0003	IRIS - H

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[24] The descriptors L (low), M (medium), and H (high) have been added for IRIS RfC values to indicate the overall level of confidence in the RfC value, as reported in the IRIS file.

[25] The multipathway exposure assessment for mercury included fate and transport analysis, that included separate oral exposure estimates for divalent mercury and methylmercury.

2.6.2 Sources of acute dose-response information

Hazard identification and dose-response assessment information for preliminary acute inhalation exposure assessments are based on the existing recommendations of OAQPS for HAP [*18*]. Depending on availability, the results from screening acute assessments are compared to both "no effects" reference levels for the general public, such as the California Reference Exposure Levels (RELs), as well as emergency response levels, such as Acute Exposure Guideline Levels (AEGLs) and Emergency Response Planning Guidelines (ERPGs), with the recognition that the ultimate interpretation of any potential risks associated with an estimated exceedance of a particular reference level depends on the definition of that level and any limitations expressed therein. Comparisons among different available inhalation health effect reference values (both acute and chronic) for selected HAP can be found in an EPA document of graphical arrays [*19*].

California Acute Reference Exposure Levels (RELs). The California Environmental Protection Agency (CalEPA) has developed acute dose-response reference values for many substances, expressing the results as acute inhalation Reference Exposure Levels (RELs).

> The acute REL (http://www.oehha.ca.gov/air/pdf/acuterel.pdf) is defined by CalEPA as "the concentration level at or below which no adverse health effects are anticipated for a specified exposure duration. [*20*]. RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact." Acute RELs are developed for 1-hour (and 8-hour) exposures. The values incorporate uncertainty factors similar to those used in deriving EPA's Inhalation Reference Concentrations (RfCs) for chronic exposures (and, in fact, California also has developed chronic RELs).

Acute Exposure Guideline Levels (AEGLs). AEGLs are developed by the National Advisory Committee (NAC) on Acute Exposure Guideline Levels (NAC/AEGL) for Hazardous Substances, and then reviewed and published by the National Research Council. As described in the Committee's "Standing Operating Procedures (SOP)" (http://www.epa.gov/opptintr/aegl/pubs/sop.pdf), AEGLs "represent threshold exposure limits for the general public and are applicable to emergency exposures ranging from 10 min to 8 h." Their intended application is "for conducting risk assessments to aid in the development of emergency preparedness and prevention plans, as well as real time emergency response actions, for accidental chemical releases at fixed facilities and from transport carriers." The document states that "the primary purpose of the AEGL program and the NAC/AEGL Committee is to develop guideline levels for once-in-a-lifetime, short-term exposures to airborne concentrations of acutely toxic, high-priority chemicals." In detailing the intended application of AEGL values, the document states that, "It is anticipated that the AEGL values will be used for regulatory and nonregulatory purposes by U.S. Federal and State agencies, and possibly the international community in conjunction with chemical emergency response, planning, and prevention programs. More specifically, the AEGL values will be used for conducting various risk assessments to aid in the development of emergency preparedness and prevention plans, as well as real-time emergency response actions, for accidental chemical releases at fixed facilities and from transport carriers."

The NAC/AEGL defines AEGL-1 and AEGL-2 as:

> "AEGL-1 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."
>
> "AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance 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."
>
> "Airborne concentrations below AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, nonsensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL."

Emergency Response Planning Guidelines (ERPGs). The American Industrial Hygiene Association (AIHA) has developed Emergency Response Planning Guidelines (ERPGs) [*21*] for acute exposures at three different levels of severity. These guidelines represent concentrations for exposure of the general population (but not particularly sensitive persons) for up to 1 hour associated with effects expected to be mild or transient (ERPG-1), irreversible or serious (ERPG-2), and potentially life-threatening (ERPG-3).

ERPG values (https://www.aiha.org/get-involved/aihaguidelinefoundation/emergencyresponseplanningguidelines/Pages/default.aspx) are described in their supporting documentation as follows: "ERPGs are air concentration guidelines for single exposures to agents and are intended for use as tools to assess the adequacy of accident prevention and emergency response plans, including transportation emergency planning, community emergency response plans, and incident prevention and mitigation."

ERPG-1 and ERPG-2 values are defined by AIHA as follows:

> "ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild

> transient adverse health effects or without perceiving a clearly defined, objectionable odor."
>
> "ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action."

In the RTR program, EPA assesses acute risk using toxicity values derived from one hour exposures. Based on an in-depth examination of the available acute value for nickel [California EPA's acute (1-hour) REL], we have concluded that this value is not appropriate to use to support EPA's risk and technology reviews rules. This conclusion takes into account: the effect on which the acute REL is based; aspects of the methodology used in its derivation; and how this assessment stands in comparison to the ATSDR toxicological assessment, which considered the broader nickel health effects database.

The broad nickel noncancer health effects database strongly suggests that the respiratory tract is the primary target of nickel toxicity following inhalation exposure. The available database on acute noncancer respiratory effects is limited and was considered unsuitable for quantitative analysis of nickel toxicity by both California EPA[26] and ATSDR[27]. The California EPA's acute (1-hour) REL is based on an alternative endpoint, immunotoxicity in mice, specifically depressed antibody response measured in an antibody plaque assay.

In addition, the current California acute (1-hour) REL for Ni includes the application of methods that are different from those described in EPA guidelines. Specifically, the (1-hour) REL applies uncertainty factors that depart from the defaults in EPA guidelines and does not apply an inhalation dosimetric adjustment factor.

Further, the ATSDR's intermediate MRL (relevant to Ni exposures for a time frame between 14 and 364 days), was established at the same concentration as the California EPA (1- hour) REL, indicating that exposure to this concentration "is likely to be without appreciable risk of adverse noncancer effects" (MRL definition)[28] for up to 364 days.

We have high confidence in the nickel ATSDR intermediate MRL. Our analysis of the broad toxicity database for nickel indicates that this value is based on the most biologically-relevant endpoint. That is, the intermediate MRL is based on a scientifically sound study of acute respiratory toxicity. Furthermore, this value is supported by a robust subchronic nickel toxicity database and was derived following guidelines that are consistent with EPA guidelines.[29] Finally, there are no AEGL-1/ERPG-1 or AEGL-2/ERPG-2 values available for nickel. Thus, for all the above mentioned reasons, we will not include Ni in our acute analysis

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[26] http://oehha.ca.gov/air/allrels.html
[27] http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=44
[28] Agency for Toxic Substances and Disease Registry (ATSDR), Toxic Substances Portal. Minimal Risk Levels (MRLs) http://www.atsdr.cdc.gov/mrls/index.asp
[29] US EPA 2002. Review of the reference dose and reference concentration processes (EPA/630/P-02/002F December 2002, http://www.epa.gov/raf/publications/pdfs/rfd-final.pdf

for this source category or in future assessments unless and until an appropriate value becomes available.

The emissions inventory for the ferroalloys source category includes emissions of six HAP with relevant and available quantitative acute dose-response threshold values. These HAP, their acute threshold values, and the source of the value are listed below in Table 2.6-3.

Table 2.6-3 Dose-Response Values for Acute Exposure

Pollutant	CAS Number	AEGL-1 (1-hr) (mg/m^3)	AEGL-2 (1-hr) (mg/m^3)	ERPG-1 (mg/m^3)	ERPG-2 (mg/m^3)	REL (mg/m^3)
Arsenic compounds	7440382					0.0002
Formaldehyde	50000	1.1	17	1.2	12	0.055
Hydrochloric acid	7647010	2.7	33	4.5	30	2.1
Hydrofluoric acid	7664393	0.82	20	1.6	16	0.24
Mercury (elemental)	7439976		1.7		2	0.0006

2.7 Risk characterization

2.7.1 General

The final product of the risk assessment is the risk characterization, in which the information from the previous steps is integrated and an overall conclusion about risk is synthesized that is complete, informative, and useful for decision makers. In general, the nature of this risk characterization depends on the information available, the application of the risk information and the resources available. In all cases, major issues associated with determining the nature and extent of the risk are identified and discussed. Further, the EPA Administrator's March 1995 *Policy for Risk Characterization* [*22*] specifies that a risk characterization "be prepared in a manner that is clear, transparent, reasonable, and consistent with other risk characterizations of similar scope prepared across programs in the Agency." These principles of transparency and consistency have been reinforced by the *Agency's Risk Characterization Handbook* [*23*], in 2002 by the Agency's information quality guidelines [*24*], and in the OMB/OSTP September 2007 Memorandum on Updated Principles for Risk Analysis[30], and are incorporated in these assessments.

Estimates of health risk are presented in the context of uncertainties and limitations in the data and methodology. Through our tiered, iterative analytical approach, we have attempted to reduce both uncertainty and bias to the greatest degree possible in these assessments, within the limitations of available time and resources. We provide summaries of risk metrics

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[30] Memorandum for the Heads of Executive Departments and Agencies - Updated Principles for Risk Analysis (September 19, 2007), From Susan E. Dudley, Administrator, Office of Information and Regulatory Affairs, Office of Management and Budget; and Sharon L. Hays, Associate Director and Deputy Director for Science, Office of Science and Technology Policy
http://www.whitehouse.gov/sites/default/files/omb/memoranda/fy2007/m07-24.pdf

(including maximum individual cancer risks and noncancer hazards, as well as cancer incidence estimates) along with a discussion of the major uncertainties associated with their derivation to provide decision makers with the fullest picture of the assessment and its limitations.

For each carcinogenic HAP included in an assessment that has a potency estimate available, individual and population cancer risks were calculated by multiplying the corresponding lifetime average exposure estimate by the appropriate URE. This calculated cancer risk is defined as the upper-bound probability of developing cancer over a 70-yr period (i.e., the assumed human lifespan) at that exposure. Because UREs for most HAP are upper-bound estimates, actual risks at a given exposure level may be lower than predicted, and could be zero.

For EPA's list of carcinogenic HAP that act by a mutagenic mode-of-action [*25*], we applied EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* [*26*]. This guidance has the effect of adjusting the URE by factors of 10 (for children aged 0-1), 3 (for children aged 2-15), or 1.6 (for 70 years of exposure beginning at birth), as needed in risk assessments. In this case, this has the effect of increasing the estimated life time risks for these pollutants by a factor of 1.6. In addition, although only a small fraction of the total POM emissions may be reported as individual compounds, EPA expresses carcinogenic potency for compounds in this group in terms of benzo[a]pyrene equivalence, based on evidence that carcinogenic POM have the same mutagenic mechanism of action as does benzo[a]pyrene. For this reason, EPA implementation policy [*27*] recommends applying the *Supplemental Guidance* to all carcinogenic PAHs for which risk estimates are based on relative potency. Accordingly, we applied the Supplemental Guidance to all unspeciated POM mixtures.

Increased cancer incidence for the entire receptor population within the area of analysis was estimated by multiplying the estimated lifetime cancer risk for each census block by the number of people residing in that block, then summing the results for the entire modeled domain. This lifetime population incidence estimate was divided by 70 years to obtain an estimate of the number of cancer cases per year.

Unlike linear dose-response assessments for cancer, noncancer health hazards generally are not expressed as a probability of an adverse occurrence. Instead, "risk" for noncancer effects is expressed by comparing an exposure to a reference level as a ratio. The "hazard quotient" (HQ) is the estimated exposure divided by a reference level (e.g., the RfC). For a given HAP, exposures at or below the reference level (HQ $\leq$ 1) are not likely to cause adverse health effects. As exposures increase above the reference level (HQs increasingly greater than 1), the potential for adverse effects increases. For exposures predicted to be above the RfC, the risk characterization includes the degree of confidence ascribed to the RfC values for the compound(s) of concern (i.e., high, medium, or low confidence) and discusses the impact of this on possible health interpretations.

The risk characterization for chronic effects other than cancer is expressed in terms of the HQ for inhalation, calculated for each HAP at each census block centroid. As discussed above, RfCs incorporate generally conservative uncertainty factors in the face of uncertain extrapolations, such that an HQ greater than one does not necessarily suggest the onset of adverse effects. The HQ cannot be translated to a probability that adverse effects will occur, and is unlikely to be proportional to adverse health effect outcomes in a population.

Screening for potentially significant acute inhalation exposures also followed the HQ approach. We divided the maximum estimated acute exposure by each available short-term threshold value to develop an array of HQ values relative to the various acute endpoints and thresholds. In general, when none of these HQ values are greater than one, there is no potential for acute risk. In those cases where HQ values above one are seen, additional information is used to determine if there is a potential for significant acute risks.

2.7.2 Mixtures

Since most or all receptors in these assessments receive exposures to multiple pollutants rather than a single pollutant, we estimated the aggregate health risks associated with all the exposures from a particular source category combined.

To combine risks across multiple carcinogens, our assessments use the mixtures guidelines' [*28*,*29*] default assumption of additivity of effects, and combine risks by summing them using the independence formula in the mixtures guidelines.

In assessing noncancer hazard from chronic exposures, in cases where different pollutants cause adverse health effects via completely different modes of action, it may be inappropriate to aggregate HQs. In consideration of these mode-of-action differences, the mixtures guidelines support aggregating effects of different substances in specific and limited ways. To conform to these guidelines, we aggregated non-cancer HQs of HAP that act by similar toxic modes of action, or (where this information is absent) that affect the same target organ. This process creates, for each target organ, a target-organ-specific hazard index (TOSHI), defined as the sum of hazard quotients for individual HAP that affect the same organ or organ system. All TOSHI calculations presented here were based exclusively on effects occurring at the "critical dose" (i.e., the lowest dose that produces adverse health effects). Although HQs associated with some pollutants have been aggregated into more than one TOSHI, this has been done only in cases where the critical dose affects more than one target organ. Because impacts on organs or systems that occur above the critical dose have not been included in the TOSHI calculations, some TOSHIs may have been underestimated. As with the HQ, the TOSHI should not be interpreted as a probability of adverse effects, or as strict delineation of "safe" and "unsafe" levels. Rather, the TOSHI is another measure of the potential for adverse health outcomes associated with pollutant exposure, and needs to be interpreted carefully by health scientists and risk managers.

Because of the conservative nature of the acute inhalation screening and the variable nature of emissions and potential exposures, acute impacts were screened on an individual pollutant basis, not using the TOSHI approach.

2.7.3 MACT-Allowable Risks

The emissions data in the dataset for the ferroalloys source category are estimates of actual emissions on an annual basis. The risk results presented in the following sections are based on these actual emissions. For the ferroalloys production source category, estimates of MACT-allowable emissions were also estimated, and the risk results based on those emissions are presented below as well. For more detail, please refer to the emissions memo in the docket, which is also Appendix 1 to this document, *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category.*

3 Risk results for the Ferroalloys source category

3.1 Source category description and results

The ferroalloys production source category consists of major source facilities that produce ferroalloys containing manganese, such as ferromanganese and silicomanganese. A ferroalloy is an alloy of iron and one or more other elements, such as nickel, chromium, manganese, and/or silicon. Silicon metal is also typically considered a ferroalloy product. Ferroalloy products are consumed primarily in iron and steel making, where they are used to produce steel and cast iron products with enhanced or special properties. Ferroalloys production normally occurs when an electric arc furnace (EAF) is charged with raw materials to begin smelting the ores. The molten product is "tapped" or poured from the furnace. Raw material and product handling (e.g., crushing and screening operations) also occur as part of the ferroalloy production process. The HAP emission sources at ferroalloys production facilities include EAFs, tapping operations, metal oxygen refining (MOR) processes, crushing and screening operations, ladle treatment, casting, and fugitive dust sources. The specific HAP that are emitted, and the quantity of these emissions, are related to the amount of HAP compounds present in the raw materials used. Metallic HAP expected to be emitted by the furnaces include arsenic, chromium, manganese, and nickel. Emissions of polycyclic organic matter (POM), such as PAH, are also expected but in relatively small quantities. Additionally, chlorine is present in coal, which is used as a raw material in the furnace, and thus hydrochloric acid emissions can be expected.

There are 2 ferroalloys production facilities operating in the U.S. Both facilities are identified as major sources of HAP. The emissions for the ferroalloys source category dataset are summarized in Table 3.1-1. The total HAP emissions for the source category are approximately 200 tons per year. Based on these data, the HAP emitted in the largest quantities are manganese compounds, hydrofluoric acid, hydrochloric acid, and formaldehyde.[31] Emissions of these four HAP make up more than 90 percent of the total emissions by mass. Persistent and bioaccumulative HAP (PB-HAP)[32] reported as emissions

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[31] As described in the emissions memo *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*, numerical estimates for HF were provided for input to the risk assessment. Upon closer investigation, we found that all test results were below the detection limit of the test method and therefore we believe HF is not emitted from these sources.

[32] Persistent and bioaccumulative HAP are defined in the EPA's *Air Toxics Risk Assessment Library*, Volume 1, EPA-453K-04-001A, as referenced in the ANPRM and provided on the EPA's Technology Transfer Network

from these facilities include lead compounds, mercury compounds, PCBs, dioxins/furans, cadmium compounds, and polycyclic organic matter. The following environmental HAP are emitted from the ferroalloys production source category and are included in the environmental risk screen: cadmium, dioxins/furans, hydrogen chloride, hydrofluoric acid, lead, mercury, and PAHs.

Table 3.1-1 Summary of Emissions from the Ferroalloys Source Category Used in the Residual Risk Assessment and Availability of Dose-Response Values

HAP[a]	Emission Estimates (tpy)	Number of Facilities where HAP Reported or Estimated (2 facilities in dataset)	Prioritized Inhalation Dose-Response Value Identified by OAQPS[b]			PB-HAP?
			Unit Risk Estimate for Cancer?	Reference Concentration for Noncancer?	Health Benchmark Values for Acute Noncancer?	
Manganese compounds	109	2		Y		
Hydrofluoric acid	41	2		Y	Y	
Hydrochloric acid	25	2		Y	Y	
Formaldehyde	7	2	Y	Y	Y	
Polycyclic Organic Matter						
2-Methylnaphthalene	1	2	Y			Y
Acenaphthene	0.4	2	Y			Y
Acenaphthylene	1	2	Y			Y
Anthracene	0.5	2				Y
Benz[a]anthracene	0.2	2	Y			Y
Benzo[a]pyrene	0.03	2	Y			Y
Benzo[b]fluoranthene	0.2	2	Y			Y
Benzo[g,h,i]perylene	0.02	2	Y			Y
Benzo[e]pyrene	0.2	2	Y			Y
Benzo[k]fluoranthene	0.05	2	Y			Y
Chrysene	0.5	2	Y			Y
Dibenzo[a,h]anthracene	0.003	2	Y			Y
Fluorene	0.5	2	Y			Y
Fluoranthene	2	2	Y			Y
Indeno[1,2,3-cd]pyrene	0.01	2	Y			Y
Perylene	0.003	2	Y			Y
Phenanthrene	3	2				Y
Pyrene	1	2				Y
Naphthalene	2	2	Y	Y		
Lead compounds	1	2		c		Y
Nickel compounds	0.4	2	Y	Y		
Mercury compounds						
Mercury (elemental)	0.2	2		Y	Y	Y
Gaseous divalent mercury	0.02	2		Y		Y

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website for Fate, Exposure, and Risk Assessment at http://www2.epa.gov/sites/production/files/2013-08/documents/volume_1_reflibrary.pdf

Table 3.1-1 Summary of Emissions from the Ferroalloys Source Category Used in the Residual Risk Assessment and Availability of Dose-Response Values

HAP[a]	Emission Estimates (tpy)	Number of Facilities where HAP Reported or Estimated (2 facilities in dataset)	Prioritized Inhalation Dose-Response Value Identified by OAQPS[b]			PB-HAP?
			Unit Risk Estimate for Cancer?	Reference Concentration for Noncancer?	Health Benchmark Values for Acute Noncancer?	
Particulate divalent mercury	0.02	2		Y		Y
Chromium compounds						
Chromium III	0.1	2				
Chromium (VI)	0.02	2	Y	Y		
Cadmium compounds	0.1	2	Y	Y		Y
Arsenic compounds	0.04	2	Y	Y	Y	
Polychlorinated Biphenyls	0.0003	2	Y			Y
Chlorinated Dibenzodioxins and furans						
1,2,3,4,6,7,8,9-Octochlorodibenzofuran	2.69E-07	2	Y	Y		Y
1,2,3,4,6,7,8,9-Octochlorodibenzo-p-dioxin	8.76E-07	2	Y	Y		Y
1,2,3,4,6,7,8-Heptachlorodibenzofuran	2.19E-07	2	Y	Y		Y
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.59E-07	2	Y	Y		Y
1,2,3,4,7,8,9-Heptachlorodibenzofuran	6.38E-08	2	Y	Y		Y
1,2,3,4,7,8-Hexachlorodibenzofuran	2.54E-07	2	Y	Y		Y
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	6.72E-08	2	Y	Y		Y
1,2,3,6,7,8-Hexachlorodibenzofuran	1.33E-07	2	Y	Y		Y
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	6.78E-08	2	Y	Y		Y
1,2,3,7,8,9-Hexachlorodibenzofuran	6.68E-08	2	Y	Y		Y
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	7.67E-08	2	Y	Y		Y
1,2,3,7,8-Pentachlorodibenzofuran	3.3E-07	2	Y	Y		Y
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1.06E-07	2	Y	Y		Y
2,3,4,6,7,8-Hexachlorodibenzofuran	1.12E-07	2	Y	Y		Y
2,3,4,7,8-Pentachlorodibenzofuran	3.29E-07	2	Y	Y		Y
2,3,7,8-Tetrachlorodibenzofuran	1.58E-06	2	Y	Y		Y

Table 3.1-1 Summary of Emissions from the Ferroalloys Source Category Used in the Residual Risk Assessment and Availability of Dose-Response Values

HAP[a]	**Emission Estimates (tpy)**	**Number of Facilities where HAP Reported or Estimated (2 facilities in dataset)**	**Prioritized Inhalation Dose-Response Value Identified by OAQPS**[b]			**PB-HAP?**
			Unit Risk Estimate for Cancer?	**Reference Concentration for Noncancer?**	**Health Benchmark Values for Acute Noncancer?**	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1.15E-07	2	Y	Y		Y

[a] Notes for how HAP were speciated for risk assessment:

- For most metals, emissions reported as the elemental metal are combined with metal compound emissions (e.g., “cadmium” emissions modeled as “cadmium & compounds”). In the absence of speciation information, we assume the reported mass is 100 percent metal.
- Chromium emissions were speciated based on test data. See Appendix 1 of this document (*Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*) for more information.
- For emissions reported generically as “mercury” or “mercury & compounds,” emissions are speciated for this category as 80 percent “mercury (elemental),” 10 percent “gaseous divalent mercury,” and 10 percent “particulate divalent mercury.” Mercury speciation profiles can be found on the EPA’s Technology Transfer Network website for emissions inventories at http://www.epa.gov/ttn/chief/net/2005inventory.html#inventorydata

[b] Specific dose-response values for each chemical are identified on EPA’s Technology Transfer Network website for air toxics at http://www2.epa.gov/fera/dose-response-assessment-assessing-health-risks-associated-exposure-hazardous-air-pollutants

[c] There is no reference concentration for lead. In considering noncancer hazards for lead in this assessment, we compared the average exposure estimates to the National Ambient Air Quality Standards (NAAQS) for lead (0.15 µg/m^3). These NAAQS for lead were adopted in October 2008 (http://www.epa.gov/air/lead/actions.html). The primary (health-based) standard is a maximum or not-to-be-exceeded, rolling three-month average, measured as total suspended particles (TSP). The secondary (welfare-based) standard is identical to the primary standard.

3.2 Baseline risk characterization

This section presents the results of the baseline risk assessment for the ferroalloys production source category based on the modeling methods described in the previous sections. All baseline risk results are developed using the best estimates of actual HAP emissions summarized in the previous section. The basic chronic inhalation risk estimates presented here are the maximum individual lifetime cancer risk, the maximum chronic hazard index, and the cancer incidence. We also present results from our acute inhalation impact screening assessments in the form of maximum hazard quotients, as well as the results of our preliminary screen for potential non-inhalation risks from PB-HAP. Also presented are the HAP “drivers,” which are the HAP that collectively contribute 90 percent of the maximum cancer risk or maximum hazard at the highest exposure location, as well as our analysis of risks associated with the maximum allowed emissions under the current MACT standards. A detailed summary of the facility-specific risk assessment results is available in Appendix 6 of this document, *Draft Detailed Risk Modeling Results*.

Baseline Inhalation Risk Assessment Results Based on Actual Emissions

Tables 3.2-1 and 3.2-2 summarize the chronic and acute inhalation risk results for this source category. The results of the chronic inhalation cancer risk assessment estimate that the maximum lifetime individual cancer risk posed by these two facilities could be as high as 20 in a million, with PAHs, chromium compounds, and nickel compounds from process fugitives as the major contributors to the risk. The total estimated cancer incidence from this source category is 0.002 excess cancer cases per year, or one excess case in every 500 years. Approximately 400 people are estimated to have cancer risks above 10 in a million and approximately 31,000 people are estimated to have cancer risks above 1 in a million considering the two facilities in this source category. The maximum chronic noncancer TOSHI value for the source category could be up to 4 from emissions of manganese from process fugitives as the major contributors to the HI. An estimated 1,500 people are exposed to TOSHI levels above 1 due to manganese emissions.

Worst-case acute hazard quotients (HQs) were calculated for every emitted HAP that has an acute benchmark, as shown in Table 3.1-1. For cases where the screening HQ was greater than 1, we further refined the estimates by determining the highest HQ value that might occur outside facility boundaries. Based on actual, baseline emissions, the highest acute screening HQ value is 1 (based on the acute RELs for arsenic compounds, formaldehyde, and hydrofluoric acid) and is shown in Table 3.2-1. This value includes a refinement of determining the highest HQ value that is outside facility boundaries.

Table 3.2-1 Summary of Source Category Level Inhalation Risks for Ferroalloys

Result		HAP "Drivers"
Facilities in Source Category		
Number of Facilities Estimated to be in Source Category	2	n/a
Number of Facilities Identified in NEI and Modeled in Risk Assessment	2	n/a
Cancer Risks		
Maximum Individual Lifetime Cancer Risk (in 1 million)	20	chromium compounds, PAH, nickel compounds
Number of Facilities with Maximum Individual Lifetime Cancer Risk:		
Greater than or equal to 100 in 1 million	0	n/a
Greater than or equal to 10 in 1 million	2	chromium compounds, PAH, nickel compounds, arsenic compounds, formaldehyde, dioxins, cadmium compounds
Greater than or equal to 1 in 1 million	2	chromium compounds, PAH, nickel compounds, arsenic compounds, formaldehyde, dioxins, cadmium compounds
Chronic Noncancer Risks		
Maximum Neurological Hazard Index	4	manganese compounds
Number of Facilities with Maximum Neurological Hazard Index:		

Table 3.2-1 Summary of Source Category Level Inhalation Risks for Ferroalloys

Result		**HAP "Drivers"**
Greater than 1	2	manganese compounds
Acute Noncancer Refined Screening Results		
Maximum Acute Hazard Quotient[33]	1 1 1 <1 <1	arsenic compounds (REL) formaldehyde (REL) hydrofluoric acid (REL) hydrochloric acid (REL) mercury (REL)
Number of Facilities With Potential for Acute Effects	0	n/a
Population Exposure		
Number of People Living Within 50 Kilometers of Facilities Modeled	380,000	n/a
Number of People Exposed to Cancer Risk:		
Greater than or equal to 100 in 1 million	0	n/a
Greater than or equal to 10 in 1 million	400	n/a
Greater than or equal to 1 in 1 million	31,000	n/a
Number of People Exposed to Noncancer Neurological Hazard Index:		
Greater than 1	1,500	n/a
Estimated Cancer Incidence (excess cancer cases per year)	0.002	n/a
Contribution of HAP to Cancer Incidence		
PAH	42%	n/a
Chromium compounds	18%	n/a
Cadmium compounds	15%	n/a
Arsenic compounds	12%	n/a

Baseline Inhalation Assessment Results Based on Allowable Emissions

Analysis of potential differences between actual emissions levels and the maximum emissions allowable under the MACT standards (i.e., MACT-allowable emissions) were also calculated for stack emissions for the two facilities.[34] Risk estimates based on the actual emissions were then scaled up using these factors. (See *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category* in

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[33] There are no reference values available (including a lack of short-term occupational values) to assess any potential risks from acute exposure to manganese. In addition, as described earlier, we do not believe that HF is emitted from these sources.

[34] MACT-allowable emissions were not calculated for process fugitive or fugitive emissions because the current MACT standard only has emission limits for stack emissions. In addition, MACT-allowable emissions were not calculated for those HAP (e.g., PAH) that do not currently have a MACT standard. Finally, for Eramet, the allowable estimates include emissions for an idle furnace that was not included in the calculation of actual emissions because it is not currently operating. MACT-allowable emissions, and associated risks, are likely underestimated.

Appendix 1 of this document, or separately in the docket, for a discussion of the development of the allowable factors.) In addition, an idled furnace at Eramet was included in the calculation of allowable risks. Risk results from the inhalation risk assessment using the MACT-allowable stack emissions indicate that the maximum lifetime individual cancer risk could be as high as 100 in a million with arsenic and cadmium emissions driving the risks, and that the maximum chronic noncancer TOSHI value could be as high as 40 at the MACT-allowable emissions level with manganese emissions driving the TOSHI value. Risks are likely higher than these presented here because process fugitive emissions increase with increased stack emissions (for which there are current MACT standards), and emissions of pollutants for which there are currently no MACT standards would also increase with increased stack emissions.

Baseline Multipathway Assessment Results Based on Actual Emissions

To identify potential multipathway health risks from PB-HAP other than lead, we first performed a screening analysis (Tier I) that compared emissions of PB-HAP emitted from the ferroalloys source category (based on actual emissions) to screening emission rates (see section 2.5). The PB-HAP emitted by facilities in this category include cadmium compounds, chlorinated dibenzodioxins and furans (as 2,3,7,8-TCDD toxicity equivalents, or TEQ), mercury compounds, polychlorinated biphenyls (PCBs), and POM (as benzo(a)pyrene TEQ). PCBs are PB-HAP but do not currently have multipathway screening values and so were not evaluated for potential non-inhalation risks. As shown in Table 3.1-1, this PB-HAP is not emitted in appreciable quantities.

The two facilities in the source category both reported emissions of these PB-HAP, and with the exception of cadmium emissions from one facility, both facilities had emission rates greater than the screening emission levels for all four PB-HAP indicating that the initial multipathway screening model does not rule out the potential for multipathway impacts of concern. One facility's emission rates of cadmium compounds exceeded the screening level by about 10 times, while the other was below the level. One facility's emission rates of mercury exceeded the screening level by 100 times, while the other facility's mercury emission rates exceeded the level by 10 times. For dioxins, one facility's emission rates exceeded the level by 100 times, while the other facility's emission rates exceeded the level by 80 times. For POM, one facility's emission rates exceeded the screening level by 200 times, while the other facility's emission rates exceeded the level by 30 times. Due to the theoretical construct of the screening model, these factors are not directly translatable into estimates of risk or hazard quotients for these facilities. Table 3.2-2 summarizes the results of this Tier I screen.

For the PB-HAP and facilities that did not screen out during our initial Tier I multipathway screening analysis, we improved our analysis with some additional site-specific information to develop a Tier II screen. (See Appendix 4 of this document, *Technical Support Document for TRIM-Based Multipathway Screening Scenario for RTR: Summary of Approach and Evaluation*, for more information about the Tier II screen.) The additional site-specific information included the land use around the facilities, the location of fishable lakes, and local wind direction and speed. The result of this analysis was the development of site-specific emission screening levels for each of the four PB-HAP. Based on this Tier II screening analysis, the cadmium emission rates for both facilities were below site-specific levels for that PB-HAP. For mercury, one facility's emissions equaled the screening level, while the other facility had emissions of mercury that exceeded its site-specific level by nine times. The PAH and dioxin emissions at both facilities exceeded their respective site-specific levels by a range of 3 to 20. Table 3.2-2 presents these results.

Similar to the results from the Tier I screen, an exceedance of a screening level in Tier II cannot be equated with a risk value or a hazard quotient (or hazard index). Rather, it represents a high-end estimate of what the risk or hazard may be. For example, an exceedance of 2 for a non-carcinogen can be interpreted to mean that we have high confidence that the hazard would be lower than 2. Similarly, an exceedance of 30 for a carcinogen means that we have high confidence that the risk is lower than 30 in a million. Our confidence comes from the conservative, or health-protective, assumptions that are in the screens: we choose inputs from the upper end of the range of possible values for the influential parameters used in the screens; and we assume that the exposed individual exhibits ingestion behavior that would lead to a high total exposure.

Table 3.2-2 Summary of Source Category Level Multipathway Screening Assessment Risk Results for Ferroalloys

			Tier I		Tier II	
PBHAP	Facilities Emitting PBHAP (2 in source category)	Max Emissions of this PBHAP (TPY)[a]	Max Emissions Divided by Screening Level	Facilities Exceeding Screening Level	Max Emissions Divided by Screening Level	Facilities Exceeding Screening Level
Carcinogens						
Chlorinated Dibenzodioxins and Furans as 2,3,7,8-Tetrachlorodibenzo-p-dioxin TEQ	2	3.89E-7 (4.48E-7)	100	2	20	2
Polycyclic Organic Matter as Benzo(a)Pyrene TEQ	2	5.67E-1 (1.48E-1)	200	2	20	2
Non-carcinogens						
Cadmium Compounds	2	1.20E-1	10	1	0.9	0
Divalent Mercury	2	3.43E-2	100	2	9	1

Notes:
a – PAH and dioxin emissions in this column were normalized to BaP and 2,3,7,8-TCDD, respectively, for oral toxicity and Tier I modeled environmental fate and transport (Tier II modeled environmental fate and transport in parentheses).

We conducted a more refined multipathway assessment for one of the facilities in the ferroalloys production source category. This facility, the Eramet facility in Marietta, Ohio was selected (1) because of its Tier II screening results and (2) based on the feasibility, with respect to the modeling framework, of obtaining parameter values for the region surrounding the facility. We expect that the exposure scenarios we assessed are among the highest that might be encountered for this source category, although not the absolute highest. The approach, data, assumptions, and results of the site-specific assessment are presented in Appendix 10 of this document (*Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Ferroalloys Production Source Category*).

The site-specific assessment, as in the screening assessments, includes some hypothetical elements, namely the hypothetical farmer and angler scenarios. We also included children in different age ranges and adults. It is important to note that even though the multipathway assessment has been conducted, no data exist to verify the existence of either the farmer or angler scenario outlined below. The farmer scenario involves an individual living for a 70-year lifetime on a farm homestead in the vicinity of the source and consuming produce grown on, and meat and animal products raised on, the farm. The individual also incidentally ingests surface soil at the location of the farm homestead. The angler scenario involves an individual who regularly consumes fish caught in freshwater lakes in the vicinity of the source of interest over the course of a 70-year lifetime. In addition, exposure estimates and risks for infants consuming contaminated breast milk were evaluated in the case of dioxins, with the assumption that the nursing mother was exposed to chemicals via one of the two scenarios described above. We evaluated variations of these two scenarios using different assumptions regarding food source (i.e., location of the farm homestead or the water body from which fish are obtained), the age of the individual exposed (for noncancer hazards), the assumed ingestion rate of each food type, and other factors. In particular, a range of fish ingestion rates was evaluated to determine the possible health risks associated with that pathway.

Results of the Site-Specific Multipathway Assessment:

- Cancer risk estimates from the site-specific assessment are presented in Table 3.2-3 (Maximum Site-Specific Results column).
  - Incremental lifetime cancer risk from exposure to PAHs is 10 in a million.
  - Incremental lifetime cancer risk from exposure to dioxins is 4 in a million.
  - For both the PAHs and dioxins, farm ingestion at the 90th percentile ingestion rate drives the risk.
- Noncancer hazards from the site-specific assessment are also presented in Table 3.2-3 (Maximum Site-Specific Results column).
  - Noncancer hazard quotients did not exceed one for any scenario for exposure to cadmium, and was driven by fish ingestion by the adult female angler at the 99th percentile ingestion rate.
  - The noncancer hazard quotient for mercury was estimated to be 1, with methyl mercury exposure to the adult female angler at the 99th percentile ingestion rate driving the risk. These risk estimates are the maximum results from the refined assessment.

Because this more refined assessment uses location-specific information where appropriate and available (e.g., location of actual lakes rather than a generic lake as in Tier I), the water body producing the maximum risk results can change between the screen and the refined assessments. In addition to showing the maximum results of the refined assessment, we can also show the comparison of results from the Tier I screen, the Tier II screen, and the site-specific assessment in order to observe the trend in screening level exceedances. The trend also shows how obtaining more site-specific data can decrease the emission rate screening level. For example, for mercury, we can see that the Tier I exceedance is 100 times the Tier I emission rate level for mercury, the Tier II exceedance is 9 times the facility-specific Tier II emission rate level for mercury, and at that same lake, the site-specific assessment produces an HQ of 0.2. (As stated above, Tier I and Tier II results are not risk estimates.)

Table 3.2-3 Summary of Source Category Level Site-Specific Multipathway Risk Results for Ferroalloys Baseline Scenario

PB-HAP	Emissions Divided by Screening Level		Site-Specific Assessment Cancer Risk or Hazard Quotient	
	Tier I	Tier II	Using Same Lake as Screen	Maximum Site-Specific Results
Dioxins (cancer)	80	7	4	4
PAH (cancer)	200	20	9	10
Cadmium (noncancer)	10	0.9	0.1	0.1
Mercury (noncancer)	100	9	0.2	1

In evaluating the potential for multipathway effects from emissions of lead, modeled maximum annual lead concentrations were compared to the NAAQS for lead (0.15 µg/m^3). Results of this analysis estimate that the NAAQS for lead would not be exceeded at either of the two facilities. This analysis estimates that the annual lead concentrations could be about 20 to 50 percent of the value of the NAAQS for lead (0.029 µg/m^3 to 0.083 µg/m^3). The maximum post-control concentration of lead at either facility is 0.005 µg/m^3, or about three percent of the NAAQS value.

Baseline Environmental Risk Screening Based on Actual Emissions

We conducted a screening-level evaluation of the potential adverse environmental risks associated with emissions of the following environmental HAP from the ferroalloys production source category: cadmium, dioxins/furans, hydrogen chloride, hydrofluoric acid,[35] lead, mercury, and PAHs. The results of the environmental screening analysis are summarized in Table 3.2-4.

In the Tier I screening analysis for PB-HAP (other than lead, which was evaluated differently), the individual modeled Tier I concentrations for one facility in the source category exceeded some sediment, fish – avian piscivorus, and surface soil benchmarks for PAHs, methyl mercury, and mercuric chloride. Therefore, we conducted a Tier II screen for PAHs, methyl mercury, and mercuric chloride.

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[35] As described earlier, we do not believe that HF is emitted from these sources.

In the Tier II screen for PAHs and methyl mercury, none of the individual modeled concentrations for any facility in the source category exceeded any of the ecological benchmarks (either the LOAEL or NOAEL). For mercuric chloride, soil benchmarks were exceeded for one facility for some individual modeled points that collectively accounted for five percent of the modeled area (2.5 percent of the area modeled in the category). However, the weighted average modeled concentration for all soil parcels was well below the soil benchmarks. For lead, we did not estimate any exceedances of the secondary lead NAAQS.

For HCl, each individual concentration (i.e., each off-site data point in the modeling domain) was below the ecological benchmarks for all facilities. The average modeled HCl concentration around each facility (i.e., the average concentration of all off-site data points in the modeling domain) did not exceed any ecological benchmark.

For HF, some individual modeled points exceeded the ecological benchmarks for one facility but accounted for less than 0.1 percent of the modeled area for that facility (0.05 percent of the modeled area for the category). The average modeled HF concentration around each facility (i.e., the average concentration of all off-site data points in the modeling domain) did not exceed any ecological benchmark.[36]

Table 3.2-4 Summary of Source Category Environmental Risk Screening Results for Ferroalloys

Environmental HAP		**Number of Facilities In Category Exceeding**				**Percent of Modeled Area in Category Exceeding[2]**	
		Tier I Screen		**Tier II Screen[1]**		**NOAEL**	**LOAEL**
		NOAEL	**LOAEL**	**NOAEL**	**LOAEL**		
PB-HAP	Pb	None	None	None	None	0%	0%
	$HgCl_2$	NA	1	NA	None	NA	2.5%
	Methyl Hg	1	None	None	None	0%	0%
	PAH	1	None	None	None	0%	0%
	Dioxins	None	None	None	None	0%	0%
Acid Gases	HF[3]	NA	None	-	-	NA	0.05%
	HCl[4]	NA	None	-	-	NA	0%

NA – Not Applicable.

1- Tier II screen is performed for PB-HAP when there are exceedances of the Tier I screen. The acid gas screen is a one tier screen.

2 - A value of 0% indicates that none of the modeled data points exceeded the benchmark. For PB-HAP the percent area is based on the Tier II results, if a Tier II analysis is performed. Otherwise, the percent area is based on the Tier I results.

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[36] As described earlier, we do not believe that HF is emitted from these sources.

3 – For HF, we evaluated two benchmarks, one from Canada and the other from the State of Washington. Although, they are both considered to be LOELs - the level between a NOAEL and a LOAEL, we have listed the results under the LOAEL column.

4 – For HCl, we evaluated one benchmark at the LOAEL level.

3.3 Post-control risk characterization

Process fugitive emissions of metal HAP are primarily driving the baseline risks. Given this, using the same risk assessment methods described above, we estimated what the risks would be if the two manganese facilities adopted control measures to limit process fugitive emissions by 95 percent (e.g., enhanced local capture).[37] Based on this scenario, we estimated that the maximum chronic noncancer inhalation TOSHI value would be reduced to 1, from the baseline estimate of 4, with manganese emissions from the MOR process baghouse outlet driving the risk. There would be no people estimated to have a TOSHI greater than 1. With respect to cancer risk, given the control scenario described above, the cancer MIR would be reduced from 20 in a million (i.e., pre-controls) to approximately 10 in a million (i.e., post-controls), with arsenic and chromium compounds from the MOR process baghouse outlet driving the risk. There is an estimated reduction in cancer incidence to 0.001 excess cancer cases per year, from 0.002 excess cancer cases per year. In addition, the number of people estimated to have a cancer risk greater than or equal to 1 in a million would be reduced from 31,000 to 6,600. We also note that post-control, the maximum worst-case acute refined HQ value would be reduced from a potential value of 1 to less than 1(using the REL values for arsenic compounds, formaldehyde, and hydrofluoric acid and the refinements described for the baseline acute assessment).

For the baseline emissions scenario, we conducted both multipathway screening assessments and a more refined assessment (results shown above). For the post-control scenario, however, we only conducted a screening assessment, with the following results:

- Both facilities' cadmium emissions are below the Tier II facility-specific emission rate levels for that PB-HAP.
- For mercury, Eramet's emissions were two times higher than its Tier II screening emission rate level. However, as shown above, for the baseline emissions scenario, which had higher mercury emissions, the refined multipathway assessment produced an HQ of 1 for mercury for Eramet. The other facility's emissions were approximately equal to its screening emission rate level.
- For dioxins, one facility's emissions were 10 times its facility-specific emission rate level for that PB-HAP, while the other facility's emissions were 4 times its screening emission rate level.
- For PAH, one facility's emissions were 20 times its facility-specific emission rate level for that PB-HAP, while the other facility's emissions were 2 times its screening rate level.

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[37] This post control scenario also includes the assumption that one facility will install controls for mercury.

Appendix 4 of this document (*Technical Support Document for TRIM-Based Multipathway Screening Scenario for RTR: Summary of Approach and Evaluation*) contains a full description of the tiered multipathway screening approach, while Appendix 10 of this document (*Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Ferroalloys Production Source Category*) contains the results of the tiered screening assessment.

As mentioned above, the highest lead concentration after controls, 0.005 µg/m3, is below the NAAQS for lead, indicating a low potential for multipathway impacts of concern due to lead.

4 General discussion of uncertainties and how they have been addressed

4.1 Exposure modeling uncertainties

Although every effort has been made to identify all the relevant facilities and emission points, as well as to develop accurate estimates of the annual emission rates for all relevant HAP, the uncertainties in our emission inventory likely dominate the uncertainties in the exposure analysis. The chronic ambient modeling uncertainties are considered relatively small in comparison, since we are using EPA's refined local dispersion model with site-specific parameters and reasonably representative meteorology. If anything, the population exposure estimates are biased high by not accounting for short- or long-term population mobility, and by neglecting processes like deposition, plume depletion, and atmospheric degradation. Additionally, estimates of the maximum individual risk (MIR) contain uncertainty, because they are derived at census block centroid locations rather than actual residences. This uncertainty is known to create potential underestimates and overestimates of the actual MIR values for individual facilities, but, overall, it is not thought to have a significant impact on the estimated MIR for a source category. Finally, we did not factor in the possibility of a source closure occurring during the 70-year chronic exposure period, leading to a potential upward bias in both the MIR and population risk estimates; nor did we factor in the possibility of population growth during the 70-year chronic exposure period, leading to a potential downward bias in both the MIR and population risk estimates.

A sensitivity analysis performed for the 1999 NATA found that the selection of the meteorology dataset location could result in a range of chronic ambient concentrations which varied from as much as 17 percent below the predicted value to as much as 84 percent higher than the predicted value. This variability translates directly to the predicted exposures and risks in our assessment, indicating that the actual risks could vary from 17 percent lower to 84 percent higher than the predicted values.

We have purposely biased the acute screening results high, considering that they depend upon the joint occurrence of independent factors, such as hourly emissions rates, meteorology and human activity patterns. Furthermore, in cases where multiple acute threshold values are considered scientifically acceptable we have chosen the most conservative of these threshold values, erring on the side of overestimating potential health risks from acute exposures. In the cases where these results indicated the potential for exceeding short-term health thresholds, we refined our assessment by developing a better understanding of the geography of the facility relative to potential exposure locations.

4.2 Uncertainties in the dose-response relationships

In the sections that follow, separate discussions are provided on uncertainty associated with cancer potency factors and for noncancer reference values. Cancer potency values are derived for chronic (lifetime) exposures. Noncancer reference values are generally derived for chronic exposures (up to a lifetime), but may also be derived for acute (<24 hours), short-term (>24 hours up to 30 days), and subchronic (>30 days up to 10 percent of lifetime) exposure durations, all of which are derived based on an assumption of continuous exposure throughout the duration specified. For the purposes of assessing all potential health risks associated with the emissions included in an assessment, we rely on both chronic (cancer and noncancer) and acute (noncancer) benchmarks, which are described in more detail below.

Although every effort is made to identify peer-reviewed dose-response values for all HAP emitted by the source category included in an assessment, some HAP have no peer-reviewed cancer potency values or reference values for chronic non-cancer or acute effects (inhalation or ingestion). Since exposures to these pollutants cannot be included in a quantitative risk estimate, an understatement of risk for these pollutants at environmental exposure levels is possible.

Additionally, chronic dose-response values for certain compounds included in the assessment may be under EPA IRIS review and revised assessments may determine that these pollutants are more or less potent than currently thought. We will re-evaluate risks if, as a result of these reviews, a dose-response metric changes enough to indicate that the risk assessment may significantly mischaracterize human health risk

Cancer assessment

The discussion of dose-response uncertainties in the estimation of cancer risk below focuses on the uncertainties associated with the specific approach currently used by the EPA to develop cancer potency factors. In general, these same uncertainties attend the development of cancer potency factors by CalEPA, the source of peer-reviewed cancer potency factors used where EPA-developed values are not yet available. To place this discussion in context, we provide a quote from the EPA's *Guidelines for Carcinogen Risk Assessment* [*30*] (herein referred to as *Cancer Guidelines*). "The primary goal of EPA actions is protection of human health; accordingly, as an Agency policy, risk assessment procedures, including default options that are used in the absence of scientific data to the contrary, should be health protective." The approach adopted in this document is consistent with this approach as described in the *Cancer Guidelines*.

For cancer endpoints EPA usually derives an oral slope factor for ingestion and a unit risk value for inhalation exposures. These values allow estimation of a lifetime probability of developing cancer given long-term exposures to the pollutant. Depending on the pollutant being evaluated, EPA relies on both animal bioassay and epidemiological studies to characterize cancer risk. As a science policy approach, consistent with the *Cancer*

Guidelines, EPA uses animal cancer bioassays as indicators of potential human health risk when other human cancer risk data are unavailable.

Extrapolation of study data to estimate potential risks to human populations is based upon EPA's assessment of the scientific database for a pollutant using EPA's guidance documents and other peer-reviewed methodologies. The EPA *Cancer Guidelines* describes the Agency's recommendations for methodologies for cancer risk assessment. EPA believes that cancer risk estimates developed following the procedures described in the *Cancer Guidelines* and outlined below generally provide an upper bound estimate of risk. That is, EPA's upper bound estimates represent a "plausible upper limit to the true value of a quantity" (although this is usually not a true statistical confidence limit).[38] In some circumstances, the true risk could be as low as zero; however, in other circumstances the risk could also be greater.[39] When developing an upper bound estimate of risk and to provide risk values that do not underestimate risk, EPA generally relies on conservative default approaches.[40] EPA also uses the upper bound (rather than lower bound or central) estimates in its assessments, although it is noted that this approach can have limitations for some uses (e.g. priority setting, expected benefits analysis).

Such health risk assessments have associated uncertainties, some which may be considered quantitatively, and others which generally are expressed qualitatively. Uncertainties may vary substantially among cancer risk assessments associated with exposures to different pollutants, since the assessments employ different databases with different strengths and limitations and the procedures employed may differ in how well they represent actual biological processes for the assessed substance. EPA's *Risk Characterization Handbook* also recommends that risk characterizations present estimates demonstrating the impact on the assessment of alternative choices, data, models and assumptions [*31*]. Some of the major sources of uncertainty and variability in deriving cancer risk values are described more fully below.

(1) The qualitative similarities or differences between tumor responses observed in experimental animal bioassays and those which would occur in humans is a source of uncertainty in cancer risk assessment. In general, EPA does not assume that tumor sites observed in an experimental animal bioassay are necessarily predictive of the sites at which

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[38] IRIS glossary http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=IRIS%20Glossary

[39] The exception to this is the URE for benzene, which is considered to cover a range of values, each end of which is considered to be equally plausible, and which is based on maximum likelihood estimates.

[40] According to the NRC report Science and Judgment in Risk Assessment (NRC, 1994) "[Default] options are generic approaches, based on general scientific knowledge and policy judgment, that are applied to various elements of the risk-assessment process when the correct scientific model is unknown or uncertain." The 1983 NRC report Risk Assessment in the Federal Government: Managing the Process defined default option as "the option chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary" (NRC, 1983a, p. 63). Therefore, default options are not rules that bind the agency; rather, the agency may depart from them in evaluating the risks posed by a specific substance when it believes this to be appropriate. In keeping with EPA's goal of protecting public health and the environment, default assumptions are used to ensure that risk to chemicals is not underestimated (although defaults are not intended to overtly overestimate risk). See EPA 2004 An Examination of EPA Risk Assessment Principles and Practices, EPA/100/B-04/001 available at: http://www.epa.gov/osa/pdfs/ratf-final.pdf

tumors would occur in humans.[41] However, unless scientific support is available to show otherwise, EPA assumes that tumors in animals are relevant in humans, regardless of target organ concordance. For a specific pollutant, qualitative differences in species responses can lead to either under-estimation or over-estimation of human cancer risks.

(2) Uncertainties regarding the most appropriate dose metric for an assessment can also lead to differences in risk predictions. For example, the measure of dose is commonly expressed in units of mg/kg/d ingested or the inhaled concentration of the pollutant. However, data may support development of a pharmacokinetic model for the absorption, distribution, metabolism and excretion of an agent, which may result in improved dose metrics (e.g., average blood concentration of the pollutant or the quantity of agent metabolized in the body). Quantitative uncertainties result when the appropriate choice of a dose metric is uncertain or when dose metric estimates are themselves uncertain (e.g., as can occur when alternative pharmacokinetic models are available for a compound). Uncertainty in dose estimates may lead to either over or underestimation of risk.

(3) For the quantitative extrapolation of cancer risk estimates from experimental animals to humans, EPA uses scaling methodologies (relating expected response to differences in physical size of the species), which introduce another source of uncertainty. These methodologies are based on both biological data on differences in rates of process according to species size and empirical comparisons of toxicity between experimental animals and humans. For a particular pollutant, the quantitative difference in cancer potency between experimental animals and humans may be either greater than or less than that estimated by baseline scientific scaling predictions due to uncertainties associated with limitations in the test data and the correctness of scaled estimates.

(4) EPA cancer risk estimates, whether based on epidemiological or experimental animal data, are generally developed using a benchmark dose (BMD) analysis to estimate a dose at which there is a specified excess risk of cancer, which is used as the point of departure (or POD) for the remainder of the calculation. Statistical uncertainty in developing a POD using a benchmark dose (BMD) approach is generally addressed though use of the 95 percent lower confidence limit on the dose at which the specified excess risk occurs (the BMDL), decreasing the likelihood of understating risk. EPA has generally utilized the multistage model for estimation of the BMDL using cancer bioassay data (see further discussion below).

(5) Extrapolation from high to low doses is an important, and potentially large, source of uncertainty in cancer risk assessment. EPA uses different approaches to low dose risk assessment (i.e., developing estimates of risk for exposures to environmental doses of an agent from observations in experimental or epidemiological studies at higher dose) depending on the available data and understanding of a pollutant's mode of action (i.e., the manner in which a pollutant causes cancer). EPA's *Cancer Guidelines* express a preference for the use of reliable, compound-specific, biologically-based risk models when feasible; however, such models are rarely available. The mode of action for a pollutant (i.e., the manner in which a

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[41] Per the EPA Cancer Guidelines: "The default option is that positive effects in animal cancer studies indicate that the agent under study can have carcinogenic potential in humans." and "Target organ concordance is not a prerequisite for evaluating the implications of animal study results for humans."

pollutant causes cancer) is a key consideration in determining how risks should be estimated for low-dose exposure. A reference value is calculated when the available mode of action data show the response to be nonlinear (e.g., as in a threshold response). A linear low-dose (straight line from POD) approach is used when available mode of action data support a linear (e.g., nonthreshold response) or as the most common default approach when a compound's mode of action is unknown. Linear extrapolation can be supported by both pollutant-specific data and broader scientific considerations. For example, EPA's *Cancer Guidelines* generally consider a linear dose-response to be appropriate for pollutants that interact with DNA and induce mutations. Pollutants whose effects are additive to background biological processes in cancer development can also be predicted to have low-dose linear responses, although the slope of this relationship may not be the same as the slope estimated by the straight line approach.

EPA most frequently utilizes a linear low-dose extrapolation approach as a baseline science-policy choice (a "default") when available data do not allow a compound-specific determination. This approach is designed to not underestimate risk in the face of uncertainty and variability. EPA believes that linear dose-response models, when appropriately applied as part of EPA's cancer risk assessment process, provide an upper bound estimate of risk and generally provide a health protective approach. Note that another source of uncertainty is the characterization of low-dose nonlinear, non-threshold relationships. The National Academy of Sciences has encouraged the exploration of sigmoidal type functions (e.g., log-probit models) in representing dose response relationships due to the variability in response within human populations. Another National Research Council (NRC) report [*32*] suggests that models based on distributions of individual thresholds are likely to lead to sigmoidal-shaped dose-response functions for a population. This report notes sources of variability in the human population: "One might expect these individual tolerances to vary extensively in humans depending on genetics, coincident exposures, nutritional status, and various other susceptibility factors..." Thus, if a distribution of thresholds approach is considered for a carcinogen risk assessment, application would depend on ability of modeling to reflect the degree of variability in response in human populations (as opposed to responses in bioassays with genetically more uniform rodents). Note also that low dose linearity in risk can arise for reasons separate from population variability: due to the nature of a mode of action and additivity of a chemical's effect on top of background chemical exposures and biological processes.

As noted above, EPA's current approach to cancer risk assessment typically utilizes a straight line approach from the BMDL. This is equivalent to using an upper confidence limit on the slope of the straight line extrapolation. The impact of the choice of the BMDL on bottom line risk estimates can be quantified by comparing risk estimates using the BMDL value to central estimate BMD values, although these differences are generally not a large contributor to uncertainty in risk assessment (Subramaniam et. al., 2006) [*33*]. It is important to note that earlier EPA assessments, including the majority of those for which risk values exist today, were generally developed using the multistage model to extrapolate down to environmental dose levels and did not involve the use of a POD. Subramaniam et. al. (2006) also provide comparisons indicating that slopes based on straight line extrapolation from a POD do not show large differences from those based on the upper confidence limit of the multistage model.

(6) Cancer risk estimates do not generally make specific adjustments to reflect the variability in response within the human population — resulting in another source of uncertainty in assessments. In the diverse human population, some individuals are likely to be more sensitive to the action of a carcinogen than the typical individual, although compound-specific data to evaluate this variability are generally not available. There may also be important life stage differences in the quantitative potency of carcinogens and, with the exception of the recommendations in EPA's Supplemental Cancer Guidance for carcinogens with a mutagenic mode of action, risk assessments do not generally quantitatively address life stage differences. However, one approach used commonly in EPA assessments that may help address variability in response is to extrapolate human response from results observed in the most sensitive species and sex tested, resulting typically in the highest URE which can be supported by reliable data, thus supporting estimates that are designed not to underestimate risk in the face of uncertainty and variability.

Chronic noncancer assessment

Chronic noncancer reference values represent chronic exposure levels that are intended to be health-protective. That is, EPA and other organizations which develop noncancer reference values (e.g., the Agency for Toxic Substances and Disease Registry – ATSDR) utilize an approach that is intended not to underestimate risk in the face of uncertainty and variability. When there are gaps in the available information, uncertainty factors (UFs) are applied to derive reference values that are intended to be protective against appreciable risk of deleterious effects. Uncertainty factors are commonly default values[42] e.g., factors of 10 or 3, used in the absence of compound-specific data; where data are available, uncertainty factors may also be developed using compound-specific information. When data are limited, more assumptions are needed and more default factors are used. Thus there may be a greater tendency to overestimate risk—in the sense that further study might support development of reference values that are higher (i.e., less potent) because fewer default assumptions are needed. However, for some pollutants it is possible that risks may be underestimated.

For non-cancer endpoints related to chronic exposures, EPA derives a Reference Dose (RfD) for exposures via ingestion, and a Reference Concentration (RfC) for inhalation exposures.

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[42] According to the NRC report *Science and Judgment in Risk Assessment* (NRC, 1994) "[Default] options are generic approaches, based on general scientific knowledge and policy judgment, that are applied to various elements of the risk-assessment process when the correct scientific model is unknown or uncertain." The 1983 NRC report *Risk Assessment in the Federal Government: Managing the Process* defined *default option* as "the option chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary" (NRC, 1983a, p. 63). Therefore, default options are not rules that bind the agency; rather, the agency may depart from them in evaluating the risks posed by a specific substance when it believes this to be appropriate. In keeping with EPA's goal of protecting public health and the environment, default assumptions are used to ensure that risk to chemicals is not underestimated (although defaults are not intended to overtly overestimate risk). See EPA 2004 *An examination of EPA Risk Assessment Principles and Practices,* EPA/100/B-04/001 available at: http://www.epa.gov/osa/pdfs/ratf-final.pdf

These values provide an estimate (with uncertainty spanning perhaps an order of magnitude) of daily oral exposure (RfD) or of a continuous inhalation exposure (RfC) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.[43] To derive values that are intended to be "without appreciable risk," EPA's methodology relies upon an uncertainty factor (UF) approach [*34*], [*35*] which includes consideration of both uncertainty and variability.

EPA begins by evaluating all of the available peer-reviewed literature to determine non-cancer endpoints of concern, evaluating the quality, strengths and limitations of the available studies. EPA typically chooses the relevant endpoint that occurs at the lowest dose, often using statistical modeling of the available data, and then determines the appropriate point of departure (POD) for derivation of the reference value. A POD is determined by (in order of preference): (1) a statistical estimation using the benchmark dose (BMD) approach; (2) use of the dose or concentration at which the toxic response was not significantly elevated (no observed adverse effect level— NOAEL); or (3) use of the lowest observed adverse effect level (LOAEL).

A series of downward adjustments using default UFs is then applied to the POD to estimate the reference value [*36*]. While collectively termed "UFs", these factors account for a number of different quantitative considerations when utilizing observed animal (usually rodent) or human toxicity data in a risk assessment. The UFs are intended to account for: (1) variation in susceptibility among the members of the human population (i.e., inter-individual variability); (2) uncertainty in extrapolating from experimental animal data to humans (i.e., interspecies differences); (3) uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure (i.e., extrapolating from subchronic to chronic exposure); (4) uncertainty in extrapolating from a LOAEL in the absence of a NOAEL; and (5) uncertainty when the database is incomplete or there are problems with applicability of available studies. When scientifically sound, peer-reviewed assessment-specific data are not available, default adjustment values are selected for the individual UFs. For each type of uncertainty (when relevant to the assessment), EPA typically applies an UF value of 10 or 3 with the cumulative UF value leading to a downward adjustment of 10-3000 fold from the selected POD. An UF of 3 is used when the data do not support the use of a 10-fold factor. If an extrapolation step or adjustment is not relevant to an assessment (e.g., if applying human toxicity data and an interspecies extrapolation is not required) the associated UF is not used. The major adjustment steps are described more fully below.

1) Heterogeneity among humans is a key source of variability as well as uncertainty. Uncertainty related to human variation is considered in extrapolating doses from a subset or smaller-sized population, often of one sex or of a narrow range of life stages (typical of occupational epidemiologic studies), to a larger, more diverse population. In the absence of pollutant-specific data on human variation, a 10-fold UF is used to account for uncertainty associated with human variation. Human variation may be larger or smaller; however, data to examine the potential magnitude of human variability are often unavailable. In some

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[43] See IRIS glossary

situations, a smaller UF of 3 may be applied to reflect a known lack of significant variability among humans.

2) Extrapolation from results of studies in experimental animals to humans is a necessary step for the majority of chemical risk assessments. When interpreting animal data, the concentration at the POD (e.g. NOAEL, BMDL) in an animal model (e.g. rodents) is extrapolated to estimate the human response. While there is long-standing scientific support for the use of animal studies as indicators of potential toxicity to humans, there are uncertainties in such extrapolations. In the absence of data to the contrary, the typical approach is to use the most relevant endpoint from the most sensitive species and the most sensitive sex in assessing risks to the average human. Typically, compound specific data to evaluate relative sensitivity in humans versus rodents are lacking, thus leading to uncertainty in this extrapolation. Size-related differences (allometric relationships) indicate that typically humans are more sensitive than rodents when compared on a mg/kg/day basis. The default choice of 10 for the interspecies UF is consistent with these differences. For a specific chemical, differences in species responses may be greater or less than this value.

Pharmacokinetic models are useful to examine species differences in pharmacokinetic processing and associated uncertainties; however, such dosimetric adjustments are not always possible. Information may not be available to quantitatively assess toxicokinetic or toxicodynamic differences between animals and humans, and in many cases a 10-fold UF (with separate factors of 3 for toxicokinetic and toxicodynamic components) is used to account for expected species differences and associated uncertainty in extrapolating from laboratory animals to humans in the derivation of a reference value. If information on one or the other of these components is available and accounted for in the cross-species extrapolation, a UF of 3 may be used for the remaining component.

3) In the case of reference values for chronic exposures where only data from shorter durations are available (e.g., 90-day subchronic studies in rodents) or when such data are judged more appropriate for development of an RfC, an additional UF of 3 or 10-fold is typically applied unless the available scientific information supports use of a different value.

4) Toxicity data are typically limited as to the dose or exposure levels that have been tested in individual studies; in an animal study, for example, treatment groups may differ in exposure by up to an order of magnitude. The preferred approach to arrive at a POD is to use BMD analysis; however, this approach requires adequate quantitative results for a meaningful analysis, which is not always possible. Use of a NOAEL is the next preferred approach after BMD analysis in determining a POD for deriving a health effect reference value. However, many studies lack a dose or exposure level at which an adverse effect is not observed (i.e., a NOAEL is not identified). When using data limited to a LOAEL, a UF of 10 or 3-fold is often applied.

5) The database UF is intended to account for the potential for deriving an underprotective RfD/RfC due to a data gap preventing complete characterization of the chemical's toxicity. In the absence of studies for a known or suspected endpoint of concern, a UF of 10 or 3-fold is typically applied.

There is no RfD or other comparable chronic health benchmark value for lead compounds. Thus, to address multipathway human health and environmental risks associated with emissions of lead from this facility, ambient lead concentrations were compared to the NAAQS for lead. In developing the NAAQS for lead, EPA considered human health evidence reporting adverse health effects associated with lead exposure, as well as an EPA conducted multipathway risk assessment that applied models to estimate human exposures to air-related lead and the associated risk (73FR at 66979). EPA also explicitly considered the uncertainties associated with both the human health evidence and the exposure and risk analyses when developing the NAAQS for lead. For example, EPA considered uncertainties in the relationship between ambient air lead and blood lead levels (73FR at 66974), as well as uncertainties between blood lead levels and loss of IQ points in children (73FR at 66981). In considering the evidence and risk analyses and their associated uncertainties, the EPA Administrator noted his view that there is no evidence- or risk-based bright line that indicates a single appropriate level. Instead, he noted, there is a collection of scientific evidence and judgments and other information, including information about the uncertainties inherent in many relevant factors, which needs to be considered together in making this public health policy judgment and in selecting a standard level from a range of reasonable values (73FR at 66998). In so doing, the Administrator decided that, a level for the primary lead standard of 0.15 $\mu g/m^3$, in combination with the specified choice of indicator, averaging time, and form, is requisite to protect public health, including the health of sensitive groups, with an adequate margin of safety (73FR at 67006). A thorough discussion of the health evidence, risk and exposure analyses, and their associated uncertainties can be found in EPA's final rule revising the lead NAAQS (73 FR 66970-66981, November 12, 2008).

We also note the uncertainties associated with the health-based (i.e., primary) NAAQS are likely less than the uncertainties associated with dose-response values developed for many of the other HAP, particularly those HAP for which no human health data exist. In 1988, EPA's IRIS program reviewed the health effects data regarding lead and its inorganic compounds and determined that it would be inappropriate to develop an RfD for these compounds, saying, "A great deal of information on the health effects of lead has been obtained through decades of medical observation and scientific research. This information has been assessed in the development of air and water quality criteria by the Agency's Office of Health and Environmental Assessment (OHEA) in support of regulatory decision-making by the Office of Air Quality Planning and Standards (OAQPS) and by the Office of Drinking Water (ODW). By comparison to most other environmental toxicants, the degree of uncertainty about the health effects of lead is quite low. It appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. The Agency's RfD Work Group discussed inorganic lead (and lead compounds) at two meetings (07/08/1985 and 07/22/1985) and considered it inappropriate to develop an RfD for inorganic lead." EPA's IRIS assessment for Lead and compounds (inorganic) (CASRN 7439-92-1), http://www.epa.gov/iris/subst/0277.htm.

We note further that because of the multi-pathway, multi-media impacts of lead, the risk assessment supporting the NAAQS considered direct inhalation exposures and indirect air-related multi-pathway exposures from industrial sources like primary and secondary lead smelting operations. It also considered background lead exposures from other sources (like contaminated drinking water and exposure to lead-based paints). In revising the NAAQS for lead, we note that the Administrator placed more weight on the evidence-based framework and less weight on the results from the risk assessment, although he did find the risk estimates to be roughly consistent with and generally supportive of the evidence-based framework applied in the NAAQS determination (73FR at 67004). Thus, when revising the NAAQS for lead to protect public health with an adequate margin of safety, EPA considered both the evidence-based framework and the risk assessment, albeit to different extents.

Acute noncancer assessment

Many of the UFs used to account for variability and uncertainty in the development of acute reference values are quite similar to those developed for chronic durations, but more often using individual UF values that may be less than 10. UFs are applied based on chemical-specific or health effect-specific information (e.g., simple irritation effects do not vary appreciably between human individuals, hence a value of 3 is typically used), or based on the purpose for the reference value (see the following paragraph). The UFs applied in acute reference value derivation include: 1) heterogeneity among humans; 2) uncertainty in extrapolating from animals to humans; 3) uncertainty in LOAEL to NOAEL adjustments; and 4) uncertainty in accounting for an incomplete database on toxic effects of potential concern. Additional adjustments are often applied to account for uncertainty in extrapolation from observations at one exposure duration (e.g., 4 hours) to arrive at a POD for derivation of an acute reference value at another exposure duration (e.g., 1 hour).

Not all acute reference values are developed for the same purpose and care must be taken when interpreting the results of an acute assessment of human health effects relative to the reference value or values being exceeded. Where relevant to the estimated exposures, the lack of threshold values at different levels of severity should be factored into the risk characterization as potential uncertainties.

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Appendix 1
Emissions Inventory Support Memorandum

MEMORANDUM

DATE: August 26, 2014

SUBJECT: Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category

FROM: Bradley Nelson, EC/R, Inc.

TO: Phil Mulrine, EPA OAQPS/SPPD/MMG

1.0 PURPOSE

The purpose of this memorandum is to document the methodologies used to estimate pollutant emissions from processes at two ferroalloy facilities; Eramet Marietta Inc. (Eramet) and Felman Production (Felman). The emission estimates developed in this task were used to create a database that will be used as input to the risk assessment modeling to estimate the risks due to emissions from these facilities as part of the "risk and technology" (RTR) review for the Ferroalloy Production source category. This analysis supplements the original RTR analysis[1] that supported proposed amendments to the national emission standards for hazardous air pollutants (NESHAP) for the ferroalloys production source category published in the Federal Register on November 23, 2011 (76 FR 72508).

2.0 BACKGROUND

Under the "technology review" provision of CAA Section 112, EPA is required to review maximum achievable control technology (MACT) standards and to revise them "as necessary (taking into account developments in practices, processes and control technologies)" no less frequently than every 8 years. Under the "residual risk" provision of the CAA section 112, within 8 years after promulgation of the MACT standards, EPA must evaluate the remaining risks due to emissions of air toxics from the source category and promulgate amendments to the standards if required to provide an ample margin of safety to protect public health or prevent an adverse environmental effect. EPA has combined the two review activities into the RTR review for the Ferroalloys Production source category.

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[1] Memorandum from Bradley Nelson, EC/R, Inc. to Conrad Chin, EPA OAQPS/SPPD/MMG, Draft Development of the RTR Emissions Dataset for the Ferroalloys Production Source Category, October 14, 2011. EPA-HQ-OAR-2010-0895-0040

The MACT standards, for Ferromanganese and Silicomanganese Production apply to new and existing ferroalloy production facilities that manufacture ferromanganese and/or silicomanganese and are major sources of hazardous air pollutant (HAP) emissions or are co-located at major sources of HAP emissions.

These ferroalloy products are produced using submerged electric arc furnaces, which are furnaces in which the electrodes are submerged into the charge. The submerged arc process is a reduction smelting operation. The reactants consist of metallic ores (ferrous oxides, silicon oxides, manganese oxides, etc.) and a carbon-source reducing agent, usually in the form of coke, charcoal, high- and low-volatility coal, or wood chips. Raw materials are crushed and sized, and then conveyed to a mix house for weighing and blending. Conveyors, buckets, skip hoists, or cars transport the processed material to hoppers above the furnace. The mix is gravity-fed through a feed chute either continuously or intermittently, as needed. At high temperatures in the reaction zone, the carbon source reacts with metal oxides to form carbon monoxide and to reduce the ores to base metal.[2] The molten material (product and slag) is tapped from the furnace, sometimes subject to post-furnace refining, and poured into casting beds on the furnace room floor. Once the material hardens, it is transported to product crushing and sizing systems and packaged for transport to the customer.

The NESHAP established emissions standards for the following HAP emission sources at a ferroalloy production facility:

- Submerged arc furnaces
- Metal oxygen refining (MOR) process
- Crushing and screening operations
- Fugitive dust sources.

The current rule contains emission standards that limit particulate matter (PM) emissions from existing and new or reconstructed emission sources. The limits for the submerged arc furnaces depend on the product produced and furnace design. The rule also includes limits for the air pollution control devices associated with the MOR process and crushing and screening operations. The current rule sets emission standards for fugitive dust sources by limiting the amount of visible emissions that can be observed from the furnace buildings.

To estimate the facility HAP emissions, an Information Collection Request (ICR) under Section 114 of the Clean Air Act (CAA) was sent to both ferroalloy production facilities on April 28, 2010 and December 21, 2012 to gather source emission testing data from the furnaces (which

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[2] EPA, AP 42, Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 12.4. Ferroalloy Production. 10/86.

include emissions that occur during charging, smelting, and tapping), MOR process and the product crushing process. The HAP source test data that were collected from the control device outlet for each furnace include: metal HAP (arsenic, cadmium, chromium (total and Cr^{+6}), lead, manganese, mercury, and nickel)[3], hydrochloric acid, hydrofluoric acid, hexavalent chromium, formaldehyde, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and chlorodibenzodioxins and chlorodibenzofurans (CDD/CDF). In addition, non-HAP emissions were measured from the furnace control device outlet for: particulate matter and carbon monoxide. The source test data collected for the crushing and sizing operations include: particulate matter, metal HAP (arsenic, total chromium, lead, manganese, mercury, and nickel).[4] The source test data collected from the MOR baghouse outlet include: particulate matter, metal HAP (arsenic, total chromium, lead, manganese, mercury, and nickel).[5]

3.0 FERROALLOY FACILITY SUMMARY

The following section describes the HAP emission sources for the Eramet and Felman ferroalloy production facilities, which are the two existing facilities in the source category. Figure 3-1 provides a schematic of the smelting, tapping, and casting emission points for a typical ferroalloys production operation.

Eramet Marietta Inc.

The Eramet facility is located in Marietta, Ohio, and ferromanganese (FeMn) and silicomanganese (SiMn) are produced using two furnaces identified as Furnace 1 and Furnace 12.

Furnace 1 is a submerged arc furnace rated at 30 megawatts (MW) and is equipped with a negative pressure fabric filter to control particulate emissions and metal HAP. The fabric filter controls emissions from the furnace smelting operation and was installed in 2011 to replace a wet scrubber system. A separate fabric filter system identified as Furnace 1 Tapping Baghouse is used to control captured fugitive emissions from the tapping process from this furnace. The casting process associated with this furnace is uncontrolled.

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[3] Total phosphorus was measured for the ICR using EPA Method 29; however this method does not distinguish between white phosphorus (which is a non-HAP) and red phosphorus (which is a HAP). Due to the uncertainty of the percentage of red phosphorus in the total phosphorus test results, it was concluded that phosphorus would not be incorporated in the emissions used for modeling.

[4] Total phosphorus was measured using Method 29 and therefore not included in the emissions used for modeling.

[5] Again, total phosphorus was measured using Method 29 and therefore not included in the emissions used for modeling.

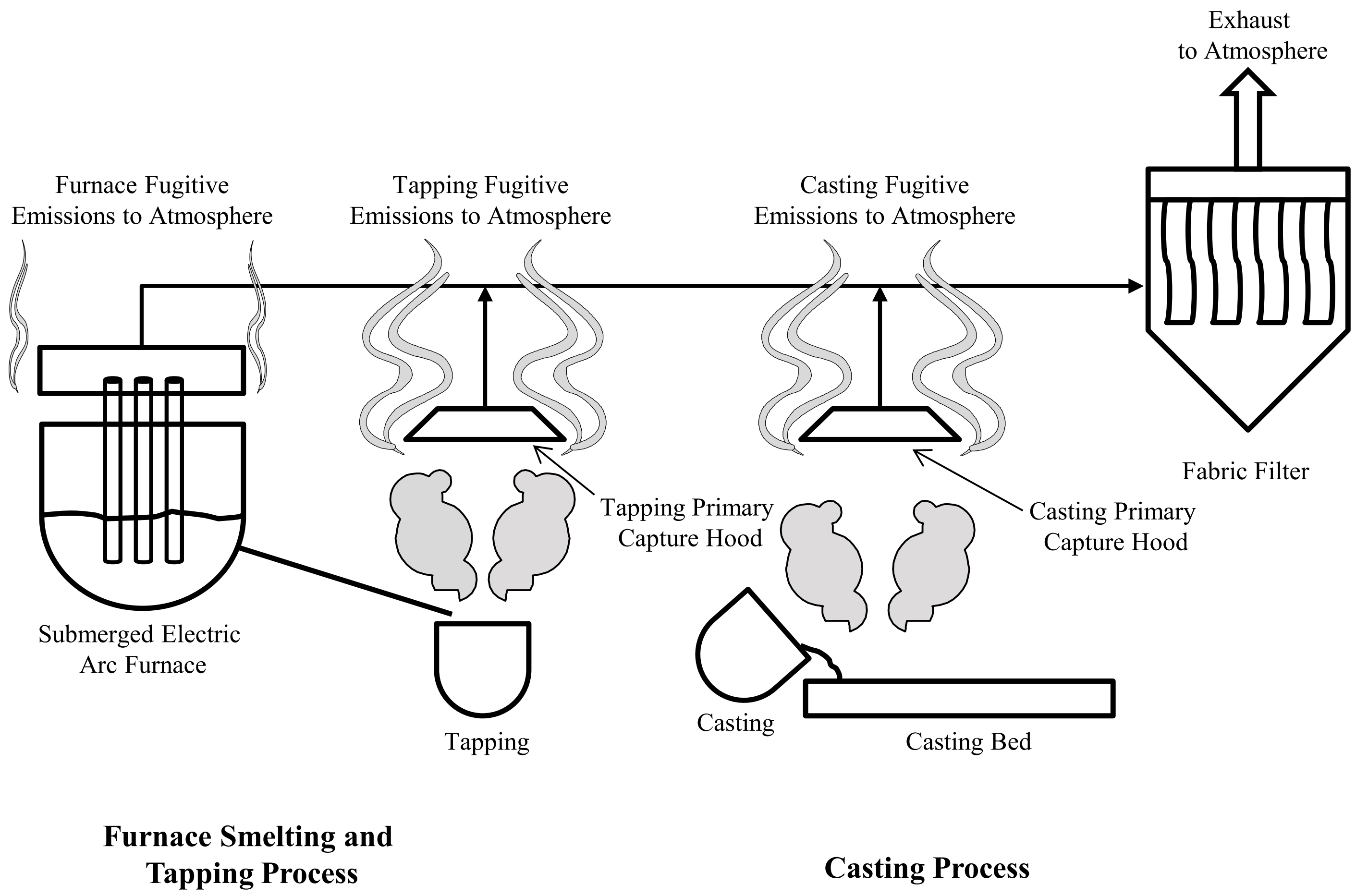

Figure 3-1. Diagram of the Ferroalloys Process and Emission Points

Furnace 12 is a submerged arc furnace rated at 22 MW and is equipped with two wet scrubbers to control emissions from the furnace smelting operation and captured fugitive emissions from the tapping process. The scrubbers operate simultaneously and exhaust through a single stack. The casting process associated with this furnace is uncontrolled.

The facility has a third furnace, Furnace 18, which is permitted, but is considered to be inoperable until extensive repair is made to the furnace. Therefore, Furnace 18 was not considered an emission source and was not included in the emission inventory for Eramet for actual emissions. However, an estimate of Furnace 18 emissions was included for the calculation of MACT "allowable" emissions. Other HAP emission sources include the MOR process controlled by a positive-pressure baghouse which also controls fugitive emissions captured from casting of the product from MOR and a crushing and sizing system (C2P) that is controlled by three negative pressure baghouses. There are also fugitive emissions that are emitted from each of these emission sources, in addition to the fugitive emissions from the casting operations for Furnace 1, Furnace 12, and the MOR process.

The emission sources used for modeling emissions from the Eramet facility were developed based on the plant configuration discussed above and data and information collected through the ICRs. For the furnaces, emission points were developed for the control device outlet emissions and for fugitive emissions from the furnace smelting and furnace tapping. For the MOR process, emission points were developed for the MOR baghouse outlet and for fugitive emissions from the MOR process. For the crushing system, emission points were developed for each of the three baghouse outlets and one emission point for fugitive emissions from the crushing operation. Emission points were also developed for fugitive emissions from casting operations associated with each of the two furnaces and for the MOR process.

Felman Production Inc.

The Felman facility is located in New Haven, West Virginia and produces SiMn using three furnaces identified as Furnace 2, Furnace 5, and Furnace 7. Furnaces 2, 5, and 7 are open submerged arc furnaces rated at 32, 20, and 20 MW respectively. Each of these furnaces is equipped with a positive-pressure baghouse to control emissions of PM and metal HAP from the furnace. The baghouse from each furnace also controls the captured fugitive emissions from the associated furnace tapping and casting processes.

The facility has a crushing and sizing system controlled using a negative pressure baghouse. There are also fugitive emissions that are emitted from each of these emissions sources, in addition to the fugitive emissions from the casting operations for Furnace 2, Furnace 5, and Furnace 7.

The Felman facility emission points used for modeling emissions were developed from the plant configuration discussed above and data and information collected through the ICR. Emission points were developed for the control device outlets for each of the three furnaces, as well as fugitive emission points for smelting and tapping at each of the three furnaces. For the crushing systems, emission points were developed for the crusher baghouse outlet and fugitive emissions from the crushing units. Emission points were also developed for casting fugitive emissions from each of the three furnaces.

4.0 POINT SOURCE POLLUTANT EMISSION DATA

The following section describes the test data that were collected from emission point sources at each of the ferroalloy facilities. This section will describe the test methods that were used to measure emissions for each pollutant from the processes that were tested. A summary of the type of pollutant data collected in the ICRs is presented in Table 4-1. More information on the test data collected in the ICR can be found in the test data review summaries[6,7] located in the docket.

These test report reviews provide a description of how the test data were analyzed and compiled, and provides a comparison of the reported test results with the calculated results used to estimate the modeling emissions. The individual test reports submitted by the facilities can also be found in the docket.

Some of the analytical results for the HAP pollutants were reported below the detection limit. For these test results, one half of the detection limit was used to estimate the emission rate of the HAP pollutant. The use of one half of the detection limit for calculating emission rates from analytical data results reported below the detection limit is based on EPA's revised procedures[8] for developing emission factors.

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[6] Memorandum from Bradley Nelson, EC/R to Conrad Chin, EPA/OAQPS/SPPD/MMG, Ferroalloys 2012 Test Report Review, May 28, 2013.

[7] Memorandum from Bradley Nelson, EC/R to Conrad Chin, EPA/OAQPS/SPPD/MMG, Ferroalloys 2013 Test Report Review, July 29, 2013.

[8] Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Emissions Factor Database, Revised Draft Report, December 17, 2010. http://www.epa.gov/ttn/chief/efpac/procedures/procedures_draft122010.pdf

Table 4-1. Summary of HAP Emissions Data Collected in the ICRs

Facility	*Process*	*Particulate Matter*		*Metal HAP*	*Mercury*	*Cr+6*	*HCl/ HF*	*Form-aldehyde*	*PAH, PCB, CDD/CDF*	
		Method 5D[a]	*Method 5*	*Method 29*	*Method 29/30B*	*SW Method 0061*	*Method 26A*	*Method 316*	*Method 23/0010*	*CARB 428/429*
Felman	Furnace	✓		✓	✓	✓	✓	✓		✓
	Crusher		✓	✓	✓					
Eramet	Furnace		✓	✓	✓	✓	✓	✓	✓	✓
	MOR		✓	✓	✓					
	Crusher		✓	✓	✓					

[a] The furnaces at Felman are each equipped with positive pressure baghouse and therefore Method 5D was used to measure PM emissions from these emission sources. All other emission sources are equipped with either a negative pressure baghouse or venturi scrubber and were measured using Method 5.

Particulate Matter

Test data for PM were received from both ferroalloy facilities for each furnace and for one product crushing operation. Eramet provided PM results from the Furnace 12 scrubber outlet, the Furnace 1 baghouse outlet, the Furnace 1 tapping baghouse outlet, the MOR process baghouse outlet, and from the crushing and sizing operation baghouses (C2P Crushing/Sizing Baghouse #1) using EPA Method 5. Felman provided PM test results from the Furnace 2 baghouse outlet, the Furnace 5 baghouse outlet, the Furnace 7 baghouse outlet using EPA Method 5D, and the baghouse outlet from the crushing and sizing operation using EPA Method 5.

Metal HAP

Test data for metal HAP (arsenic, cadmium, chromium, lead, manganese, mercury, and nickel) were collected from the Furnace 12 scrubber outlet, the Furnace 1 baghouse outlet, the Furnace 1 tapping baghouse outlet, and from Baghouse #1 from the product crushing operation at Eramet. The metal HAP data for Felman were obtained from the Furnace 2 baghouse outlet, the Furnace 5 baghouse outlet, and the baghouse controlling emissions from the crushing and sizing operation. The furnace and product crushing test data from both facilities were collected using EPA Method 29 for arsenic (As), cadmium (Cd), total chromium (Cr), lead (Pb), manganese (Mn), total mercury (Hg), and nickel (Ni). Additional mercury test data were collected for both facilities using EPA Method 30B. The EPA Method 29 analytical results were corrected using the reported field blank[9] results from the analytical test report.

Hexavalent Chromium

Hexavalent chromium (Cr^{+6}) test data were collected from Furnace 2 and Furnace 12 for the Felman and Eramet facilities respectively, using EPA SW Method 0061. No hexavalent chromium data were requested for the product crushing operations. Hexavalent chromium emissions were estimated for the furnaces that were not tested and the product crushing operations by using the hexavalent chromium/PM ratio from the tested sources. A discussion of this calculation is provided in Section 5.0.

Hydrochloric Acid/Hydrofluoric Acid

Test data for hydrochloric acid (HCl) and hydrofluoric acid (HF) were collected from the Furnace 12 scrubber outlet, and the Furnace 1 baghouse outlet at Eramet. Test data for HCl was also collected for the Furnace 1 tapping baghouse at Eramet. Test data for HCl and HF were collected

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[9] The primary purpose of field blanks is to trace sources of artificially introduced contamination. The field blank results include total ambient conditions during sampling and laboratory sources of contamination.

for the Furnace 2 baghouse outlet at Felman. In addition, HCl data was collected for the Furnace 5 and Furnace 7 baghouse outlets at Felman. The HCl and HF data for both facilities were collected using EPA Method 26A. The product crushing processes at both facilities were not tested for HCl or HF, because it believed that these are non-combustion processes and thus do not emit these HAP pollutants.

The test data for HCl is a mixture of detected and non-detected analytical results. There were a total of 29 runs that reported non-detect analytical results out of the total of 45 test runs for HCl. For the analytical results that were reported as non-detect, one half of the detection limit was used to estimate the HCl concentration for the test runs. For HF, all of the test results were reported as non-detect, and again, one half of the detection limit was used to estimate the HF concentration for the test runs. While we calculated numerical estimates for HF based on the assumption that non-detects were equal to ½ detection limit and included these estimates in the inputs to our risk model, we have no evidence that HF is emitted from these sources. Therefore, for purposes of our estimates of emissions and associated risks, we are assuming that HF is not emitted from these sources.

Formaldehyde

Testing for formaldehyde was performed on the Furnace 12 scrubber outlet, the Furnace 1 baghouse outlet, and the Furnace 1 tapping baghouse outlet at Eramet, and the Furnace 2 baghouse outlet, Furnace 5 baghouse outlet, and Furnace 7 baghouse outlet at Felman. All of the formaldehyde test data was collected using EPA Method 316. Formaldehyde testing was not performed on any of the product crushing processes, because it believed that these are non-combustion processes and thus do not emit these HAP pollutants.

The test data for formaldehyde reported 6 runs below the detection limit out of a total of 18 test runs. The emissions rates for the detected formaldehyde runs ranged from 0.01 to 0.26 pounds per hour with an average and median of 0.07 and 0.05 pounds per hour, respectively. For the analytical results that were reported as non-detect, one half of the detection limit was used to estimate the formaldehyde concentration for the test runs.

PAH/PCB/CDD/CDF

Test data for polychlorinated biphenyls (PCB), chlorinated dibenzo-p-dioxins (CDD), and chlorinated dibenzo-p-furans (CDF) were collected at the Furnace 12 scrubber outlet, Furnace 1 baghouse outlet, and the Furnace 1 tapping baghouse outlet at Eramet. The test methods used to collect the samples were EPA Method 23, Method 0010, California Air Resources Board (CARB) Method 428 and CARB 429. Test data were collected for PAH, PCB, and CDD/CDF data for the Furnace 2 baghouse outlet and the Furnace 5 baghouse outlet at Felman using CARB methods 428 and 429. Test data for PAH were collected at the Furnace 7 baghouse outlet at Felman using CARB method 429. No PAH, PCB, or CDD/CDF emissions data were collected for the product crushing units, because these are non-combustion processes and thus do not emit these HAP pollutants.

The analytical results for CDD/CDF reported 230 of the individual compounds were below the detection limit out of a total of 306 reported individual compounds. For the individual CDD/CDF compounds that were detected, the emissions ranged from 1.8 x 10^{-10} to 7.3 x 10^{-8} pounds per hour with an average and median of 6.5 x 10^{-8} and 3.5 x 10^{-9} pounds per hour, respectively. For PCBs, 107 out of 207 reported individual compounds were reported below the detection limit. The emissions from these detected individual PCB compounds ranged from 7.0 x 10^{-10} to 7.5 x 10^{-6} pounds per hour with an average and median of 5.8 x 10^{-7} and 4.6 x 10^{-8} pounds per hour, respectively. For PAHs, 18 out of 513 individual compounds analytical results were reported below the detection limit. For the individual PAH compounds that were detected, the emission values ranged from 1.9 x 10^{-6} to 1.9 x 10^{-1} pounds per hour with an average and median of 7.6 x 10^{-3} and 1.5 x 10^{-3} pounds per hour, respectively. For the test results that were reported below the detection limit, one half of the detection limit was used to calculate the concentration and emission rate for the purposes of estimating emissions for the risk assessment modeling.

Other Data

In addition to the pollutant data described above, analyses of the coal/coke and furnace exhaust concentrations of oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO) were measured. The O_2 and CO_2 concentrations were measured using EPA Method 3A, and the CO concentration was measured using EPA Method 10. For coal/coke, the samples were analyzed using ASTM D3177-02 for sulfur, D3172-07 for proximate analysis, and D3176-09 for ultimate analysis. Visible emission data from the furnace building using EPA Method 9 were also provided in the test reports. These visible emission reports provide opacity readings from the furnace buildings for furnace smelting and tapping operations during the furnace control device outlet tests.

5.0 METHODOLOGY FOR DEVELOPING EMISSION ESTIMATES

The test data provided in the ICR responses were used to develop a modeling emissions database for estimating the risks associated with the HAP emissions from the ferroalloy production facilities. The analytical results provided in the ICR responses were used to calculate emissions for each of the pollutants. This section describes the methodology used to estimate annual emissions from all of the sources at each of the ferroalloy facilities. A summary of the estimated annual HAP emissions is provided at the end of this section.

Some of the pollutant emissions were based on one or more analytical results that were reported below the detection limit. For these analytical results, one half of the detection limit was used to estimate the pollutant concentration. For some HAP (e.g., dioxins, furans, PCBs), the majority of the test results were below detection limit. For HF, all the results were below detection. Nevertheless, to be conservative (i.e., overestimating rather than underestimating emissions and risks), we developed estimated emissions for these HAP using the method described above.

5.1 Furnace Smelting Emissions

The furnace annual emissions for all pollutants were estimated using the information provided in the facility's ICR test reports. The annual emissions for the tested furnace units were calculated using stack gas parameters and analytical results provided in the submitted test reports and converted to annual emissions assuming the furnaces operate 24 hours per day for 365 days per year (i.e., 8,760 hours of operation per year). We have PM test results for all stack emissions points. For some of the other pollutants, we only have data for a subset of emissions points. For those pollutants that were not tested for a specific emissions point, the annual emissions were estimated by multiplying the PM emissions rate by the pollutant-to-PM ratio from a comparable emission source. A more detailed description for each facility is provided in the paragraphs below.

Eramet

The Eramet facility provided ICR test data for all pollutants for the Furnace 12 scrubber outlet and the Furnace 1 baghouse outlet with the exception of Cr^{+6}, which was not tested at the Furnace 1 baghouse outlet. Eramet also provided test data from the Furnace 1 and 12 smelting baghouse outlets and the Furnace 1 tapping baghouse outlet during production of FeMn and SiMn.

The main source of manganese (Mn) and mercury (Hg) emissions from the furnace smelting process is the manganese ore used by Eramet to produce the ferroalloys product, which may contain Hg as an impurity. The amount of Mn ore used to produce a ton of FeMn is greater than the amount of Mn ore used to produce a ton of SiMn. Therefore, Mn and Hg emissions are higher during the production of FeMn than during the production of SiMn. The other HAP pollutant emissions were assumed to be equivalent during the production of either FeMn or SiMn.

To estimate the annual Mn and Hg emissions for these emission sources, it was assumed that FeMn and SiMn were produced equally during the year by each furnace (e.g., 4,380 hours per year producing SiMn and 4,380 hours per year producing FeMn). This assumption was based on conversations with Eramet on the historical production of the FeMn and SiMn products at their facility. The annual emissions were calculated by averaging the emissions during the production of each product and multiplying that average value by the number of production hours. The FeMn and SiMn totals were then added to calculate the annual emissions. The equation for estimating the furnace smelting baghouse outlet and the furnace tapping baghouse Mn emissions is provided below.

$$Mn_{Annual} = Mn_{SiMn} * 4{,}380 + Mn_{FeMn} * 4{,}380$$

where;

Mn_{Annual} = Annual Mn emissions from furnace smelting baghouse outlet or the tapping baghouse outlet when producing FeMn and SiMn,
Mn_{SiMn} = Average Mn test results when producing SiMn in pounds per hour,
Mn_{FeMn} = Average Mn test results when producing FeMn in pounds per hour,
4,380 hours per year.

The same equation is used to estimate the annual Hg emissions using the average Hg test results for FeMn and SiMn production. The formula is as follows;

$$Hg_{Annual} = Hg_{SiMn} * 4{,}380 + Hg_{FeMn} * 4{,}380$$

where;

Hg_{Annual} = Annual Hg emissions from furnace smelting baghouse outlet or the tapping baghouse outlet when producing FeMn and SiMn,
Hg_{SiMn} = Average Hg test results when producing SiMn in pounds per hour,
Hg_{FeMn} = Average Hg test results when producing FeMn in pounds per hour,
4,380 hours per year.

To estimate the Cr^{+6} emissions from the Furnace 1 baghouse outlet, the Furnace 1 baghouse outlet PM emission rate was multiplied by the Furnace 12 scrubber outlet Cr^{+6}-to-PM ratio. The equation for the Cr^{+6} emissions estimation for the Furnace 1 baghouse outlet are shown below:

$$Cr^{+6}_{Furnace\ 1} = PM_{Furnace\ 1} * \left(\frac{Cr^{+6}_{Furnace\ 12}}{PM_{Furnace\ 12}}\right)$$

where;

$Cr^{+6}_{Furnace\ 1}$ = Estimated Cr^{+6} emissions from EAF 1 in tons per year,
$PM_{Furnace\ 1}$ = PM test results for the Furnace 1 baghouse outlet in tons per year,
$Cr^{+6}_{Furnace\ 12}$ = Cr^{+6} test results from the Furnace 12 scrubber outlet in tons per year, and
$PM_{Furnace\ 12}$ = PM test results from the Furnace 12 scrubber outlet in tons per year.

Felman

The Felman facility submitted several test reports for Furnaces 2, 5, and 7 that provided pollutant test data. The test reports for Furnace 2 provided test data for PM, metal HAP, Cr^{+6}, HCl, HF, formaldehyde, PAH, CDD/CDF, and PCB. The test reports for Furnace 5 provided test data for PM, metal HAP, HCl, formaldehyde, PAH, CDD/CDF, and PCB. The test reports for Furnace 7 provided test data for PM, metal HAP, HCl, formaldehyde, and PAH. The Cr^{+6} and HF emissions for Furnaces 5 and 7 were estimated using the pollutant-to-PM ratio from Furnace 2 using the same estimation approach used for Eramet, as described above. The CDD/CDF and PCB emissions from Furnace 7 were assumed to be the same as the reported emissions from Furnace 5. This assumption is based on the fact that both Furnace 5 and Furnace 7 are the same size and produce the same product.

5.2 Furnace Smelting Fugitive Emissions

At the top of the furnaces there is hooding that captures the vast majority of the emissions coming out of the top of the furnace smelting operation and these emissions are vented to a control device (either a baghouse or scrubber). Therefore, we have developed estimates of the fugitive emissions from the top of these furnaces. As shown in table 5-2, we estimate that about 98% of these emissions are captured and directed to a control device. This estimate is based on observations of the furnace smelting process and hood system. However, it is not a closed system and we believe there are some fugitive emissions coming from this source.

We have not identified any emissions factors based on the direct measurement of fugitive emissions from ferroalloys production furnaces to estimate these emissions. Therefore, we used a mass balance approach to estimate these emissions. The specific method is described in the following paragraphs.

The furnace smelting fugitive emissions were estimated by calculating the uncontrolled PM emissions from the furnace and estimating the percentage of the uncontrolled PM emissions that are captured from the furnace. The difference between the uncontrolled pollutant emissions and the estimated captured pollutant emissions were assumed to be the furnace fugitive emissions. The uncontrolled PM pollutant emissions were calculated using the furnace annual emissions for PM and the estimated control efficiency. A summary of the assumed fabric filter and scrubber control efficiencies for the pollutants is presented in Table 5-1. These control efficiencies are based on expected control efficiencies found on the EPA Clean Air Technology Center website.[10] A summary of the assumed process fugitive capture efficiencies is provided in Table 5-2. These capture efficiencies are based on visual observations of the fugitive capture during process operations. It was also assumed that 92 percent of the furnace control device emissions are generated from the furnace and 8 percent of the furnace control device emissions are generated

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[10] EPA Technology Transfer Network, Clean Air Technology Center, General Information on CATC Products, http://www.epa.gov/ttncatc1/products.html

Table 5-1. Assumed Control Device Efficiencies used to Estimate Furnace Fugitive Emissions

Pollutant(s)	***Scrubber Control Efficiency (%)***	***Fabric Filter Control Efficiency (%)***
Particulate Matter	90	98
Metal HAP	90	98
Hexavalent Chromium	90	98
Mercury	15	15
Hydrochloric Acid/Hydrofluoric Acid	90	0
Formaldehyde	90	0
PAH, PCB, CDD/CDF	50	50

Table 5-2. Assumed Baseline Capture Efficiencies used to Estimate Process Fugitive Emissions

Pollutant(s)	***Assumed Fugitive Capture Efficiency (%)***
Eramet	
Furnace 1 and 12 Smelting	98
Furnace 1 Tapping	20
Furnace 12 Tapping	30
MOR Process	40
Furnace 1 and 12 Casting	0
MOR Casting	40
Crushing and Sizing	95
Felman	
Furnace 2, 5, & 7 Smelting	98
Furnace 2, 5, & 7 Tapping	70
Furnace 2, 5, & 7 Casting	40
Crushing and Sizing	85

during tapping of the furnace. These assumptions are based on engineering judgment of the furnace operations and the tapping fugitive capture systems. The equation used to estimate fugitive PM emissions from the furnace smelting process is shown below;

$$PM_{smelt} = \left[(PM_{out}) * \left(\frac{1}{1-CE}\right) * 0.92 * \left(\frac{1}{Capt_{smelt}}\right)\right] - \left[(PM_{out}) * \left(\frac{1}{1-CE}\right) * 0.92\right]$$

where;

PM_{smelt} = Estimated fugitive PM emissions from the furnace in tons per year,
PM_{out} = Control device outlet PM emissions in tons per year,
CE = Control efficiency of the furnace control device,
0.92 = Percentage of uncontrolled emissions generated from the furnace, and
$Capt_{smelt}$ = Estimated capture efficiency of the furnace smelting operations.

Other furnace smelting fugitive HAP pollutants from the furnace smelting operation were calculated by multiplying the calculated PM furnace smelting fugitive emissions value by the HAP pollutant-to-PM ratio for the associated furnace. The HAP pollutants that were estimated from the furnace smelting process include; metal HAP (e.g., Mn, As, Cd, Cr, Ni, Pb), Cr^{+6}, HCl, HF, formaldehyde, PAH, CDD/CDF, and PCB. The equation for estimating these fugitive HAP pollutants from the furnace smelting process is shown below;

$$HAP_{smelt} = PM_{smelt} * \left(\frac{HAP_{out}}{PM_{out}}\right)$$

where;

HAP_{smelt} = Estimated fugitive HAP emissions from furnace smelting in tons per year,
PM_{smelt} = Estimated fugitive PM emissions from furnace smelting in tons per year,
HAP_{out} = Reported outlet HAP emissions from the associated furnace in tons per year, and
PM_{out} = Reported outlet PM emissions from the associated furnace in tons per year.

This approach was used to calculate metal HAP (e.g., Mn, As, Cd, Cr, Ni, Pb), Cr^{+6}, HCl, HF, formaldehyde, PAH, CDD/CDF, and PCB fugitive emissions from the furnace smelting operation for each of the furnaces at Eramet and Felman.

The fugitive emissions for mercury were calculated using a different methodology because of the large difference in control efficiency between PM and mercury. As shown in Table 5-1, the control efficiency for PM using a fabric filter is 98 percent (90 percent with a scrubber), whereas the control efficiency for mercury using either the fabric filter or scrubber is 15 percent. The lower control efficiency for mercury is based on the assumption that 80 percent of the total mercury emissions from the furnace smelting process are gaseous elemental mercury and 20 percent are gaseous mercuric chloride.[11] The furnace control devices can effectively control particulate mercury (e.g., mercuric chloride) from the exhaust stream, but little or no control of gaseous elemental mercury emissions or gaseous mercuric chloride.

Therefore, to account for the difference in control efficiency, an equation using the different control efficiencies for PM and mercury were substituted into the equation for calculating HAP fugitive emissions from smelting process above. The equation used to estimate fugitive mercury emissions from the furnace smelting process is provided below;

$$Hg_{smelt} = \frac{(1 - CE_{PM})}{(1 - CE_{Hg})} PM_{smelt} * \left(\frac{Hg_{out}}{PM_{out}}\right)$$

where;

CE_{PM} = Control efficiency of PM for the control device (98%),
CE_{Hg} = Control efficiency of mercury for the control device (15%),
Hg_{smelt} = Estimated fugitive mercury emissions from furnace smelting in tons per year,
PM_{smelt} = Estimated fugitive PM emissions from furnace smelting in tons per year,
Hg_{out} = Reported outlet HAP emissions from the associated furnace in tons per year, and
PM_{out} = Reported outlet PM emissions from the associated furnace in tons per year.

5.3 Furnace Tapping Fugitive Emissions

The furnaces at these facilities are typically tapped several times per day from the lower section of the furnace. This process results in significant fugitive emissions. The percent capture of tapping fugitive emissions varies significantly across furnaces. As shown in table 5-2, we estimate that the range is about 20% to 70% capture. This variability relates to the design of the tapping system (e.g., use of cascading tapping ladles vs. single ladles), tapping hood design and capacity of the air handling system.

We evaluated available emissions factors (EFs) that could be used to estimate these emissions. We did not identify reliable factors that were specific to this industry. However, we found EFs from the steel industry, from a similar process, that we believe are appropriate to use to estimate emissions for tapping from Ferroalloys furnaces. After searching for, and reviewing, available emissions factors, we determined that AP-42 EF for Basic Oxygen Furnace (BOF) tapping were the best available EFs to use. Therefore, the furnace tapping fugitive PM emissions for the Eramet and Felman facilities were estimated using an AP-42 emission factor (EF) for Basic Oxygen Furnace (BOF) tapping[12]. The AP-42 documentation for BOF tapping fugitives lists two types of EFs

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[11] EPA, Technology Transfer Network Clearinghouse for Inventories & Emissions Factors Speciate Version 4.3, September 2011.

[12] AP-42, Compilation of Air Pollutant Emission Factors, Chapter 12.5 Iron and Steel Production, October 1986. http://www.epa.gov/ttn/chief/ap42/ch12/final/c12s05.pdf (see Table 12.5-1)

available to estimate these emissions; one measured at the source (which is 0.92 pound PM per ton of product) and one measured at the building monitor (which is 0.29 pound PM per ton of product). After reviewing these EFs, we determined that the BOF tapping building monitor EF was not based on measurements at the building monitor, but on measurements taken in the primary hood using an in-stack filter. The EF incorporates a capture efficiency of 93 percent which was assumed to estimate the building monitor EF. The BOF tapping at source EF was conducted in the hood duct leading to the wet scrubber. Based on this information, the BOF tapping at source EF was determined to be more appropriate and was chosen to estimate the fugitive emissions from tapping from the ferroalloy furnaces.

As mentioned above, the EF for BOF tapping at source is listed as 0.92 pound of PM per ton of product produced (lb/Ton). However, after reviewing the source of the EF, it was determined that the test data used to determine the EF was based on an estimated capture of 70% of the total emissions (with 30 percent escaping to the building). Therefore, to estimate the total PM emissions from BOF tapping, the EF of 0.92 lb/Ton was divided by 70 percent to obtain the total PM EF of 1.3 lb/Ton. This EF and the following equation were used to estimate fugitive PM emissions from tapping of the furnaces at Eramet and Felman.

$$PM_{tap} = (1.3) * P * \left(1 - Capt_{tap}\right) * 8760/2000$$

where;

PM_{tap} = Estimated fugitive PM emissions from tapping in tons per year,
1.3 = PM fugitive EF for BOF tapping in pounds per ton of steel produced,
P = Reported production of product for the associated furnace in tons per hour, and
$Capt_{tap}$ = Estimated capture efficiency of the furnace tapping operations (see Table 5-2),
8760 = Hours of operation per year,
2000 = Pounds per ton.

The emissions of metal HAP (e.g., Mn, As, Cd, Cr, Ni, and Pb), Cr^{+6}, HCl, and HF from the furnace tapping process were estimated using the HAP-to-PM ratio from the respective furnace outlet emissions. The equation for estimating these fugitive HAP emissions is provided below;

$$HAP_{tap} = PM_{tap} * \left(\frac{HAP_{out}}{PM_{out}}\right)$$

where;

HAP_{tap} = Estimated fugitive HAP (e.g., Mn, Ni, Pb, As) emissions from tapping in tons per year,
PM_{tap} = Estimated fugitive PM emissions from tapping in tons per year,

HAP_{out} = Reported outlet HAP (e.g., Mn, Ni, Pb, As) emissions from the associated furnace in tons per year, and
PM_{out} = Reported outlet PM emissions from the associated furnace in tons per year.

The majority of Hg, PCB, PAH, CDD/CDF and formaldehyde emissions are assumed to come from the furnace smelting operation, due to the volatility of these HAP and the heat generated in the smelting process. The emissions test results from the Furnace 1 tapping baghouse compared to the test results from the primary furnace 1 stack confirms that this is the case. For example, the measured mercury emissions were about 15,000 times higher from the furnace 1 primary baghouse compared to the tapping baghouse. This shows that the vast majority of mercury emissions are emitted through the stacks and not as fugitives. However, emissions of these HAP were measured in the Furnace 1 tapping baghouse at Eramet (emissions were not zero), and therefore are assumed to be emitted to some degree as fugitives during the furnace tapping process. To estimate these fugitive emissions, an EF was developed using the available test data from the Furnace 1 tapping baghouse for each of these pollutants. For mercury, the EF was developed using the PM and Hg emission result from the Furnace 1 tapping baghouse at Eramet and the tapping PM EF used to calculate the fugitive PM emissions from tapping. The equation for calculating the Hg EF is as follows;

$$FeMn\ EF_{Hg\ tap} = (1.3) * \left(\frac{0.0000526}{2.34}\right)$$

where;

$FeMn\ EF_{Hg\ tap}$ = Hg fugitive EF from furnace tapping in pounds per ton of FeMn produced,
1.3 = PM fugitive EF for BOF tapping in pounds per ton of steel produced,
0.0000526 = Reported outlet Hg emissions from the Furnace 1 tapping baghouse in tons per year, and
2.34 = Reported outlet PM emissions from the Furnace 1 tapping baghouse in tons per year.

This calculation provides an Hg tapping fugitive EF of 2.91×10^{-5} pounds per ton of FeMn produced. The Hg emission rate was calculated using 2013 test data from the Furnace 1 tapping baghouse and the PM emissions rate was calculated using 2011, 2012[13] and 2013[14] test data from the Furnace 1 tapping baghouse. The reported test results are based on the production of FeMn, which produces higher Hg emissions rates in comparison to SiMn production. Because there was no Hg test data from the Furnace 1 tapping baghouse during SiMn production, an Hg EF was developed for SiMn production using the calculated FeMn Hg emissions factor and applying a ratio

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[13] Memorandum from Bradley Nelson, EC/R to Conrad Chin, EPA/OAQPS/SPPD/MMG, Ferroalloys 2012 Test Report Review, May 28, 2013.
[14] Memorandum from Bradley Nelson, EC/R to Conrad Chin, EPA/OAQPS/SPPD/MMG, Ferroalloys 2013 Test Report Review, July 29, 2013.

of the Furnace 1 baghouse outlet Hg emissions for SiMn and FeMn production. The equation for calculating the Hg EF for SiMn production is as follows;

$$SiMn\ EF_{Hg\ tap} = (2.91\ x\ 10^{-5}) * \left(\frac{0.00678}{0.0288}\right)$$

where;

$SiMn\ EF_{Hg\ tap}$ = Hg fugitive EF from furnace tapping in pounds per ton of SiMn produced,
2.91 x 10^{-5} = Hg fugitive EF from furnace tapping in pounds per ton of FeMn produced,
0.00678 = Reported outlet Hg emissions from the Furnace 1 baghouse outlet during SiMn production in pounds per year, and
0.0288 = Reported outlet Hg emissions from the Furnace 1 baghouse outlet during FeMn production in pounds per year.

This calculation provides an Hg tapping fugitive EF of 6.85 x 10^{-6} pounds per ton of SiMn produced. The SiMn Hg EF was used to estimate Hg fugitive emissions from the tapping process for Furnaces 2, 5, and 7 at Felman, which produce only SiMn. This factor may overestimate the mercury emissions from Felman, because Felman uses a lower mercury content manganese ore in comparison to the manganese ore used by Eramet. However, since there is no specific test data from the tapping process at Felman, it is believed that this SiMn Hg emissions factor will provide a conservative estimate of fugitive Hg emissions from tapping. For Eramet, an average of the FeMn and the SiMn Hg EFs (1.80 x 10^{-5} pounds per ton of FeMn/SiMn produced) was used to estimate Hg fugitive emissions from the tapping process. An average was used because of the assumption (as described in Section 5.1) of 50 percent annual SiMn production and 50 percent annual FeMn production for both Furnaces 1 and 12 at Eramet. These EFs and the following equation were used to estimate fugitive Hg emissions from tapping of the furnaces at Eramet and Felman.

$$Hg_{tap} = (EF_{Hg\ tap}) * P * (1 - Capt_{tap}) * 8760/2000$$

where;

Hg_{tap} = Estimated fugitive Hg emissions from tapping in tons per year,
$EF_{Hg\ tap}$ = Hg fugitive EF for tapping in pounds per ton of product (SiMn or SiMn/FeMn),
P = Reported production of product for the associated furnace in tons per hour, and
$Capt_{tap}$ = Estimated capture efficiency of the furnace tapping operations,
8760 = Hours of operation per year,
2000 = Pounds per ton.

The estimated capture efficiency of the tapping operations for each of the furnaces are provided in Table 5-2.

The PCB, PAH, CDD/CDF and formaldehyde fugitive emissions from the tapping process were calculated using the same methodology used to estimate fugitive Hg emissions. An EF was developed for each of the organic HAP compounds using the test data from the Furnace 1 tapping baghouse. It was assumed for this analysis that there is no variation of fugitive organic HAP fugitive emissions based on product (e.g., SiMn or FeMn production). As an example, the equation for calculating the naphthalene EF is as follows;

$$EF_{Naphthalene\ tap} = (1.3) * \left(\frac{1.34\ x\ 10^{-2}}{2.34}\right)$$

where;

$EF_{Naphthalene\ tap}$ = Naphthalene fugitive EF from furnace tapping in pounds per ton of FeMn or SiMn produced,
1.3 = PM fugitive EF for BOF tapping in pounds per ton of steel produced,
1.34 x 10^{-2} = Reported outlet naphthalene emissions from the Furnace 1 tapping baghouse in tons per year, and
2.34 = Reported outlet PM emissions from the Furnace 1 tapping baghouse in tons per year.

This calculation provides a naphthalene tapping fugitive EF of 7.42 x 10^{-3} pounds per ton of FeMn or SiMn produced. This methodology was used to estimate the fugitive organic HAP emissions factor for each of the organic HAP compounds. A table of the organic HAP fugitive EFs for the tapping process is provided in Table 5-3. These EFs and the following equation were used to estimate fugitive organic HAP emissions from tapping of the furnaces at Eramet and Felman. An example of the naphthalene fugitive emission calculation is provided below;

$$Naphthalene_{tap} = (EF_{Naphthalene\ tap}) * P * (1 - Capt_{tap}) * 8760/2000$$

where;

$Naphthalene_{tap}$ = Estimated fugitive naphthalene emissions from tapping in tons per year,
$EF_{Naphthalene\ tap}$ = Naphthalene fugitive EF for tapping in pounds per ton of product (SiMn or SiMn/FeMn),
P = Reported production of product for the associated furnace in tons per hour, and
$Capt_{tap}$ = Estimated capture efficiency of the furnace tapping operations,
8760 = Hours of operation per year,
2000 = Pounds per ton.

The estimated capture efficiencies of the tapping operations for each furnace are provided in Table 5-2.

5.4 Casting/MOR Fugitive Emissions

We also evaluated available emissions factors that could be used to estimate casting and MOR fugitive emissions. We identified one EF for casting specific to this industry from Ohio EPA of 2.4 lb/ton. However, we could not find any documentation to support this emissions factor, so we determined it was not appropriate to use it. We did not find any other EFs specific to this industry. However, we did identify EFs from the Steel industry from AP-42 for a similar source known as hot metal transfer.[15] Similar to the tapping EFs, we identified two EFs (one "at the monitor" and one "at the source"). The "hot metal transfer at monitor" EF is 0.056 lb/ton and the EF for the "hot metal transfer at source" is 0.19 lb/ton. However, we evaluated these EFs further and concluded there was no actual test at the "monitor". Furthermore the 0.056 lb/ton test assumed 100% capture (the test was conducted using an in-stack filter). Therefore, we determined it was not appropriate to use the "at monitor" EF. The only remaining available EF that seemed valid was the 0.19 lb/ton EF. Thus, after searching for, and reviewing available emissions factors, we concluded the best available EF to use to estimate these emissions was the 0.19 lb/ton EF.

The MOR process involves the top lance injection of oxygen to reduce the carbon content and increase the manganese content of the molten FeMn product. The majority of the fugitive emissions from this process occur during the transfer of the molten metal from the tapping vessel to the MOR vessel, and during the waiting period for the MOR vessel to become free. Other fugitive emissions from this source occur during the injection of oxygen. However this process is well controlled and is not expected to be a significant source of fugitive emissions. Since the majority of fugitive emissions from MOR occur during pouring and waiting, it was assumed that the 'hot metal transfer at source" EF of 0.19 lb/ton would be appropriate for estimating fugitive emission from the MOR.

Therefore, particulate matter emissions from casting and the MOR process were estimated using an AP-42 PM EF for hot metal transfer (at source) of 0.19 pounds of fugitive PM emissions per ton of hot metal. This EF was used to estimate the fugitive PM emissions from casting and MOR operations. This EF and the following equation were used to estimate fugitive PM emissions from product casting at Eramet and Felman and the MOR process at Eramet.

$$PM_{cast} = (0.19) * P * (1 - Capt_{cast}) * 8760/2000$$

where;

PM_{cast} = Estimated fugitive PM emissions from casting in tons per year,
0.19 = PM EF for hot metal transfer in pounds per ton of steel produced,

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[15] AP-42, Compilation of Air Pollutant Emission Factors, Chapter 12.5 Iron and Steel Production, October 1986. http://www.epa.gov/ttn/chief/ap42/ch12/final/c12s05.pdf (see Table 12.5-1)

P = Reported production of product for the associated furnace in tons per hour, and
$\text{Capt}_{\text{cast}}$ = Estimated capture efficiency of the casting/MOR operations,
8760 = Hours of operation per year,
2000 = Pounds per ton.

The casting/MOR fugitive emissions for metal HAP (e.g., Mn, As, Cd, Cr, Ni, Pb), Cr^{+6}, HCl, and HF were estimated using the HAP-to-PM profile based on furnace emissions of each of the pollutants and multiplying that profile by the estimated casting fugitive PM emission rate. The equation used to estimate these HAP emissions is shown below;

$$HAP_{cast} = PM_{cast} * \left(\frac{HAP_{out}}{PM_{out}}\right)$$

where;

HAP_{cast} = Estimated HAP emissions from casting/MOR in tons per year,
PM_{cast} = Estimated PM emissions from casting/MOR in tons per year,
HAP_{out} = HAP emissions from the associated EAF in tons per year, and
PM_{out} = PM emissions from the associated EAF in tons per year.

Fugitive emissions of mercury from the casting process were calculated using the Hg tapping EFs and a ratio of the tapping and casting fugitive PM EFs. The equation for calculating the Hg EF for SiMn production and FeMn/SiMn production is as follows;

$$SiMn\ EF_{Hg\ cast} = (6.85\ x\ 10^{-6}) * \left(\frac{0.19}{1.3}\right)$$

where;

SiMn $\text{EF}_{\text{Hg cast}}$ = Hg fugitive EF from casting in pounds per ton of SiMn produced,
$6.85 \text{ x } 10^{-6}$ = Hg fugitive EF for tapping in pounds per ton of SiMn produced,
0.19 = PM EF for hot metal transfer in pounds per ton of steel produced,
1.3 = PM fugitive EF for BOF tapping in pounds per ton of steel produced.

Table 5-3. Summary of Organic HAP Fugitive Emission Factors for Tapping and Casting at Ferroalloys Production Facilities

Organic HAP Pollutant	***Furnace 1 Tapping Baghouse Emissions (Tons/yr)***	***Tapping EF (lb/Ton)***	***Casting EF (lb/Ton)***
Naphthalene	1.34E-02	7.42E-03	1.08E-03
2-Methylnaphthalene	8.11E-03	4.50E-03	6.57E-04
Acenaphthylene	6.55E-03	3.63E-03	5.31E-04
Acenaphthene	3.18E-03	1.76E-03	2.58E-04
Fluorene	3.66E-03	2.03E-03	2.96E-04
Phenanthrene	1.24E-02	6.88E-03	1.01E-03
Anthracene	2.44E-03	1.36E-03	1.98E-04
Fluoranthene	2.42E-03	1.34E-03	1.96E-04
Pyrene	1.87E-03	1.03E-03	1.51E-04
Benzo(a)anthracene	2.01E-04	1.12E-04	1.63E-05
Chrysene	3.42E-04	1.89E-04	2.77E-05
Benzo(b)fluoranthene	1.66E-04	9.23E-05	1.35E-05
Benzo(k)fluoranthene	8.32E-05	4.61E-05	6.74E-06
Benzo(e)pyrene	2.19E-04	1.21E-04	1.77E-05
Benzo(a)pyrene	6.13E-05	3.40E-05	4.97E-06
Perylene	8.76E-06	4.86E-06	7.10E-07
Indeno(1,2,3-cd)pyrene	3.94E-05	2.19E-05	3.19E-06
Dibenz(a,h)anthracene	1.31E-05	7.29E-06	1.06E-06
Benzo(g,h,i)perylene	9.20E-05	5.10E-05	7.45E-06
Formaldehyde	3.81E-02	2.11E-02	3.09E-03
2,3,7,8-Tetrachlorodibenzo-p-dioxin	6.18E-10	3.42E-10	Not measured
1,2,3,7,8-Pentachlorodibenzo-dioxin	8.45E-10	4.69E-10	Not measured
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	5.74E-10	3.18E-10	Not measured
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	5.56E-10	3.08E-10	Not measured
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	5.65E-10	3.13E-10	Not measured
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.05E-09	5.83E-10	Not measured
1,2,3,4,6,7,8,9-Octochlorodibenzo-p-dioxin	8.72E-09	4.83E-09	Not measured
2,3,7,8-Tetrachlorodibenzofuran	9.02E-10	5.00E-10	Not measured
1,2,3,7,8-Pentachlorodibenzofuran	6.79E-10	3.76E-10	Not measured
2,3,4,7,8-Pentachlorodibenzofuran	1.07E-09	5.95E-10	Not measured
1,2,3,4,7,8-Hexachlorodibenzofuran	6.75E-10	3.74E-10	Not measured
1,2,3,6,7,8-Hexachlorodibenzofuran	5.21E-10	2.89E-10	Not measured
2,3,4,6,7,8-Hexachlorodibenzofuran	7.84E-10	4.35E-10	Not measured
1,2,3,7,8,9-Hexachlorodibenzofuran	6.18E-10	3.42E-10	Not measured
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.53E-09	8.50E-10	Not measured
1,2,3,4,7,8,9-Heptachlorodibenzofuran	5.74E-10	3.18E-10	Not measured
1,2,3,4,6,7,8,9-Octochlorodibenzofuran	1.54E-09	8.52E-10	Not measured
Polychlorinated biphenyls	2.14E-07	1.19E-07	Not measured
Particulate Matter	2.345	----	----

The result of this calculation gives an Hg casting fugitive EF of 1.00 x 10^{-6} pounds per ton of SiMn produced. The same methodology and equation were used with the average FeMn/SiMn Hg EF derived in Section 5.3 to calculate the FeMn/SiMn Hg EF which results in an Hg casting fugitive EF of 2.63 x 10^{-6} pounds per ton of FeMn/SiMn produced. These EFs were then used to estimate fugitive Hg emissions from casting from the furnaces at Eramet and Felman using the equation below;

$$Hg_{cast} = (EF_{Hg\ cast}) * P * (1 - Capt_{cast}) * 8760/2000$$

where;

Hg_{cast} = Estimated fugitive Hg emissions from casting in tons per year,
$EF_{Hg\ cast}$ = Hg fugitive EF for casting in pounds per ton of product (SiMn or SiMn/FeMn),
P = Reported production of product for the associated furnace in tons per hour, and
$Capt_{cast}$ = Estimated capture efficiency of the furnace casting operations (see table 5-2),
8760 = Hours of operation per year,
2000 = Pounds per ton.

The estimated capture efficiency of the casting operations for each of the furnaces are provided in Table 5-2.

For casting, it was assumed that the fugitive emissions of PCB and CDD/CDF occur during the tapping process, but do not occur during the casting process because these HAPs are products of incomplete combustion and no combustion occurs outside of the furnace. Therefore, only fugitive emissions of PAH and formaldehyde were estimated for casting. The PAH and formaldehyde fugitive emissions from casting were calculated using the same methodology used to estimate fugitive Hg emissions. An EF was developed for each of the organic HAP compounds using the tapping EF and the ratio of the tapping and casting fugitive PM EFs. Again, no distinction was made between SiMn or FeMn production. As an example, the equation for calculating the naphthalene EF is as follows;

$$EF_{Naphthalene\ cast} = (7.42\ x\ 10^{-3}) * \left(\frac{0.19}{1.3}\right)$$

where;

$EF_{Naphthalene\ cast}$ = Naphthalene fugitive EF from furnace casting in pounds per ton produced,
7.42 x 10^{-3} = Naphthalene fugitive EF for BOF tapping in pounds per ton of steel produced,
0.19 = PM EF for hot metal transfer in pounds per ton of steel produced,
1.3 = PM fugitive EF for BOF tapping in pounds per ton of steel produced.

This calculation provides a naphthalene casting fugitive EF of 1.08 x 10^{-3} pounds per ton of FeMn or SiMn produced. This methodology was used to estimate the fugitive PAH and formaldehyde emissions factor for each of the compounds. Table 5-3 lists the organic HAP fugitive EFs for the tapping process. These EFs and the following equation were used to estimate fugitive PAH and formaldehyde emissions from tapping of the furnaces at Eramet and Felman. An example of the naphthalene fugitive emission calculation is provided below;

$$Naphthalene_{cast} = (EF_{Naphthalene\ cast}) * P * (1 - Capt_{cast}) * 8760/2000$$

where;

$Naphthalene_{cast}$ = Estimated fugitive naphthalene emissions from casting in tons per year,
$EF_{Naphthalene\ cast}$ = Naphthalene fugitive EF for casting in pounds per ton of product (SiMn or SiMn/FeMn),
P = Reported production of product for the associated furnace in tons per hour, and
$Capt_{cast}$ = Estimated capture efficiency of the furnace casting operations (see table 5-2),
8760 = Hours of operation per year,
2000 = Pounds per ton.

The estimated capture efficiencies of the casting operations for each of the furnaces are provided in Table 5-2.

5.5 Product Crushing Operations Emissions

The product crushing emissions were calculated using the test data provided in the test reports submitted by the facilities. The product crushing and sizing operation at Eramet is controlled by three baghouses. The facility provided test data for one of the baghouses, and the other two baghouses were assumed to have the same emissions. Felman listed two product crushing and sizing units in their ICR, but noted that only one of the systems is operated.

The hourly emissions reported in the test report were multiplied by the annual hours of operation to estimate the annual emission from the product crusher. In the case of Eramet, the product crushing and sizing system is limited to 5840 hours per year by permit. Therefore, 5840 hours per year was used to calculate annual emissions from the Eramet crushing and sizing system. For Felman, the crushing and sizing system was estimated to operate 6240 hours per year. These hours of operation were provided by the facilities in their estimates of baseline emissions.[16,17]

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[16] QSEM Solutions, Inc., Eramet Marietta Inc. Technical Comments to Alternative Approach to NESHAP Subpart XXX Compliance - November 23, 2011 Proposed Rule, June 29, 2012.

[17] Email from Amy M Lincoln, Beveridge & Diamond, P.C. to Conrad Chin, EPA, RE: Felman Fugitive Emissions Control and Test Protocols, 8/06/2012.

5.6 Product Crushing Operations Fugitive Emissions

The annual fugitive emissions from the product crushing operations were estimated by using the AP-42 EFs for Metallic Minerals Processing.[18] The facilities provided information on the number of emission sources of fugitive emissions from the product and sizing process. These emission sources were classified into the following EF groups; primary crushing, secondary crushing and material handling and transfer. The filterable PM-10 EFs were used from each of the classifications because these are the respirable portion of PM emissions from the crushing and sizing operation. The EFs for primary crushing, secondary crushing, and material handling and transfer are 0.05, 0.12, and 0.06 pounds per ton processed respectively. The PM-10 EF for secondary crushing was listed as non-detect, however the PM-10 EF was estimated by reducing the PM EF for secondary crushing by a factor of 10. This is the same factor of reduction that is shown for primary crushing. The fugitive emissions were calculated by totaling the number of each crushing and sizing operation and multiplying that by the emissions factor, capture efficiency, and the crushing and sizing production rate as shown in the equation below:

$$E_{FCSPM} = \left[\sum CS * (EF_{CS}) * P_{CS} * (1 - CAP_{CS})\right] * H/2000$$

where;

E_{FCSPM} = Estimated fugitive emissions from crushing and sizing in tons per year,
ΣCS = Number of crushing, screening, conveyor, or material handling emission points,
EF_{CS} = Crushing, screening, conveyor, or material handling EF in pounds per ton,
P_{EAF} = Crushing and sizing production rate in tons per hour,
CAP_{CS} = Assumed capture efficiency for the crushing and sizing operations (95%),
H = number of hours of operation during the year, and
2000 pounds per ton.

The sum of the emissions from the PM fugitive crushing, screening, conveyor, and material handling emission points provides the crushing and sizing fugitive emissions. Metal HAP fugitive emissions were calculated using the metal HAP-to-PM ratios from the crushing baghouse emissions data and multiplying that ratio by the calculated fugitive PM emissions for the crushing and sizing fugitives as shown in the equation below. The number of operating hours per year is based on the normal annual operating hours or is limited to the number of hours by permit.

$$HAP_{CS} = \left[(PM_{CS}) * \left(\frac{HAP_{CSout}}{PM_{CSout}}\right)\right]$$

where;

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[18] AP-42, Compilation of Air Pollutant Emission Factors, Chapter 11.24 Metallic Mineral Processing, August 1982. http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s24.pdf (see Table 11.24-2)

HAP_{CS} = Estimated fugitive HAP emissions from crushing and sizing in tons per year,
PM_{CS} = Estimated fugitive PM emissions from crushing and sizing in tons per year,
HAP_{CSout} = Calculated HAP emissions from crushing and sizing baghouse outlet, and
PM_{CSout} = Calculated PM emissions from crushing and sizing baghouse outlet.

5.7 Baseline Annual HAP Emissions for the Ferroalloy Production Facilities

The baseline annual HAP emissions were calculated for each of the previously described emission points and are summarized in Table 5-4. The test data from Eramet Furnace 1 and 12 smelting baghouse outlets and the Furnace 1 tapping baghouse outlet provided HAP emission results for both production of FeMn and SiMn. To estimate the annual HAP emissions for these emission sources, it was assumed that both Furnaces 1 and 12 produce FeMn 4,380 hours of the year and SiMn is produced 4,380 hours of the year (see section 5.1). The furnaces at Felman Production produce only SiMn, and thus no such adjustments to the annual emissions were necessary. As shown in Table 5-4, fugitive emissions were estimated to be 82 percent of the total HAP emissions from Eramet and 73 percent of the total HAP emissions from Felman.

5.8 Enhanced Capture Annual HAP Emissions for the Ferroalloy Production Facilities

For purposes of the supplemental analysis, we developed an enhanced capture control option to evaluate residual risk. The enhanced capture annual HAP emissions were calculated assuming 95 percent of fugitive HAP emissions would be captured by the enhanced capture system. Some of the fugitive emission sources were assumed to only use primary capture to achieve 95 percent capture. Other fugitive emission sources were assumed to use both primary and secondary capture to achieve a total of 95 percent capture of fugitive emissions. Captured fugitive HAP emissions from the enhanced primary capture system were routed to the assumed source control device and reduced using the control efficiencies listed in Table 5-1. Secondary fugitive HAP emissions were assumed to be routed to a new control device and reduced by the control efficiency values listed in Table 5-1. A summary of the assumptions and calculations are provided for each of the facilities below. A schematic of the enhanced capture system is provided in Figure 5-1.

Table 5-4. Summary of the Baseline Facility Process Annual HAP Emissions (Tons/year) for the Ferroalloy Production Industry

Unit Description	**Arsenic**	**Cadmium**	**Chromium (III)**	**Chromium (VI)**	**Lead**	**Manganese**	**Mercury**	**Nickel**	**Hydrogen Chloride**	**Total PAH**	**Form- aldehyde**	**Total CDD/CDF**	**Total PCBs**	**Total HAP**
Eramet Marietta														
Furnace #1 Baghouse Outlet	0.000399	0.00231	0.000714	0.000206	0.0222	1.33	0.0780	0.00316	0.661	2.75	0.338	3.35E-08	5.20E-07	5.18
Furnace #1 Fugitives	0.000374	0.00217	0.000670	0.000194	0.0208	1.25	0.0017	0.00296	0.620	2.58	0.317	3.14E-08	4.88E-07	4.79
Furnace #1 Tapping Baghouse	0.000105	0.0000482	0.000866	0.0000668	0.0108	0.325	0.0000526	0.00125	0.180	0.0553	0.0381	2.18E-08	2.14E-07	0.611
Furnace #1 Tapping Fugitives	0.00326	0.0189	0.00584	0.00169	0.181	24.3	0.0008	0.0259	5.41	1.4	0.96	5.51E-07	5.40E-06	32.3
Furnace #12 Scrubber Outlet	0.00353	0.0283	0.00158	0.00120	0.106	6.88	0.085	0.00234	0.545	0.560	0.145	8.48E-08	3.63E-07	8.35
Furnace #12 Fugitives	0.000662	0.00531	0.000297	0.000225	0.0198	1.29	0.00189	0.000439	0.102	0.105	0.0272	1.59E-08	6.81E-08	1.55
Furnace #12 Tapping Fugitives	0.00417	0.0335	0.00187	0.00142	0.125	20.4	0.0007	0.00277	0.645	1.221	0.842	4.82E-07	4.73E-06	23.3
MOR Process Baghouse Outlet	0.00110	0.00193	0.00426	0.0000821	0.000933	0.982	0.00212	0.00147	0.0373	0.0383	0.00990	NM	NM	1.08
MOR Process Fugitives	0.00486	0.00856	0.0188	0.000363	0.00413	5.22	0.000176	0.00649	0.165	0.300	0.2070	NM	NM	5.94
Furnace #1 Casting	0.000596	0.00346	0.00107	0.000308	0.0331	4.44	0.00015	0.00472	0.988	0.25	0.176	NM	NM	5.90
Furnace #12 Casting	0.000871	0.00699	0.000391	0.000297	0.0261	4.27	0.00014	0.000577	0.135	0.245	0.1691	NM	NM	4.85
MOR casting	0.00486	0.00856	0.0188	0.000363	0.00413	5.22	0.000176	0.00649	0.165	0.300	0.2070	NM	NM	5.94
C2P Crushing/Sizing Baghouse #1	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P Crushing/Sizing Baghouse #2	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P Crushing/Sizing Baghouse #3	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P crushing and sizing fugitives	0.000567	NM	0.00555	0.000442	0.000603	6.35	NM	0.00646	NM	NM	NM	NM	NM	6.37
Fugitive Emissions Total	**0.0202**	**0.0875**	**0.0534**	**0.00530**	**0.415**	**72.7**	**0.00576**	**0.0568**	**8.23**	**6.40**	**2.91**	**1.08E-06**	**1.07E-05**	**90.9**
Eramet Marietta Total	**0.0258**	**0.120**	**0.0647**	**0.00717**	**0.555**	**86.7**	**0.171**	**0.0695**	**9.65**	**9.81**	**3.44**	**1.22E-06**	**1.18E-05**	**111**
Felman Production														
Furnace No. 2 Baghouse Outlet	0.00277	0.000311	0.00564	0.00155	0.180	1.25	0.01035	0.0793	3.48	0.342	0.331	4.12E-07	3.53E-05	5.69
Furnace No. 2 Fugitives	0.00260	0.000292	0.00530	0.00146	0.169	1.17	0.000228	0.0745	3.27	0.321	0.311	3.87E-07	3.31E-05	5.33
Furnace No. 2 Tapping Fugitives	0.00329	0.000369	0.00670	0.00184	0.214	3.97	0.000091	0.0942	4.14	0.407	0.281	1.61E-07	1.57E-06	9.11
Furnace No. 5 Baghouse Outlet	0.000710	0.000175	0.0089	0.00141	0.0173	0.761	0.00219	0.00461	0.351	0.321	0.309	6.41E-07	4.85E-05	1.78
Furnace No. 5 Fugitives	0.000666	0.000164	0.00833	0.00132	0.0163	0.714	0.0000484	0.00433	0.330	0.302	0.290	6.02E-07	4.55E-05	1.67
Furnace No. 5 Tapping Fugitives	0.000459	0.000113	0.00574	0.000913	0.0112	1.96	0.0000450	0.00298	0.227	0.201	0.139	7.95E-08	7.79E-07	2.55
Furnace No. 7 Baghouse Outlet	0.00117	0.000288	0.0146	0.00232	0.0285	2.44	0.00446	0.00759	0.857	0.269	0.611	6.41E-07	4.85E-05	4.24
Furnace No. 7 Fugitives	0.00110	0.000271	0.0137	0.00218	0.0268	2.29	0.000098	0.00713	0.804	0.253	0.573	6.02E-07	4.55E-05	3.97
Furnace No. 7 Tapping Fugitives	0.000459	0.000113	0.00574	0.000913	0.0112	1.96	0.0000450	0.00298	0.337	0.201	0.139	7.95E-08	7.79E-07	2.66
Furnace No. 2 Casting	0.000961	0.0001080	0.00196	0.000539	0.0625	1.160	0.0000266	0.0275	1.21	0.1188	0.0820	NM	NM	2.66
Furnace No. 5 Casting	0.000134	0.0000331	0.00168	0.000267	0.00328	0.574	0.0000132	0.000872	0.0664	0.0588	0.0406	NM	NM	0.746
Furnace No. 7 Casting	0.000134	0.0000331	0.00168	0.000267	0.00328	0.574	0.0000132	0.000872	0.0985	0.0588	0.0406	NM	NM	0.778
Crushing/Screening System #1	0	NM	0	0	0	0	NM	0	NM	NM	NM	NM	NM	0.00
Crushing/Screening System #2	0	NM	0.000161	0.0000444	0.000463	0.210	NM	0	NM	NM	NM	NM	NM	0.211
Crushing/Screening #1 Fugitives	0	NM	0	0	0	0	NM	0	NM	NM	NM	NM	NM	0.00
Crushing/Screening #2 Fugitives	0	NM	0.00359	0.000988	0.0103	3.25	NM	0	NM	NM	NM	NM	NM	3.27
Fugitive Emissions Total	**0.00980**	**0.00150**	**0.0544**	**0.0107**	**0.528**	**17.6**	**0.000609**	**0.215**	**10.5**	**1.92**	**1.90**	**1.91E-06**	**1.27E-04**	**32.8**
Felman Production Total	**0.0144**	**0.00227**	**0.0837**	**0.0160**	**0.754**	**22.3**	**0.0176**	**0.307**	**15.2**	**2.85**	**3.15**	**3.61E-06**	**2.60E-04**	**44.7**

Eramet Marietta

The methodology for calculating the enhanced capture emissions from Eramet were based on the proposed fugitive emissions capture plan[19] submitted by the facility. The submitted capture plan proposed increasing the primary capture of fugitive tapping emissions from the furnaces to 95 percent, adding 95 percent primary capture to the casting beds for Furnaces 1 and 12, and adding primary and secondary capture to the MOR building to achieve a total capture of 95 percent from the MOR process and MOR casting. A mass balance approach was taken to calculate the enhanced capture emissions from many of the emission sources that are equipped with control devices. Even though, the baghouse or scrubber is a constant outlet device (e.g., the particulate matter concentration in the stack gas is constant), the volumetric flow rate to the control device will increase due to the addition of the enhanced capture fugitive streams, hence increasing the emission rate from the control device outlet. A description of the assumptions used to calculate the enhanced capture emissions from each of the emission sources is provided in the following sections.

Furnace 1 and Associated Emission Sources

The enhanced capture emissions from the Furnace 1 tapping process were calculated assuming an increase of the primary capture of the fugitive emissions from the estimated 20 percent at baseline to 95 percent at the enhanced capture level. The captured emissions from tapping were assumed to be routed to the Furnace 1 baghouse, instead of the dedicated Furnace 1 tapping baghouse. The Furnace 1 baghouse was noted in the control plan to have extra capacity to control fugitive emission streams from both Furnace 1 tapping and casting. An example of the enhanced capture PM emissions calculation for Furnace 1 tapping fugitives is shown below:

$$3.70 = \frac{59.2}{(1 - 20\%)} * (1 - 95\%)$$

where;

3.70 = Enhanced capture fugitive PM emissions from Furnace 1 tapping in tons per year,
59.2 = Baseline fugitive PM emissions from Furnace 1 tapping in tons per year,
20% = Baseline capture percent of Furnace 1 tapping emissions, and
95% = Enhance capture percent of Furnace 1 tapping emissions.

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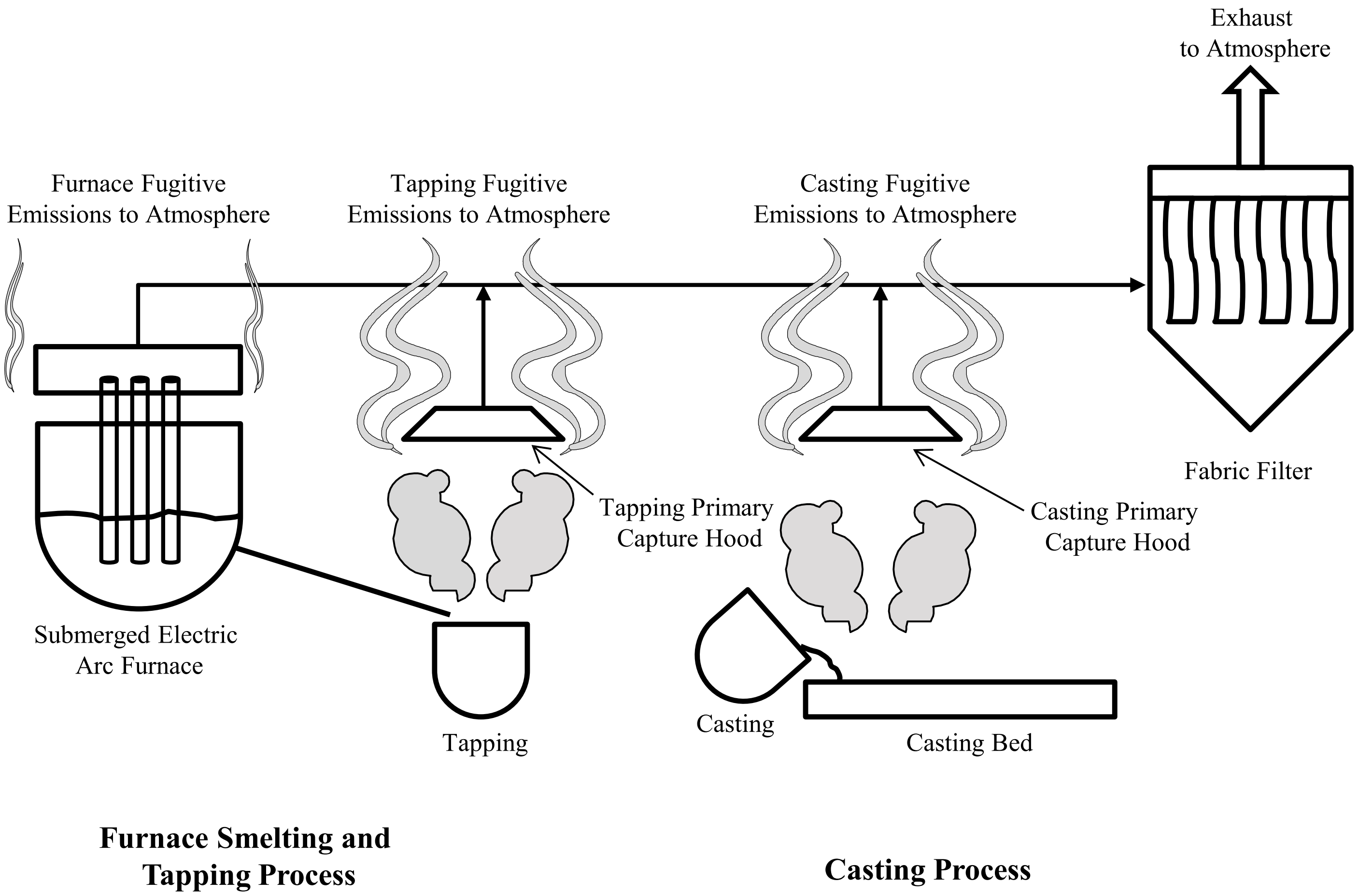
[19] QSEM Solutions, Inc., Eramet Marietta Inc. Technical Comments to Alternative Approach to NESHAP Subpart XXX Compliance - November 23, 2011 Proposed Rule, June 29, 2012.


Exhaust
to Atmosphere
Furnace Fugitive
Emissions to Atmosphere
Tapping Fugitive
Emissions to Atmosphere
Casting Fugitive
Emissions to Atmosphere
Fabric Filter
Tapping Primary
Capture Hood
Casting Primary
Capture Hood
Submerged Electric
Arc Furnace
Tapping
Casting
Casting Bed
Furnace Smelting and
Tapping Process
Casting Process

The enhanced capture casting fugitive emissions from Furnace 1 were also calculated using the same methodology above. The only exception is that there is currently no capture of fugitive emissions from Furnace 1 casting. The control plan submitted by Eramet proposed adding primary capture of 95 percent to the Furnace 1 casting area and routing the captured emissions to the Furnace 1 tapping baghouse, which in the proposed plan will only be used to control captured fugitive emissions for Furnace 1 casting. An example of the enhanced capture PM emissions calculation for Furnace 1 casting fugitive is shown below:

$$0.541 = 10.8 * (1 - 95\%)$$

where;

0.541 = Enhanced capture fugitive PM emissions from Furnace 1 casting in tons per year,
10.8 = Baseline fugitive PM emissions from Furnace 1 casting in tons per year, and
95% = Enhanced capture percent of Furnace 1 casting emissions.

No changes to the capture system for the Furnace 1 smelting operation were proposed in Eramet's capture plan. The current system was assumed to achieve 98 percent capture of fugitive emission from the furnace operations, therefore the calculated fugitive emissions at the enhanced capture level are the same as the calculated fugitive emissions from baseline. There is an increase in the Furnace 1 baghouse outlet emissions in the enhanced capture scenario because the emissions from Furnace 1 tapping, and the Furnace 1 tapping baghouse are now routed to the Furnace 1 baghouse. The Furnace 1 tapping baghouse was assumed to control captured fugitive emissions from Furnace 12 tapping and Furnace 12 casting in the enhanced capture scenario. The enhanced capture emission rate from the Furnace 1 baghouse outlet was calculated by adding the baseline emissions from the Furnace 1 baghouse and the Furnace 1 tapping baghouse with the difference of fugitive emissions from Furnace 1 tapping. An example of the PM emissions calculation is shown below:

$$10.7 = 7.23 + 2.34 + (59.2\text{-}3.70)*(1\text{-}98\%)$$

where;

10.7 = Enhanced capture PM emissions from the Furnace 1 baghouse outlet in tons per year,
7.23 = Baseline PM emissions from the Furnace 1 baghouse outlet in tons per year,
2.34 = Baseline PM emissions from the Furnace 1 tapping baghouse in tons per year,
59.2 = Baseline fugitive PM emissions from Furnace 1 tapping in tons per year,
3.7 = Enhanced capture fugitive PM emissions from Furnace 1 tapping in tons per year, and
98% = Assumed PM control efficiency of the Furnace 1 baghouse.

Note that the control efficiency is only applied to the fugitive casting emissions. The PM emissions from the Furnace 1 baghouse and Furnace 1 tapping baghouse are already provided as controlled emissions.

As noted in the calculation above, the outlet emissions from the Furnace 1 tapping baghouse were moved to the Furnace 1 baghouse in the enhanced capture scenario. This baghouse now controls captured fugitive emissions from Furnace 1 casting in the enhanced capture scenario. The enhanced capture emission rate from this baghouse was calculated by adding the difference of fugitive emissions from Furnace 1 casting. Again, a mass balance approach was taken by subtracting the difference in Furnace 1 casting emissions from baseline to enhanced capture. An example of the PM emissions calculation for the Furnace 1 tapping baghouse is shown below:

$$0.206 = (10.8\text{-}0.541)(1\text{-}98\%)$$

where;

0.206 = Enhanced capture PM emissions from the Furnace 1 tapping baghouse outlet in tons per year,
10.8 = Baseline fugitive PM emissions from Furnace 1 casting in tons per year,
3.7 = Enhanced capture fugitive PM emissions from Furnace 1 casting in tons per year, and
98% = Assumed PM control efficiency of the Furnace 1 tapping baghouse.

Furnace 12 and Associated Emission Sources

The enhanced capture emissions from the Furnace 12 tapping process were calculated assuming an increase of the primary capture of the fugitive emissions from the estimated 30 percent at baseline to 95 percent at the enhanced capture level. The captured emissions from tapping were assumed to be routed to a new Furnace 12 tapping/casting baghouse, instead of the Furnace 12 scrubber. The control noted that the Furnace 12 scrubber did not have the capacity to control the enhanced capture fugitive emission stream from both Furnace 12 tapping. An example of the enhanced capture PM emissions calculation for Furnace 12 tapping fugitives is shown below:

$$3.56 = \frac{49.8}{(1 - 30\%)} * (1 - 95\%)$$

where;

3.56 = Enhanced capture fugitive PM emissions from Furnace 12 tapping in tons per year,
59.2 = Baseline fugitive PM emissions from Furnace 12 tapping in tons per year,
30% = Baseline capture percent of Furnace 12 tapping emissions, and
95% = Enhance capture percent of Furnace 12 tapping emissions.

The enhanced capture casting fugitive emissions from Furnace 12 were also calculated using the same methodology above. The only exception is that there is currently no capture of fugitive emissions from Furnace 12 casting. The control plan submitted by Eramet proposed adding primary capture of 95 percent to the Furnace 12 casting area and routing the captured emissions to a new Furnace 12 tapping/casting baghouse. An example of the enhanced capture PM emissions calculation for Furnace 12 casting fugitive is shown below:

$$0.520 = 10.4 * (1 - 95\%)$$

where;

0.520 = Enhanced capture fugitive PM emissions from Furnace 12 casting in tons per year,
10.4 = Baseline fugitive PM emissions from Furnace 12 casting in tons per year, and
95% = Enhanced capture percent of Furnace 12 casting emissions.

No changes to the capture system for the Furnace 12 smelting operation were proposed in Eramet's capture plan. The current system was assumed to achieve 98 percent capture of fugitive emission from the furnace operations, therefore the calculated fugitive emissions at the enhanced capture level are the same as the calculated fugitive emissions from baseline. There is a decrease in the Furnace 12 scrubber outlet emissions in the enhanced capture scenario because the captured emissions from Furnace 12 tapping are now being routed to a dedicated Furnace 12 tapping/casting baghouse. The enhanced capture emission rate from the Furnace 12 scrubber was calculated by assuming that captured tapping emissions are 8 percent of the total emissions from the furnace control device outlet. Therefore, the enhanced capture Furnace 12 scrubber outlet emissions were assumed to be 92 percent of the baseline Furnace 12 scrubber outlet emissions. An example of the PM emissions calculation is shown below:

$$38.7 = 42.1 * 0.92$$

where;

38.7 = Enhanced capture PM emissions from the Furnace 12 scrubber outlet in tons per year,
42.1 = Baseline PM emissions from the Furnace 12 scrubber outlet in tons per year, and
0.92 = Assumed fraction of emissions from the furnace smelting process.

As noted above, the captured emissions from Furnace 12 tapping and casting are routed to a new Furnace 12 tapping/casting baghouse in the enhanced capture scenario. The enhanced capture emission rate from this baghouse was calculated by adding the difference of fugitive emissions from both tapping and casting from Furnace 12. An example of the PM emissions calculation for the Furnace 12 tapping/casting baghouse is shown below:

$$1.19 = [(10.4 - 0.520) + (49.8 - 3.56) + (42.1 - 38.7)] * (1 - 98\%)$$

where;

1.19 = Enhanced capture PM emissions from the Furnace 12 tapping/casting baghouse outlet in tons per year,
10.4 = Baseline fugitive PM emissions from Furnace 12 casting in tons per year,
0.520 = Enhanced capture fugitive PM emissions from Furnace 12 casting in tons per year,
49.8 = Baseline fugitive PM emissions from Furnace 12 tapping in tons per year,
3.56 = Enhanced capture fugitive PM emissions from Furnace 12 tapping in tons per year,
42.1 = Baseline PM emissions from the Furnace 12 scrubber outlet in tons per year,
3.56 = Enhanced capture PM emissions from the Furnace 12 scrubber outlet in tons per year, and
98% = Assumed PM control efficiency of the Furnace 12 tapping/casting baghouse.

MOR and Associated Emission Sources

The enhanced capture fugitive emissions for the MOR process were calculated based on the control plan submitted by Eramet. The control plan proposed increasing the primary capture of the MOR process and adding secondary capture to the building for an overall capture of 95 percent of fugitive emissions generated by the MOR process. To calculate this scenario, it was assumed that the primary capture would be increased from 40 percent at baseline to 80 percent at the enhanced capture level. An additional capture of 75 percent was used to estimate the secondary capture effect to the MOR process fugitive emissions. An example of the calculation is shown below:

$$1.06 = \frac{12.7}{(1 - 40\%)} * (1 - 80\%) * (1 - 75\%)$$

where;

1.06 = Enhanced capture PM emissions from the MOR process in tons per year,
12.7 = Baseline fugitive PM emissions from MOR process in tons per year,
40% = Baseline capture percentage of fugitive emissions from the MOR process,
80% = Primary capture percentage of MOR process fugitives for enhanced capture, and
75% = Secondary capture percentage of MOR process fugitives for enhanced capture.

The enhanced capture MOR casting fugitive emissions were calculated using the same assumptions as above for primary and secondary capture at the enhanced capture level. An example of the enhanced capture PM fugitive emissions from MOR casting is shown below.

$$1.06 = \frac{12.7}{(1 - 40\%)} * (1 - 80\%) * (1 - 75\%)$$

where;

1.06 = Enhanced capture PM emissions from the MOR casting in tons per year,
12.7 = Baseline fugitive PM emissions from MOR casting in tons per year,
40% = Baseline capture percentage of fugitive emissions from the MOR casting,
80% = Primary capture percentage of MOR casting fugitives for enhanced capture, and
75% = Secondary capture percentage of MOR casting fugitives for enhanced capture.

The enhanced capture emissions from the MOR baghouse were calculated to include the primary captured fugitive emissions from the MOR process and MOR casting. An example of the enhanced capture PM emissions from the MOR baghouse is shown below. The equation calculates the MOR fugitive emissions that are only captured by the primary capture system.

$$3.22 = 2.88 + [12.7 - \frac{12.7}{(1-40\%)} * (1-80\%) + 12.7 - \frac{12.7}{(1-40\%)} * (1-80\%)]*(1\text{-}98\%)$$

where;

3.22 = Enhanced capture PM emissions from the MOR baghouse outlet in tons per year,
12.7 = Baseline fugitive PM emissions from the MOR process in tons per year,
40% = Baseline capture percentage of fugitive emissions from the MOR process,
80% = Primary capture percentage of MOR process fugitives for enhanced capture,
12.7 = Baseline fugitive PM emissions from the MOR casting in tons per year,
40% = Baseline capture percentage of fugitive emissions from MOR casting,
80% = Primary capture percentage of MOR casting fugitives for enhanced capture, and
98% = Assumed PM control efficiency of the MOR process baghouse.

The fugitive emissions captured by the secondary capture system in the MOR building were assumed to be sent to a new MOR secondary baghouse. An estimate of the PM emissions from this baghouse is provided in the calculation below. The equation calculates the fugitive MOR emissions that are only captured by the secondary capture system.

$$0.127 = [\frac{12.7}{(1-40\%)} * (1-80\%) - 1.06 + \frac{12.7}{(1-40\%)} * (1-80\%) - 1.06]*(1\text{-}98\%)$$

where;

0.127 = Enhanced capture PM emissions from the MOR secondary baghouse outlet in tons per year,
12.7 = Baseline fugitive PM emissions from the MOR process in tons per year,
40% = Baseline capture percentage of fugitive emissions from the MOR process,
80% = Primary capture percentage of MOR process fugitives for enhanced capture,
1.06 = Enhanced capture PM emissions from the MOR process in tons per year,
12.7 = Baseline fugitive PM emissions from the MOR casting in tons per year,
40% = Baseline capture percentage of fugitive emissions from MOR casting,
80% = Primary capture percentage of MOR casting fugitives for enhanced capture,

1.06 = Enhanced capture PM emissions from the MOR casting in tons per year, and
98% = Assumed PM control efficiency of the MOR secondary baghouse.

Crushing & Screening Operations

The control plan submitted by Eramet did not include any capture enhancements to the crushing and sizing system. Therefore, the enhanced capture crushing and screening baghouse and fugitive emissions are the same as the calculated baseline emissions for these sources.

Felman Production

The methodology for calculating the enhanced capture emissions from Felman were based on the proposed fugitive emissions capture plan[20] submitted by the facility. The submitted capture plan proposed increasing the primary capture of fugitive and adding secondary capture to the furnace building to achieve an overall capture efficiency of 95 percent. To achieve the overall 95 percent capture, it was assumed that the primary capture would be increased to 80 percent and the secondary capture would capture 75 percent of the remaining fugitive emissions in the building. A mass balance approach was taken to calculate the enhanced capture emissions from many of the emission sources that are equipped with control devices. A description of the assumptions used to calculate the enhanced capture emissions from each of the emission sources is provided in the following sections.

Furnace and Associated Emission Sources

Because the furnace smelting, tapping, and casting operation for Furnace 2, 5, and 7 occur in the same building, the same calculation methodology was used for each of these operations. The emissions estimate for fugitive tapping emissions for the enhanced capture scenario were calculated by applying both the primary capture efficiency and the secondary capture efficiency to the tapping operation for Furnaces 2, 5, and 7. An example of the enhanced capture PM tapping fugitive emissions estimate for Furnace 2 is shown in the equation below.

$$2.88 = \frac{17.3}{(1 - 70\%)} * (1 - 80\%) * (1 - 75\%)$$

Where;

2.88 = Enhanced capture PM fugitive emissions from Furnace 2 tapping in tons per year,
17.3 = Baseline fugitive PM emissions from Furnace 2 tapping in tons per year,
70% = Baseline capture percentage of fugitive emissions from the Furnace 2 tapping,
80% = Primary capture percentage of furnace tapping fugitives for enhanced capture, and

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[20] Chu and Gassman, Design Narrative, July 9, 2012.

75% = Secondary capture percentage of furnace tapping fugitives for enhanced capture.

The casting fugitive emissions are calculated using the same methodology above for tapping fugitive emissions. The emissions estimate for fugitive casting emissions for the enhanced capture scenario were calculated by applying both the primary capture efficiency and the secondary capture efficiency to the casting operation for Furnaces 2, 5, and 7. An example of the enhanced capture PM casting fugitive emissions estimate for Furnace 2 is shown in the equation below.

$$0.420 = \frac{5.04}{(1-40\%)} * (1-80\%) * (1-75\%)$$

Where;

0.420 = Enhanced capture PM fugitive emissions from Furnace 2 casting in tons per year,
5.04 = Baseline fugitive PM emissions from Furnace 2 casting in tons per year,
40% = Baseline capture percentage of fugitive emissions from the Furnace 2 casting,
80% = Primary capture percentage of furnace casting fugitives for enhanced capture, and
75% = Secondary capture percentage of furnace casting fugitives for enhanced capture.

The proposed control plan submitted by Felman also included changes to the capture of the furnace smelting emissions for Furnace 2, 5, and 7. These changes are expected to increase the fugitive capture from the furnace smelting operations from 98 to 99 percent. Therefore, there is a reduction in the enhanced capture furnace fugitive emissions from Furnaces 2, 5, and 7. An example of the furnace smelting fugitive emission calculation for Furnace 2 is shown below:

$$1.70 = \frac{13.6}{(1-98\%)} * (1-99\%) * (1-75\%)$$

where;

1.70 = Enhanced capture PM fugitive emissions from Furnace 2 smelting in tons per year,
13.6 = Baseline fugitive PM emissions from Furnace 2 smelting in tons per year,
98% = Baseline capture percentage of fugitive emissions from the Furnace 2 smelting,
99% = Primary capture percentage of furnace smelting fugitives for enhanced capture, and
75% = Secondary capture percentage of furnace smelting fugitives for enhanced capture.

The furnace baghouse outlet emissions from each of the furnaces increase due to the addition of primary enhanced capture emissions from smelting, tapping, and casting. An example of the PM baghouse outlet emissions from Furnace 2 is shown in the equation below:

$$14.8 = 14.5 + [13.6 - \frac{13.6}{(1-98\%)} * (1-99\%) + 17.3 - \frac{17.3}{(1-70\%)} * (1-80\%)$$
$$+5.04 - \frac{5.04}{(1-40\%)} * (1-80\%)] * (1-98\%)$$

where;

14.8 = Enhanced capture PM emissions from the Furnace 2 baghouse outlet in tons per year,
14.5 = Baseline fugitive PM emissions from the Furnace 2 baghouse outlet in tons per year,
13.6 = Baseline fugitive PM emissions from Furnace 2 smelting in tons per year,
98% = Baseline capture percentage of fugitive emissions from the Furnace 2 smelting,
99% = Primary capture percentage of furnace smelting fugitives for enhanced capture,
17.3 = Baseline fugitive PM emissions from Furnace 2 tapping in tons per year,
70% = Baseline capture percentage of fugitive emissions from the Furnace 2 tapping,
80% = Primary capture percentage of furnace tapping fugitives for enhanced capture,
5.04 = Baseline fugitive PM emissions from Furnace 2 casting in tons per year,
40% = Baseline capture percentage of fugitive emissions from the Furnace 2 casting,
80% = Primary capture percentage of furnace casting fugitives for enhanced capture, and
98% = Assumed PM control efficiency of the Furnace 2 baghouse.

The Felman control plan proposed that captured secondary fugitive emissions from the furnace smelting, tapping, and casting processes would be controlled by a new secondary furnace baghouse. An example of the calculated PM emissions from this baghouse is shown below:

$$0.742 = \frac{12.4}{(1 - 75\%)} * (75\%) * (1 - 98\%)$$

where;

0.742 = Enhanced capture PM emissions from the secondary furnace baghouse in tons per year,
12.4 = Sum of the enhanced capture fugitive PM emissions from smelting, tapping, and casting for Furnaces 2, 5, and 7 in tons per year,
75% = Secondary capture percentage of the furnace building fugitives for enhanced capture, and
98% = Assumed PM control efficiency of the secondary furnace baghouse.

Crushing & Screening Operations

The control plan submitted by Felman did not include any primary capture enhancements to the crushing and sizing system, but does include secondary capture of fugitive emissions from this process. The secondary fugitive capture system for the crushing and screening operation is expected to achieve 75 percent capture. An example of the PM fugitive emissions calculation for the crushing and screening operation is shown below:

$$2.19 = 8.74 * (1 - 75\%)$$

where;

2.19 = Enhanced capture fugitive PM emissions from crushing and screening in tons per year,
8.74 = Baseline fugitive PM emissions from crushing and screening in tons per year, and
75% = Secondary capture percentage for crushing and screening.

The Felman control plan proposed that captured secondary fugitive emissions from the crushing and screening process would be controlled by a new secondary crushing baghouse. An example of the calculated PM emissions from this baghouse is shown below:

$$0.0656 = \frac{2.19}{(1 - 75\%)} * (75\%) * (1 - 98\%)$$

where;

0.0656 = Enhanced capture PM emissions from the secondary crushing baghouse in tons per year,
2.19 = Enhanced capture fugitive PM emissions from crushing and screening in tons per year,
75% = Secondary capture percentage of crushing fugitives for enhanced capture, and
98% = Assumed PM control efficiency of the secondary crushing baghouse.

A summary of the primary and secondary capture assumptions for fugitive emissions from Eramet and Felman is provided in Table 5-5. A summary of the enhanced capture emissions for Eramet and Felman isprovided in Table 5-6.

Table 5-5. Summary of Fugitive Capture Assumptions Used to Estimate the Enhanced Capture Emissions

Fugitive Emission Source	Enhanced Capture HAP Emission Calculation Assumption
Eramet Marietta	
Furnace 1 and 12 Furnace Fugitives	No change from baseline. Source is assumed to achieve 98% capture.
Furnace 1 Tapping Fugitives	The tapping capture is assumed to increase from 20% at baseline to 95%. Captured emissions routed to Furnace 1 baghouse.
Furnace 12 Tapping Fugitives	The tapping capture is assumed to increase from 30% at baseline to 95%. Captured emissions routed to Furnace 12 tapping/casting baghouse (currently Furnace 1 tapping baghouse).
Furnace 1 Casting Fugitives	The casting capture is assumed to increase from 0% at baseline to 95%. Captured emissions routed to Furnace 1 baghouse.
Furnace 12 Casting Fugitives	The casting capture is assumed to increase from 0% at baseline to 95%. Captured emissions routed to Furnace 12 tapping/casting baghouse (currently Furnace 1 tapping baghouse).
MOR Process and Casting Fugitives	The MOR process and MOR casting primary capture is assumed to increase from 40% at baseline to 80%, and installation of secondary capture of 75% for a total overall capture of 95%. Captured primary emissions routed to MOR baghouse and captured secondary emissions routed to a new MOR secondary baghouse.
Crushing and Sizing Fugitives	No change from baseline. Source is assumed to achieve 95% capture.
Felman Production	
Furnace 2, 5, 7 Furnace Fugitives	The furnace primary capture is assumed to increase from 98% at baseline to 99%, and installation of secondary capture of 75% for a total capture of 99.75%. Captured primary emissions routed to their respective furnace baghouse and captured secondary emissions routed to a new secondary baghouse.
Furnace 2, 5, 7 Tapping Fugitives	The tapping primary capture is assumed to increase from 70% at baseline to 80%, and installation of secondary capture of 75% for a total capture of 95%. Captured primary emissions routed to their respective furnace baghouse and captured secondary emissions routed to a new secondary baghouse.
Furnace 2, 5, 7 Casting Fugitives	The casting primary capture is assumed to increase from 40% at baseline to 80%, and installation of secondary capture of 75% for a total capture of 95%. Captured primary emissions routed to their respective furnace baghouse and captured secondary emissions routed to a new secondary baghouse.
Crushing and Sizing Fugitives	The crushing and sizing primary capture is to be 85%, and installation of secondary capture of 75% for a total capture of 96%. Captured primary emissions routed to the crushing and sizing baghouse and captured secondary emissions routed to a new secondary baghouse.

Table 5-6. Summary of the Enhanced Capture Ferroalloys Production Facility Annual HAP Emissions (Tons/year)

Unit Description	Arsenic	Cadmium	Chromium (III)	Chromium (VI)	Lead	Manganese	Mercury	Nickel	Hydrogen Chloride	Total PAH	Form-aldehyde	Total CDD/CDF	Total PCBs	Total HAP
Eramet Marietta														
Furnace #1 Baghouse Outlet	0.000565	0.00272	0.00169	0.000305	0.0364	2.11	0.00926	0.00490	5.91	3.46	1.28	3.14E-07	3.27E-06	12.8
Furnace #1 Fugitives	0.000374	0.00217	0.000670	0.000194	0.0208	1.25	0.00172	0.00296	0.620	2.58	0.317	3.14E-08	4.88E-07	4.79
Furnace #1 Casting Baghouse	0.0000113	0.0000657	0.0000203	0.00000586	0.000630	0.0843	0.000121	0.0000897	0.939	0.121	0.167	0.00E+00	0.00E+00	1.31
Furnace #1 Tapping Fugitives	0.000204	0.00118	0.000365	0.000105	0.0113	1.52	0.0000512	0.00162	0.338	0.0872	0.0602	3.44E-08	3.38E-07	2.02
Furnace #12 Scrubber Outlet	0.00324	0.0260	0.00145	0.00110	0.0973	6.33	0.0278	0.00215	0.501	0.515	0.133	7.80E-08	3.34E-07	7.63
Furnace #12 Fugitives	0.000662	0.00531	0.000297	0.000225	0.0198	1.29	0.00189	0.000439	0.102	0.105	0.0272	1.59E-08	6.81E-08	1.55
Furnace #12 Tapping Fugitives	0.000298	0.00239	0.000134	0.000101	0.00894	1.46	0.0000493	0.000198	0.0461	0.0872	0.0602	3.44E-08	3.38E-07	1.66
MOR Process Baghouse Outlet	0.00123	0.00216	0.00476	0.0000917	0.00104	1.12	0.00232	0.00164	0.257	0.238	0.286	NM	NM	1.92
MOR Process Fugitives	0.000405	0.000713	0.00157	0.0000302	0.000344	0.435	0.0000147	0.000541	0.0137	0.0250	0.0173	NM	NM	0.495
Furnace #1 Casting	0.0000298	0.000173	0.0000534	0.0000154	0.00166	0.222	0.00000749	0.000236	0.0494	0.0127	0.00879	NM	NM	0.295
Furnace #12 Casting	0.0000436	0.000349	0.0000195	0.0000148	0.00131	0.213	0.00000720	0.0000289	0.00673	0.0123	0.00846	NM	NM	0.242
MOR casting	0.000405	0.000713	0.00157	0.0000302	0.000344	0.435	0.0000147	0.000541	0.0137	0.0250	0.0173	NM	NM	0.495
C2P Crushing/Sizing Baghouse #1	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P Crushing/Sizing Baghouse #2	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P Crushing/Sizing Baghouse #3	0.000133	NM	0.00130	0.000103	0.000141	1.49	NM	0.00151	NM	NM	NM	NM	NM	1.49
C2P crushing and sizing fugitives	0.000567	NM	0.00555	0.000442	0.000603	6.35	NM	0.00646	NM	NM	NM	NM	NM	6.37
Furnace #12 Tap/Cast Baghouse	0.0000940	0.000755	0.0000422	0.0000320	0.00282	0.460	0.049729	0.0000623	0.727	0.683	0.943	2.24E-07	2.19E-06	2.87
MOR Secondary Baghouse	0.0000486	0.0000856	0.000188	0.00000363	0.0000413	0.0522	0.0000749	0.0000649	0.0824	0.0750	0.104	NM	NM	0.314
Fugitive Emissions Total	**0.00299**	**0.0130**	**0.0102**	**0.00116**	**0.0652**	**13.2**	**0.00375**	**0.0130**	**1.19**	**2.94**	**0.516**	**1.16E-07**	**1.23E-06**	**17.9**
Eramet Marietta Total	**0.00858**	**0.0448**	**0.0223**	**0.00301**	**0.204**	**27.8**	**0.0930**	**0.0265**	**9.61**	**8.03**	**3.43**	**7.32E-07**	**7.02E-06**	**49.2**
Felman Production														
Furnace No. 2 Baghouse Outlet	0.00283	0.000318	0.00576	0.00159	0.184	1.30	0.0105	0.0811	7.31	0.529	0.634	5.35E-07	4.38E-05	10.1
Furnace No. 2 Fugitives	0.000325	0.0000365	0.000662	0.000182	0.0211	0.146	0.0000285	0.00931	0.409	0.0401	0.0388	4.83E-08	4.14E-06	0.666
Furnace No. 2 Tapping Fugitives	0.000548	0.0000616	0.00112	0.000307	0.0357	0.661	0.0000152	0.0157	0.690	0.0678	0.0468	2.68E-08	2.62E-07	1.52
Furnace No. 5 Baghouse Outlet	0.000721	0.000178	0.00902	0.00143	0.0176	0.789	0.00224	0.00469	0.636	0.450	0.528	8.05E-07	6.00E-05	2.44
Furnace No. 5 Fugitives	0.0000833	0.0000206	0.00104	0.000166	0.00203	0.0893	0.00000605	0.000541	0.0412	0.0377	0.0363	7.53E-08	5.69E-06	0.208
Furnace No. 5 Tapping Fugitives	0.0000765	0.0000189	0.000957	0.000152	0.00187	0.327	0.00000750	0.000497	0.0379	0.0335	0.0231	1.32E-08	1.30E-07	0.426
Furnace No. 7 Baghouse Outlet	0.00118	0.000292	0.0148	0.00235	0.0289	2.48	0.00453	0.00769	1.44	0.385	0.971	8.05E-07	6.00E-05	5.34
Furnace No. 7 Fugitives	0.000137	0.0000338	0.00171	0.000273	0.00335	0.286	0.0000123	0.000891	0.101	0.0316	0.0717	7.53E-08	5.69E-06	0.497
Furnace No. 7 Tapping Fugitives	0.0000765	0.0000189	0.000957	0.000152	0.00187	0.327	0.00000750	0.000497	0.0561	0.0335	0.0231	1.32E-08	1.30E-07	0.444
Furnace No. 2 Casting	0.0000801	0.00000900	0.000163	0.0000449	0.00521	0.0967	0.00000221	0.00229	0.101	0.00990	0.00683	NM	NM	0.222
Furnace No. 5 Casting	0.0000112	0.00000276	0.000140	0.0000222	0.000273	0.0479	0.00000110	0.0000727	0.00554	0.00490	0.00338	NM	NM	0.0622
Furnace No. 7 Casting	0.0000112	0.00000276	0.000140	0.0000222	0.000273	0.0479	0.00000110	0.0000727	0.00821	0.00490	0.00338	NM	NM	0.0649
Crushing/Screening System #1	0	NM	0	0	0	0	NM	0	NM	NM	NM	NM	NM	0.00
Crushing/Screening System #2	0	NM	0.000161	0.0000444	0.000463	0.210	NM	0	NM	NM	NM	NM	NM	0.211
Crushing/Screening #1 Fugitives	0	NM	0	0	0	0	NM	0	NM	NM	NM	NM	NM	0.00
Crushing/Screening #2 Fugitives	0	NM	0.000897	0.000247	0.00258	0.813	NM	0	NM	NM	NM	NM	NM	0.817
Secondary Crushing Baghouse	0	NM	0.0000538	0.0000148	0.000155	0.0488	NM	0	NM	NM	NM	NM	NM	0.0490
Secondary Furnace Baghouse	0.0000809	0.0000123	0.000414	0.0000793	0.00430	0.122	0.000208	0.00179	4.35	0.396	0.760	3.78E-07	2.41E-05	5.63
Fugitive Emissions Total	**0.00135**	**0.000205**	**0.00779**	**0.00157**	**0.0742**	**2.84**	**0.0000815**	**0.0299**	**1.45**	**0.264**	**0.253**	**2.52E-07**	**1.60E-05**	**4.93**
Felman Production Total	**0.00616**	**0.00101**	**0.0380**	**0.00708**	**0.310**	**7.80**	**0.0175**	**0.125**	**15.2**	**2.02**	**3.15**	**2.78E-06**	**2.04E-04**	**28.7**

In addition to the changes to the fugitive capture efficiencies for enhanced capture, Eramet was also assumed to control mercury emissions from both Furnaces 1 and 12. The mercury emissions are generated during the smelting process from the manganese ore used to produce FeMn and SiMn in both of the furnaces, although there may be trace amounts in the coke or coal used in the smelting process. The production of FeMn generates considerably more mercury emissions than SiMn production, and is considered to be a significant source of mercury emissions. Since FeMn is produced in each of the furnaces at Eramet, activated carbon injection (ACI) was assumed to be retrofit prior to the control device. The ACI control technology was assumed to achieve 70 percent mercury reduction on Furnace 12 (currently equipped with a venturi scrubber) and 90 percent reduction on Furnace 1 (currently equipped with a fabric filter). Felman produces only SiMn in each of their three furnaces and was not found to be a significant source of mercury emissions based on the test data results. Therefore, no mercury controls were assumed to be retrofit on the furnace outlets.

6.0 MODELING DATABASE

Section 112(f)(2) of the Clean Air Act (CAA) directs EPA to assess the risk remaining (residual risk) after the application of maximum achievable control technology (MACT) standards under section 112(d). EPA is to promulgate more stringent standards for a category or subcategory of sources subject to MACT standards under section 112(d) if promulgation of such standards is necessary to protect public health with an ample margin of safety or to prevent (taking into consideration various factors) adverse environmental effects.

In an effort to streamline the process of making residual risk decisions, EPA plans to address residual risk and perform a technology review simultaneously for multiple source categories. For this source category, the first part of this approach is to compile and review facility-specific data collected by EPA, and to conduct preliminary risk assessments. The risk assessment will include both chronic and acute inhalation risks. The chronic risks are based on long-term, annual average emissions, while the acute risks are based on short-term hourly emissions and account for the maximum potential short term emission rates for the industry.

6.1 Chronic Modeling Database

The chronic modeling database was assembled using the annual pollutant emissions calculated for processes that were tested (e.g., furnace control device outlet, MOR baghouse outlet, crushing and sizing baghouse outlet), and from AP-42 EFs for fugitive sources that were not tested (e.g., furnace tapping, MOR pouring, crushing and sizing) at each of the ferroalloy facilities. The HAP emissions and the source IDs were then assembled into a database that included other facility descriptors and emission location parameters (i.e., latitude, longitude, emission release height, emission velocity, emission temperature, release length and width). Negative pressure baghouse and scrubber emission outlets were set up as point sources in the database. Fugitive and positive pressure baghouse outlets were set up as area sources.

6.2 Acute Modeling Factors

Rather than developing a separate acute modeling database, acute multipliers were developed for the process emission points. Processes that operate continually, like the furnace control device outlets, furnace fugitive emissions, and secondary fugitive capture devices, are considered as steady-state operations. Estimated yearly emissions from steady-state emissions points are divided by 8760 to calculate estimated hourly emissions. Therefore these processes were given an acute multiplier of 1.

Other emission sources such as, tapping fugitives, MOR fugitives, and casting fugitives are the operations that might conceivably result in an emissions spike. These emission points are assumed to operate 25 percent of the time (30 minutes out of each two hour period.) This is a conservative estimate, because it is very unlikely that all furnaces would ever be tapped simultaneously, and it is impossible for tapping and casting from a given furnace to occur simultaneously since casting of the molten metal must occur after it is tapped. This methodology is also likely to overestimate the operating frequency of product sizing operations. Following this reasoning, estimated yearly emissions from intermittent emissions points are divided by 2190 to calculate estimated hourly emissions. Therefore these processes were given an acute multiplier of 4. A table of the acute multiplier for each of the emissions sources is provided in Table 6-1.

6.3 MACT Allowables

The modeling emissions calculated from the ICR test data represent an estimate of the mass emissions actually emitted during the specified annual time period. These “actual” emission levels are often lower than the emission levels that a facility might be allowed to emit and still comply with the MACT standards. The emissions level allowed to be emitted by the MACT standards is referred to as the “MACT-allowable” emissions level. This represents the highest emissions level that could be emitted by the facility without violating the MACT standards. The assessment of these risks at the MACT-allowable level reflects the maximum level sources could emit and still comply with national emission standards. For process sources, the NESHAP specifies numerical emissions limits for particulate matter (as a surrogate for non-mercury (or particulate) metal HAP) from the electric (submerged) arc furnaces (including smelting and tapping emissions), with the specific limits depending on furnace type, size, and product being made. The NESHAP also specifies a numerical concentration limit for PM (as a surrogate for non-mercury (or particulate) metal HAP) for the crushing and screening process.

Table 6-1. Listing of Acute Multipliers for Ferroalloy Emission Points

Facility	Process Description	FacilityID	SourceID	Acute Multiplier
Eramet	Furnace #1 casting	39167NEI11660	M_CA0001	4
Eramet	Furnace #12 casting	39167NEI11660	M_CA0002	4
Eramet	MOR casting	39167NEI11660	M_CA0003	4
Eramet	Electric Arc Furnace #1 Fugitives	39167NEI11660	M_OE0004	1
Eramet	Electric Arc Furnace #12 Fugitives	39167NEI11660	M_OE0005	1
Eramet	Electric Arc Furnace #1 Tapping Fugitives	39167NEI11660	M_OE0006	4
Eramet	Electric Arc Furnace #12 Tapping Fugitives	39167NEI11660	M_OE0007	4
Eramet	C2P crushing and sizing fugitives	39167NEI11660	M_PC0007	4
Eramet	MOR Process Fugitives	39167NEI11660	M_SE0006	4
Eramet	MOR Process Secondary Baghouse	39167NEI11660	M_BV0001	1
Eramet	Electric Arc Furnace #1 Building Baghouse	39167NEI11660	M_BV0101	1
Eramet	Electric Arc Furnace #12 Building Baghouse	39167NEI11660	M_BV1201	1
Eramet	Electric Arc Furnace #1 Baghouse Outlet	39167NEI11660	M_OE0008	1
Eramet	Electric Arc Furnace #12 Scrubber Outlet	39167NEI11660	M_OE0009	1
Eramet	Electric Arc Furnace #1 Tapping Baghouse	39167NEI11660	M_OE0017	1
Eramet	Casting #12 Baghouse	39167NEI11660	M_OE0019	1
Eramet	C2P Crushing/Sizing Baghouse #1	39167NEI11660	M_PC0014	4
Eramet	C2P Crushing/Sizing Baghouse #2	39167NEI11660	M_PC0015	4
Eramet	C2P Crushing/Sizing Baghouse #3	39167NEI11660	M_PC0016	4
Eramet	MOR Process Baghouse Outlet	39167NEI11660	M_SE0013	1
Felman	ELECTRIC ARC FURNACE NO. 2 CASTING FUGITIVES	54053NEIWV053FELMAN	M_CA0001	4
Felman	ELECTRIC ARC FURNACE NO. 5 CASTING FUGITIVES	54053NEIWV053FELMAN	M_CA0002	4
Felman	ELECTRIC ARC FURNACE NO. 7 CASTING FUGITIVES	54053NEIWV053FELMAN	M_CA0003	4
Felman	ELECTRIC ARC FURNACE NO. 2	54053NEIWV053FELMAN	M_OE0008	1
Felman	ELECTRIC ARC FURNACE NO. 2 FUGITIVES	54053NEIWV053FELMAN	M_OE0011	1
Felman	ELECTRIC ARC FURNACE NO. 5	54053NEIWV053FELMAN	M_OE0012	1
Felman	ELECTRIC ARC FURNACE NO. 5 FUGITIVES	54053NEIWV053FELMAN	M_OE0013	1
Felman	ELECTRIC ARC FURNACE NO. 7	54053NEIWV053FELMAN	M_OE0014	1
Felman	ELECTRIC ARC FURNACE NO. 7 FUGITIVES	54053NEIWV053FELMAN	M_OE0015	1
Felman	ELECTRIC ARC FURNACE NO. 2 TAPPING FUGITIVES	54053NEIWV053FELMAN	M_OE0016	4
Felman	ELECTRIC ARC FURNACE NO. 5 TAPPING FUGITIVES	54053NEIWV053FELMAN	M_OE0017	4
Felman	ELECTRIC ARC FURNACE NO. 7 TAPPING FUGITIVES	54053NEIWV053FELMAN	M_OE0018	4
Felman	CRUSHING AND SCREENING SYSTEM #1 FUGITIVES	54053NEIWV053FELMAN	M_PC0007	4
Felman	CRUSHING AND SCREENING SYSTEM #2 FUGITIVES	54053NEIWV053FELMAN	M_PC0009	4
Felman	BUILDING EVACUATION BAGHOUSE	54053NEIWV053FELMAN	M_BV0101	1
Felman	SECONDARY CRUSHING 1 BAGHOUSE	54053NEIWV053FELMAN	M_BV0202	1
Felman	SECONDARY CRUSHING 2 BAGHOUSE	54053NEIWV053FELMAN	M_BV0303	1
Felman	SECONDARY FURNACE BAGHOUSE	54053NEIWV053FELMAN	M_BV0404	1
Felman	CRUSHING AND SCREENING SYSTEM #1	54053NEIWV053FELMAN	M_PC0006	4
Felman	CRUSHING AND SCREENING SYSTEM #2	54053NEIWV053FELMAN	M_PC0008	4

To estimate emissions at the MACT-allowable level, a ratio of MACT-allowable to actual emissions for each of the process source types that are regulated under the existing NESHAP (i.e., furnace control device outlet, MOR baghouse outlet, crushing and screening outlet). This ratio is based on the maximum emission limits allowed by the MACT standards compared to the reported actual emissions. These ratios for each emission point type at the facilities in this source category were used to estimate the maximum potential risk estimates that could occur assuming emissions are continuously emitted at the maximum allowed emissions level. Mercury is not included with metal HAP because the emissions are not currently regulated by the MACT rule and the emissions are primarily in gaseous elemental form. A table of the MACT-allowable ratios for metal HAP is presented in Table 6-2. An example of the MACT-allowable calculation for the Furnace 1 baghouse is shown below:

$$19.8 = \frac{(35.9 * 0.50) + (29.8 * 0.50)}{(1.79 * 0.50) + (1.52 * 0.50)}$$

where;

0.50 = the assumed fraction of time the facility is producing FeMn or SiMn,
35.9 = the MACT allowable PM emissions rate in pounds per hour when producing SiMn,
29.8 = the MACT allowable PM emission rate in pounds per hour when producing FeMn,
1.79 = the actual average PM emissions rate in pounds per hour based on test data collected during the production of SiMn, and
1.52 = the actual average PM emissions rate in pounds per hour based on test data collected during the production of FeMn.

As noted in Section 3.0, Eramet has a third furnace (Furnace 18) that is idle because of damage to the furnace and is unlikely to be repaired and operated by the facility in the near future. However, the furnace is still included in their operating permit; therefore, the emissions will be included in the allowable emissions file calculations. This is consistent with RTR policy/procedures, which states that if a process unit and/or facility has not been operating for an extended period of time (years), and is not currently operating, but the unit or facility could theoretically reopen and start again in the future (e.g., still in permit), the emissions should not be included in the calculation of "actual" emissions, but should be included in the estimated potential emissions in the "allowables" file.

Table 6-2. Summary of MACT-Allowable Ratios for Eramet and Felman

Emission Source	Source ID	Actual PM Emissons (lb/hr)	MACT-Allowable PM Emissions (lb/hr)	Actual PM Conc. (gr/dscf)	MACT-Allowable PM Conc. (gr/dscf)	MACT-Allowable/ Actual Ratio	Comment
Eramet (Facility ID: 39167NEI11660)							
Furnace 1 Baghouse Outlet[1]	M_OE0008	1.79/1.52	35.9/29.8			19.8	63.1652(b)(3)/ 63.1652(b)(2)
Furnace 12 Scrubber Outlet[1]	M_OE0009	12.06/7.16	35.9/29.8			3.57	63.1652(b)(3)/ 63.1652(b)(2)
Furnace 18 Scrubber Outlet[2]	M_OE0010	7.61	6.9			0.9	63.1652(a)(1)
MOR Baghouse Outlet	M_SE0006			0.0004	0.03	81.1	63.1652(d)
C2P BH1 Outlet	M_PC0014			0.0033	0.03	9.1	63.1652(e)(2)
C2P BH2 Outlet	M_PC0015			0.0033	0.03	9.1	63.1652(e)(2)
C2P BH3 Outlet	M_PC0016			0.0033	0.03	9.1	63.1652(e)(2)
Felman (Facility ID: 54053NEIWV053FELMAN)							
Furnace 2 BH Outlet	M_OE0008	3.32	27.2			8.2	63.1652(b)(4)
Furnace 5 BH Outlet	M_OE0012	3.01	27.2			9.0	63.1652(b)(4)
Furnace 7 BH Outlet	M_OE0014	4.96	27.2			5.5	63.1652(b)(4)
Sizing #2 BH	M_PC0006			0.0011	0.03	27.7	63.1652(e)(2)

[1] The actual and MACT allowable emissions for Furnace 1 and Furnace 12 are shown as SiMn and FeMn respectively. The MACT/Allowable ratio assumes that the furnace produces SiMn, 50% of the time and FeMn, 50% of the time.

[2] Furnace 18 is a 13.5 MW semi-sealed furnace that is assumed to have 50/50 production of SiMn and FeMn. The MACT allowable limit assumes that Furnace 18 would be a new source and would have to meet the new source limit of 0.51 lb/hr/MW (13.5 MW * 0.51 lb/hr/MW = 6.9 lb/hr).

Table 6-3. Summary of Assigned Emission Process Groups for the Ferroalloys SCC

SCC	*SCC1_DESCRIPTION*	*SCC3_DESCRIPTION*	*SCC6_DESCRIPTION*	*SCC8_DESCRIPTION*	*Emission Process Group*
30300601	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	50% FeSi: Electric Smelting Furnace	Open EAF
30300602	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	75% FeSi: Electric Smelting Furnace	Open EAF
30300603	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	90% FeSi: Electric Smelting Furnace	Open EAF
30300604	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Silicon Metal: Electric Smelting Furnace	Open EAF
30300605	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Silicomanaganese: Electric Smelting Furnace	Open EAF
30300606	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	80% Ferromanganese	Open EAF
30300607	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	80% Ferrochromium	Open EAF
30300608	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Raw Material Unloading	Fugitive Dust Sources
30300609	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Raw Material Crushing	Raw Material Crushing & Screening Operations
30300610	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Ore Screening	Raw Material Crushing & Screening Operations
30300611	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Ore Dryer	Raw Material Crushing & Screening Operations
30300613	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Raw Material Storage	Fugitive Dust Sources
30300614	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Raw Material Transfer	Fugitive Dust Sources
30300615	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Ferromanganese: Blast Furnace	Other
30300616	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Ferrosilicon: Blast Furnace	Other
30300617	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Cast House	Casting
30300618	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Mix House/Weighing	Fugitive Dust Sources
30300619	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Raw Material Charging	Fugitive Dust Sources
30300620	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Tapping	Tapping Operation
30300621	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Casting	Casting
30300622	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Cooling	Fugitive Dust Sources
30300623	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Product Crushing	Product Crushing & Screening Operations
30300624	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Product Storage	Fugitive Dust Sources
30300625	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Product Loading	Fugitive Dust Sources
30300651	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Sealed Furnace: Ferromanganese: Electric Arc Furnace	Other
30300652	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Sealed Furnace: Ferrochromium: Electric Arc Furnace	Other
30300653	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Sealed Furnace: Ferrochromium Silica: Electric Arc Furnace	Other
30300654	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Sealed Furnace: EAF - Other Alloys: Specify in Comment	Other
30300699	Industrial Processes	Primary Metal Production	Ferroalloy, Open Furnace	Other Not Classified	Other
30300701	Industrial Processes	Primary Metal Production	Ferroalloy, Semi-covered Furnace	Ferromanganese: Electric Arc Furnace	Semi-closed EAF
30300702	Industrial Processes	Primary Metal Production	Ferroalloy, Semi-covered Furnace	Electric Arc Furnace: Other Alloys/Specify	Open EAF
30300703	Industrial Processes	Primary Metal Production	Ferroalloy, Semi-covered Furnace	Ferrochromium: Electric Arc Furnace	Semi-closed EAF
30300704	Industrial Processes	Primary Metal Production	Ferroalloy, Semi-covered Furnace	Ferrochromium Silicon: Electric Arc Furnace	Semi-closed EAF

Note: Highlighted SCCs are included in the Ferroalloys modeling database.

6.4 Emission Process Groups

The emission sources from the test data were divided into emission process groups using the Standard Classification Codes (SCC) supplied by the facility in the ICR. The emission process groups provided in the SCC list for the Ferroalloys category were; open EAF, fugitive dust sources, raw material crushing and screening operations, casting, and other. Table 6-3 presents a summary of the SCC and the assigned emission process group. As shown in Table 6-3, the emission process groups assigned in the modeling database for the emission sources were: Open EAF, Raw Material Crushing and Screening Operations, Fugitive Dust Sources, and Casting.

6.5 Latitude/Longitude QA/QC

The latitude and longitude coordinates provided by the facilities were reviewed to ensure that the coordinates matched the location of the emission points. This was done by plotting each emission point on a map of the facility using Google Earth. The plotted emission points were then evaluated in comparison to building layout diagrams provided by the facilities to determine if the emission point matched the expected location of the emission point. If it was determined that the emission point did not match the expected location on the diagrams, the point was moved to the expected location and new latitude and longitude coordinates were determined. The map and the emission point coordinates were sent to the facilities for confirmation of the locations in the December 21, 2013 ICR submittal.

6.6 Stack and Fugitive Parameters QA/QC

The stack and fugitive emission parameters provided by the facility in the ICR were verified to ensure they were correct. The volumetric flow rates for the point sources were checked by calculating the volumetric flow rate using the velocity and duct dimensions. The calculated flow rates were compared with the volumetric flow rates provided in the test reports. If the flow rate difference exceeded 30 percent, engineering judgments were made to revise the velocity or duct dimension data. Fugitive parameters were assigned using the Google Earth map for each of the facilities and estimating the length, width, and angle of the fugitive emissions. These parameters were sent to the facilities for confirmation of the values that were determined in the December 21, 2013 ICR submittal.

Appendix 2
Technical Support Document for HEM-AERMOD Modeling

Modeling for the Residual Risk and Technology Review Using the Human Exposure Model 3 – AERMOD Version

Updated 01/08/2014

Technical Support Document

Prepared for:

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Health and Environmental Impacts Division
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Disclaimer

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Contents

Figures

Tables

1. Introduction

This document describes the general modeling approach used to estimate the risks to human populations in support of the Residual Risk and Technology Review (RTR) currently being carried out by the U.S. Environmental Protection Agency (EPA). It is important to note that risk characterizations of individual source categories under the RTR program may not follow every item/approach noted in this document. The reader is referred to the main body of the risk assessment document for more details on source category specific approaches that may have been included in the analysis.

The model used in these risk assessments is the Human Exposure Model, Version 3 (HEM-3). HEM-3 incorporates AERMOD, a state of the art air dispersion model developed under the direction of the American Meteorological Society / Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC).

Section 2 of this report provides an overview of the HEM-3-AERMOD system; and Section 3 describes inputs and choices made in implementing the model for the RTR program. Quality assurance efforts undertaken in the modeling effort are discussed in Section 4, and uncertainties associated with the modeling effort are discussed in Section 5.

2. Overview of the HEM-3 – AERMOD System

HEM-3 performs three main operations: dispersion modeling, estimation of population exposure, and estimation of human health risks. The state-of-the-art American Meteorological Society (AMS) EPA Regulatory Model (AERMOD)[1,2] is used for dispersion modeling. AERMOD can handle a wide range of different source types which may be associated with an industrial source complex, including stack (point) sources, area and polygon sources, and volume sources.

To prepare dispersion modeling inputs and carry out risk calculations, HEM-3 draws on four data libraries, which are provided with the model. The first is a library of meteorological data for over 824 stations, which are used for dispersion calculations. A second library of Census block ("centroid") internal point locations and populations provides the basis of human exposure calculations. The Census library also includes the elevations of every Census block, which are used in the dispersion calculations for the RTR assessments. A third library of pollutant unit risk estimates and reference concentrations is used to calculate population risks. These unit risk estimates and reference concentrations are based on the latest values recommended by EPA for hazardous air pollutants (HAP) and other toxic air pollutants. The fourth data library, which provides deposition parameters for gaseous pollutants, is used only when the user opts to compute deposition and plume depletion (not computed for the RTR assessments to date).

HEM-3 has been implemented in two versions: a single facility version, and a multiple facility version ("Multi HEM-3"). Multi HEM-3 is used in the RTR risk assessment modeling. Both versions operate under the same general principles. In essence, Multi HEM-3 provides a platform for running the single facility version multiple times. In both versions, source location and emissions data are input through a set of Excel™ spreadsheets. The main difference is in the user interface for other model inputs. Single HEM-3 includes a graphical user interface (GUI) for the selection of various dispersion modeling options. In Multi HEM-3, a control file replaces many of these GUI inputs.

The model estimates cancer risks and noncancer adverse health effects due to inhalation exposure at Census block internal point locations (or "centroids"), at concentric rings surrounding the facility center, and at other receptor locations that can be specified by the user. Cancer risks are computed using EPA's recommended unit risk estimates for Hazardous Air Pollutants (HAP) and other toxic air pollutants. The resulting estimates reflect the excess cancer risk for an individual breathing the ambient air at a given receptor site 24-hours per day over a 70-year lifetime. The model estimates the numbers of people exposed to various cancer risk levels. In addition, HEM-3 estimates the total incremental cancer risks for people living within different distances of the modeled emission sources.

Potential noncancer health effects due to chronic exposures are quantified using hazard quotients and hazard indices for various target organs. The "hazard quotient" (HQ) for a given chemical and receptor site is the ratio of the ambient concentration of the chemical to the reference concentration. The "hazard index" (HI) for a given organ is the sum of hazard quotients for substances that affect that organ. HEM-3 computes target-organ-specific hazard indices (TOSHI) for HAPs and other toxic air pollutants, and estimates the numbers of people exposed to different hazard index levels. In addition, maximum short term ("acute") concentrations are computed for all pollutants, and concentrations are compared with threshold levels for acute health effects.

The following sections outline the methodologies used in the HEM-3–AERMOD system. Section 2.1 describes the preparation of dispersion modeling inputs, Section 2.2 describes the running of AERMOD, Section 2.3 describes calculations performed by HEM-3 to calculate risks and exposures, and Section 2.4 details the sources and methods used to produce HEM-3's data libraries. The HEM-3 User's Manuals – for single HEM-3 and Multi HEM-3 – provide additional details on the input data and algorithms used in the model.[3] Specific model options used in the RTR assessments are discussed in Chapter 3.

2.1 Preparation of Dispersion Modeling Inputs

HEM-3 compiles data that will be needed for dispersion modeling, and prepares an input file suitable for running AERMOD. The dispersion modeling inputs can be divided into three main components: emission source data, information on the modeling domain and receptors for which impacts will be computed, and meteorological data.

2.1.1 Compiling Emission Source Data

A series of Excel™ spreadsheet files are used to specify the emissions and configuration of the facility to be modeled. At a minimum, two files are needed: a pollutant emission file, and an emission location file. The emission file includes an emission source identification code for each emission source at the facility, the names of pollutants emitted by each source, and the emission rate for each pollutant. In addition, if the model run is to incorporate deposition or plume depletion, the emission file must also specify the percentage of each pollutant that is in the form of particulate matter. The balance is assumed to be in vapor form.

The emission location file includes the coordinates of each source, as well as information on the configuration and other characteristics of the source. HEM-3 can analyze point sources, area and polygon sources, and volume sources - configurations that are described in AERMOD's documentation.[1, 2] For stack (point) sources, the location file must provide the stack height, stack diameter, emission velocity, and emission temperature. The file must also provide dimensions for each area or volume source, as well as the height of the source above the ground. For area sources, the angle of rotation from north can also be specified. The user can also provide the terrain elevation at the base of each source. (The controlling hill height is also used in AERMOD's flow calculations. Calculation of the controlling hill height by HEM-3 is discussed in Section 2.4.2.) If the terrain elevations are not provided by the user, HEM-3 will calculate elevations and controlling hill heights based on elevations and hill heights provided by the Census database for the Census blocks nearest to the facility.

If particulate deposition and plume depletion are to be considered, then HEM-3 requires a third input file to specify the particle size distribution. This input file must include the average particle diameter, the mass fraction percentage, and the average particle density for each size range emitted. Another optional file can be used to specify building dimensions if building wake effects are to be modeled.

2.1.2 Defining the Modeling Domain and Receptors

HEM-3 defines a modeling domain for each facility that is analyzed based on parameters specified by the model user or calculated by the model. These parameters are summarized in Table 2-1. The modeling domain is circular, and is centered on the facility, with a radius specified by the user. For the RTR analysis, the radius of the modeling domain is 50 kilometers (km). HEM-3 identifies all of the Census block locations in the modeling domain from its Census database, and divides the blocks into two groups based on their distance from the facility. For the inner group of Census blocks (closest to the facility), each block location is modeled as a separate receptor in AERMOD. The cutoff distance for modeling individual Census blocks is generally set to 3 km for the RTR assessments, although it can be set differently by the model user. The model user can also provide an Excel™ spreadsheet specifying additional locations to be included as model receptors in AERMOD. These additional discrete "user receptors" may include facility boundary locations, monitoring sites, individual residences, schools, or other locations of interest.

For Census blocks in the outer group, beyond this modeling cutoff distance, emission impacts are interpolated based on modeling results for a polar receptor network. The user also specifies an "overlap" distance, within which Census block coordinates will be considered to be on facility property. The following paragraphs provide more details on the treatment of blocks near the facility, on the polar receptor network, and on the determination of receptor elevations and controlling hill heights to be used in AERMOD.

Table 2-1. Parameters Used to Delineate the Modeling Domain in HEM-3

Parameter	Typical value
Modeling domain size – maximum radial distance to be modeled from facility center	50 km
Cutoff distance for modeling of individual blocks[a]	3,000 m
Overlap distance – where receptors are considered on facility property[a]	30 m
Polar receptor network:	
Distance to the innermost ring[b]	≥100 m
Number of concentric rings	13
Number of radial directions	16

[a] Measured from each stack at the facility, and from the edges of each area or volume source

[b] Generally model-calculated to encompass all emission sources but not less than 100 meters from the facility center

Treatment of Nearby Census Blocks and Screening for Overlapping Blocks

Census block locations near the facility are modeled as separate receptors within AERMOD. The cutoff distance for modeling of individual Census blocks may be chosen by the user, but is typically 3000 meters for the RTR assessments. This distance is not measured from the center of the facility, but is the minimum distance from any source at the facility. Therefore, any Census block location that is within the cutoff distance from any emission source is treated as a discrete AERMOD receptor.

HEM-3 checks Census blocks that are very close to the facility in order to assess whether they overlap any point, area or volume emission sources. In addition, the user can specify an overlap distance, within which receptors will be considered to be on facility property. The default value for the overlap distance is 30 meters, or approximately equal to the width of a narrow buffer and a roadway. HEM-3 tests each nearby receptor to determine whether it is within this distance from any stack or from the perimeter of any area or volume source. If a receptor falls within this distance, HEM-3 will not calculate risks based on the location of that receptor, but will instead assume that the risks associated with the receptor are the same as the highest predicted value for any receptor that is not overlapping. The location for calculating the default impact may be either another Census block, one of the polar grid receptors, or one of the additional discrete user-specified receptor locations.

Polar receptor network

The polar receptor network used in HEM-3 serves three functions. First, it is used to estimate default impacts if one or more Census locations are inside the overlap cutoff distance used to represent the facility boundary. Second, it is used to evaluate potential acute effects that may occur due to short-term exposures in locations outside the facility boundary. Third, the polar receptor network is used to interpolate long-term and short-term impacts at Census block locations that are outside the cutoff distance for modeling of individual blocks.

Generally, the model calculates the inner radius (or first ring distance) for the polar receptor network to be just outside the emission source locations, but not less than 100 meters from the facility center. However, the user can override the default distance calculated by the model to fit the size and shape of the facility properties to be modeled. Likewise, the model will also use default values for the number of concentric rings to be analyzed (13 rings by default), and the number of radial directions (16 radials by default), although these default values can also be changed by the user to meet the needs of a specific modeling study. The inner radius of the polar network should be the minimum distance from the facility center that is generally outside of facility property. (For complex facility shapes, it is sometimes useful to specify an inner ring that encroaches on facility property in some directions.) HEM-3 will distribute the radial directions evenly around the facility. For the concentric rings, the model will generate a logarithmic progression of distances starting at the inner ring radium and ending at the outer radium of the modeling domain.

Elevations and hill heights for model receptors

HEM-3 includes terrain elevations by default for the RTR assessments, but the user can choose to exclude terrain effects when running AERMOD. If the default terrain option is used, HEM-3 obtains elevations and controlling hill heights for Census block receptors from its internal Census location library. Section 2.4.2 describes the derivation of these elevations and hill heights.

Elevations and controlling hill heights for the polar grid receptors are also estimated based on values from the Census library. HEM-3 divides the modeling domain into sectors based on the polar receptor network, with each Census block assigned to the sector corresponding to the closest polar grid receptor. Each polar grid receptor is then assigned an elevation based on the highest elevation for any Census block in its sector. The controlling hill height is also set to the maximum hill height within the sector. If a sector does not contain any blocks, the model defaults to the elevation and controlling hill height of the nearest block outside the sector.

2.1.3 Selection of Meteorological Data

In addition to source and receptor information, AERMOD requires surface and upper air meteorological observations in a prescribed format. The model user can select a meteorological station from the HEM-3 meteorological data library, or add new files to the library if site-specific data are available. If the user does not specify a meteorological station, HEM-3 will select the closest station to the center of the modeling domain, as is generally done for the RTR assessments.

2.2 Running of AERMOD

Based on the user input data and other data described in the previous section, HEM-3 produces an input file suitable for AERMOD. HEM-3 then runs AERMOD as a compiled executable program. No changes have been made from the version of AERMOD released to the public by EPA. The following sections give additional information on how AERMOD is used within HEM-3.

2.2.1 AERMOD Dispersion Options Used by HEM-3

AERMOD provides a wide array of options for controlling dispersion modeling calculations. In general, HEM-3 uses the regulatory default options when running AERMOD.[1] These options include the following:

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

The following additional AERMOD options are available to the HEM-3 user:

- Calculation of wet and dry deposition rates for vapor and particulate matter;
- Consideration of plume depletion (due to deposition) when calculating air concentrations;
- Consideration of building wake effects;
- Calculation of short term (acute) impacts; and
- Use of the FASTALL option, which conserves model runtime by simplifying the AERMOD algorithms used to represent meander of the pollutant plume.

As noted in Section 2.1, the calculation of deposition or depletion and the consideration of building wake effects require additional user inputs.

The user can opt to analyze short term impacts on a number of different time scales (i.e., 1 hour, 6 hours, 8 hours, or 24 hours) however only one short term time scale can be selected per run. If the user chooses to analyze short term impacts, a multiplier must be specified to reflect the ratio between the maximum short term emission rate and the long term average emission rate. The default multiplier for short term emissions is a factor of 10. This means that in the default case the maximum short term emission rate is assumed to be 10 times the long term average emission rate. The multiplier can be set to 1.0 if emissions from the facility are known to be constant. For RTR assessments, acute impacts are generally included in the modeling and the default multiplier of 10 is used, unless more source-specific information is available upon which to base the acute factor for the source category being modeled.

2.2.2 Use of Dilution Factors

To save computer run time when analyzing the impacts of multiple pollutants, HEM-3 does not model each pollutant separately. Instead, AERMOD is used to compute a series of dilution factors, specific to each emission source and receptor. 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 the user chooses not to analyze deposition and plume depletion, the dilution factor does not vary from pollutant to pollutant. If deposition and depletion is chosen as a model option, separate dilution coefficients must be computed for each gaseous pollutant. In addition, separate dilution factors must be computed for different components of particulate matter if the components do not have the same particle size distribution. In the current version of HEM-3, this can be done by creating a separate emission record for each pollutant emitted by from each source. (Common location data and source configurations can be used for different pollutant records representing the same emission source.)

2.3 Postprocessing of AERMOD Results in HEM-3

HEM-3 estimates total excess cancer risks and potential chronic noncancer health effects for all Census block locations in the modeling domain, all user-defined receptors, and all points in the polar receptor network. Potential chronic noncancer health effects are expressed in terms of TOSHI. Based on the results for Census blocks and other receptors, HEM-3 estimates the maximum individual risk (MIR) and maximum TOSHI for populated receptors, and determines the locations of these maximum impacts. The model also determines the concentrations of different pollutants at the sites of the maximum risks, and the contributions of different emission sources to these maximum estimated risks. It should be noted that the locations may differ for the maximum individual cancer risk and for the hazard indices for different target organs.

For acute impacts, HEM-3 calculates the maximum short term concentrations for all pollutants emitted by the facility. These maximum short term concentrations are compared with various threshold levels for acute health effects (e.g., the California EPA reference exposure level [REL] for no adverse effects).

At the option of the model user, HEM-3 will also compute the long term and short term predicted ambient concentrations of all pollutants emitted by the facility at all of the receptors in the modeling domain. In addition, pollutant contributions from each emission source at the facility are computed under this option.

Section 2.3.1. describes methods used to calculate cancer risks and hazard indices for receptors that are explicitly modeled using AERMOD. Section 2.3.2 describes the interpolation approach used to estimate cancer risks and hazard indices at Census blocks that are not explicitly modeled.

2.3.1 Calculation of Impacts at Modeled Receptors

As noted in Section 2.2.2, HEM-3 does not model each pollutant separately unless deposition or depletion is being analyzed. Instead, AERMOD is used to compute a series of dilution factors, specific to each emission source and receptor. HEM-3 also conserves computer memory by computing cancer risks and hazard indices directly, without recording the concentration of each pollutant at each receptor. The following algorithms are used to compute cancer risks and TOSHI for chronic noncancer health effects.

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 TOSHI:

$$TOSHI_T = \sum_{i,j} TOSHI_{i,j}$$

$$TOSHI_{i,j} = DF_{i,j} \times CF \times \sum_k [E_{i,k} / RfC_k]$$

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 [(µg/m^3) / (g/sec)] at the given receptor for source i and pollutant type j
$CF =$ conversion factor, 0.02877 [(g/sec) / (ton/year)]
$\sum_k =$ sum over all pollutants k within pollutant type j (particulate or gas)
$E_{i,k} =$ emissions of pollutant k from source i and in pollutant type j
$URE_k =$ cancer unit risk factor for pollutant k
$TOSHI_T =$ total target-organ-specific hazard index at a given receptor
$TOSHI_{i,j} =$ target-organ-specific hazard index at the given receptor for source i and pollutant type j
$RfC_k =$ non-cancer health effect reference concentration for pollutant k

The above equations are equivalent to the following simpler equations:

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

$$HI_T = \sum_{i,k} AC_{i,k} / RC_k$$

where:

$AC_{i,k}$ = ambient concentration (µg/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 is not available for a given chemical, then that chemical is not included in the calculation of cancer risk. Likewise, if the noncancer reference concentration is not available for a given chemical, that chemical is not included in the calculation of hazard indices. Note also that separate reference concentrations are used for acute and chronic hazard indices.

HEM-3 computes short term concentrations and records the highest short term concentration for each pollutant. In addition, the user can opt to compute and record the short term and long concentrations at each receptor. Concentrations are computed as follows.

Long term concentrations:

$$AC_{T,k} = \sum_i AC_{i,k}$$

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

Short term concentrations:

$$AC_T = \sum_i AC_{i,k}$$

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

where:

$AC_{T,k}$ = total estimated ambient concentration for pollutant k at a given receptor

$\sum_i$ = the sum over all sources i (µg/m^3)

$AC_{i,k}$ = estimated ambient concentration of pollutant k at the given receptor as a result of emissions from source i (µg/m^3)

M = ratio between the estimated maximum short term emission rate and the long term average emission rate (dimensionless)

2.3.2 Interpolation of Impacts at Outer Census Blocks

For Census blocks outside of the cutoff distance for individual block modeling, HEM-3 estimates cancer risks and hazard indices by interpolation from the polar receptor network. Impacts at the polar grid receptors are estimated using AERMOD modeling results and the algorithms described in Section 2.3.1. If terrain elevation is part of the modeling, then an elevation is estimated for each polar receptor. HEM-3 estimates elevations and controlling hill heights for the polar grid receptors based on values from the census library. HEM-3 divides the modeling domain into sectors based on the polar grid receptor network, with each census block assigned to the sector corresponding to the closest polar grid receptor.

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

The impacts at each outer Census block are interpolated 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, hazard index, or concentration) 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

2.3.3 Calculation of Population Exposures and Incidence

Using the predicted impacts for Census blocks, HEM-3 estimates the numbers of people exposed to various cancer risk levels and TOSHI levels. This is done by adding up the populations for receptors that have predicted cancer risks or TOSHI above the given threshold.

The model also estimates the total annual excess cancer risk (incidence) for the entire modeling region. The following equation is used:

$$TCR = \sum_m [CR_m \times P_m] / LT$$

where:

TCR = the estimated total annual cancer risk, or incidence, (cancers/year) to the population living within the modeling domain
$\sum_m$ = the sum over all Census blocks m within distance the modeling domain
CR_m = the total lifetime cancer risk (from all modeled pollutants and emission sources) at Census block m
P_m = the population at Census block m
LT = the average lifetime used to develop the cancer unit risk factor, 70 years

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

$$TCR_{i,j} = \sum_{m} [(\sum_{k} E_{i,k} \times URE_{k}) \times DF_{i,j,m} \times CF / LT]$$

$$TCR_{i,k} = TCR_{i\,j} \times E_{i,k} \times URE_{k} / (\sum_{k} E_{i,k} \times URE_{k})$$

where:

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

$\sum_{m}$ = the sum over all Census blocks m within distance the modeling domain

$\sum_{k}$ = the sum over all pollutant k, within pollutant type j

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

URE_{k} = unit risk factor for pollutant k

$DF_{i,j,m}$ = dilution factor at receptor m, for emissions of pollutant type j (which includes pollutant k), from source i

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

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

2.3.4 Model Outputs

The following is a summary of the outputs produced by HEM-3. These are written to a collection of files in Excel™ and dBase™ format (dbf).

- Maximum long term impacts at populated locations
  - maximum lifetime individual cancer risk (MIR)
  - maximum TOSHI for the following health effects
    - respiratory system effects
    - liver effects
    - neurological system effects
    - developmental effects
    - reproductive system effects
    - kidney effects
    - ocular system effects
    - endocrine system effects
    - hematological system effects
    - immunological system effects
    - skeletal system effects
    - spleen effects
    - thyroid effects
    - whole body effects
  - locations of the maximum cancer risk and TOSHI
  - Census block identification codes for the maximum cancer risk and TOSHI, and number of people in the Census block

    - contributions of different chemicals and emission sources to the maximum risk and TOSHI

- Maximum acute impacts
    - maximum short term ambient concentration for each chemical
    - threshold levels for acute health effects of each chemical (compared with the maximum short term concentrations)
    - locations of the maximum impacts for different chemicals (often polar receptors)
    - Census block identification codes at the locations of maximum concentration, and number of people in the block
    - contribution of each emission source at the facility to the maximum short term concentration of each chemical

- Outputs for all receptors
    - maximum individual cancer risk and TOSHI (all target organs) for each Census block and each user-specified discrete receptor (monitoring sites, etc.)
    - maximum individual cancer risk and TOSHI (all target organs) for each polar grid receptor
    - estimated deposition (optional)
    - predicted ambient concentration resulting from each emission source at each Census block and polar grid receptor (optional)

- Population exposures and total cancer risk, or incidence
    - estimated numbers of people exposed to different levels of lifetime individual cancer risk (1 in a million, 1 in 100,000, etc.)
    - estimated numbers of people exposed to different levels of TOSHI (1, 2, 10, etc.)
    - total cancer risk, or incidence, in estimated cancer deaths per year, over the entire modeling domain, and for each pollutant and source combination

2.4 Data Libraries Used in HEM-3

2.4.1 Chemical Health Effects Information

HEM-3 includes a library of available health effects data for HAPs. For each pollutant, the library includes the following parameters, where available:

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

Unit risk estimates and reference concentrations included in the HEM-3 chemical library have been taken from EPA's database of recommended dose-response factors for HAPs, which is updated periodically, consistent with continued research on these parameters.[4] The URE represents the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 microgram per cubic meter (µg/m^3) in air (e.g., if the

URE = 1.5×10^{-6} per $\mu g/m^3$, 1.5 excess tumors are expected to develop per 1 million people if all 1 million people were exposed daily for a lifetime to 1 microgram of the chemical in 1 cubic meter of air).[5]

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 non-cancer health effects during a lifetime. No adverse effects are expected as a result of exposure if the ratio of the potential exposure concentration to the RfC, defined as the hazard quotient (HQ), is less than 1.[5]

The reference benchmark concentration for acute health effects, similar to the chronic RfC, is the concentration below which no adverse health effects are anticipated when an individual is exposed to the benchmark concentration for 1 hour (or 8 hours, depending on the specific acute benchmark used and the formulation of that benchmark). Target organs are those organs (e.g., kidney) or organ systems (e.g., respiratory) which may be impacted with chronic non-cancer health effects by exposure to the chemical in question. A more in-depth discussion of the development and use of these parameters for estimating cancer risk and non-cancer hazard may be found in the EPA’s Air Toxics Risk Assessment Library.[6]

The model user can add pollutants and associated health effects to HEM-3’s chemical health effects (dose-response) library, as needed.

2.4.2 Census Block Locations and Elevation Data

The HEM-3 Census library includes Census block identification codes, locations, populations, elevations, and controlling hill heights for all of the over 6 million Census blocks identified in the 2010 Census and the over 5 million Census blocks identified in the 2000 Census. The model user may choose to use either Census database according to their modeling needs. The location coordinates reflect the internal “centroid” of the block, which is a point selected by the Census to be roughly in the center of the block. For complex shapes, the internal point may not be in the geographic center of the block. Locations and population data for Census blocks in the 50 states and Puerto Rico were extracted from the LandView® database For the 2000 Census[7] and from the U.S. Census Bureau website for the 2010 Census.[8] Locations and populations for blocks in the Virgin Islands were obtained from the U.S. Census Bureau website.

U.S. Geological Survey data was used to estimate the elevation of each census block in the continental U.S. and Hawaii. The data used for the 2000 Census elevations have a resolution of 3 arc seconds, or about 90 meters.[9] The data used for the 2010 Census elevations have a resolution of 1/3 of an arc second, or about 10 meters.[10] Using analysis tools (ArcGIS® 9.1 software application for the 2000 Census, and ArcGIS® 10 for the 2010 Census), elevation was estimated for each census block in Alaska and the U.S. Virgin Islands. The point locations of the census blocks in Alaska and the U.S. Virgin Islands were overlaid with a raster layer of North American Digital Elevation Model (DEM) elevations (in meters).[9] An elevation value was assigned to each census block point based on the closest point in the ArcGIS elevation raster file.

An algorithm used in AERMAP, the AERMOD terrain processor, is used to determine controlling hill heights.[11,12] These values are used for flow calculations within AERMOD.

To save run time and resources, the HEM-3 census block elevation database is substituted for the DEM data generally used in AERMAP. As noted above, the census block elevations were originally derived from the DEM database. To determine the controlling hill height for each census block, a cone is projected away from the block centroid location, representing a 10% elevation grade. The controlling hill height is selected based on the highest elevation above that 10% grade (in accordance with the AERMAP methodology). The distance cutoff for this calculation is 100 km. (This corresponds to an elevation difference at a 10% grade of 10,000 m, which considerably exceeds the maximum elevation difference in North America.)

2.4.3 Meteorological Data

HEM-3 includes an extensive library of meteorological data to support the AERMOD dispersion model. Currently 824 meteorological stations have been preprocessed for AERMOD as part of the RTR effort. Section 3.3 includes a depiction of these meteorological stations and Appendix 2 discusses the preparation of meteorological data for the RTR in more detail.

2.4.4 Gaseous Deposition Parameters

HEM-3 provides options to compute the deposition of air pollutants, and to take into account the impacts of plume depletion due to deposition of gaseous and particulate pollutants. If the deposition and depletion option is selected by the model user for gaseous pollutants, a number of pollutant properties are required by AERMOD. (These include the diffusivity of the pollutant in air, the diffusivity of the pollutant in water, the Henry's Law constant, and a parameter reflecting the cuticular resistance to uptake of the pollutant by leaves r_{CL}).[13] HEM-3 includes a library of these parameters for most gaseous HAPs. This library is based on a compendium of gaseous deposition parameters developed by Argonne National Laboratories.[14] It should be noted, however, that the deposition and depletion option of HEM-3 and AERMOD have not been used to date for the RTR assessments.

3. Modeling for the Residual Risk Technology Review

This section discusses the general approach used to implement the HEM-3 AERMOD system for the RTR modeling analyses. Separate reports have been prepared for each of the emission source categories analyzed to date. These reports provide information on the emissions inputs and results for specific emission categories.

3.1 Emission Source Inputs

HEM-3 and AERMOD require detailed data on emissions from each emission source included in the modeling analysis. These data include:

- pollutants emitted;
- emission rate for each pollutant;
- emission source coordinates;
- stack height (or emission height for fugitive and other area sources);
- stack diameter (or configuration of fugitive and other area sources);
- emission velocity; and
- emission temperature.

Emissions data for the RTR assessments are compiled form a variety of data sources (i.e., the 2005 National Emissions Inventory (NEI)[15] ,information data requests). Each source category under the RTR program, in most cases, utilizes the latest best available data. These data include HAP emission rates, emission source coordinates, stack heights, stack diameters, flow rates, and exit temperatures. EPA performs an engineering review of the NEI data. In cases where new or better data were known to exist for a particular source category, that information is integrated into the data used in modeling for that category. For each source category, the emissions are summarized in the source category specific report. Detailed computer files containing all emission and release characteristics are available in the docket prepared for the specific RTR source category proposed or final rule.

As noted in the previous section, industrial emission sources can be characterized in AERMOD as point, area, polygon, or volume sources. Fugitive emissions are generally characterized as low point sources with minimal exit velocities. For some categories, additional information was available on the configuration of fugitive emission sources. This information was incorporated into the emissions database as part of the engineering review. Thus, fugitive emission sources were characterized as area or volume sources when sufficient configuration information was available.

3.2 Pollutant Cross-Referencing

Because the NEI is developed from a number of different data sources, a single chemical may be listed in the inventory under different names (i.e. a “common name” and one or more structure-based names). In addition, pollutant groupings such as polycyclic organic matter (POM), can be listed in the NEI under the names of individual member compounds, and under different synonyms (e.g. polynuclear aromatic hydrocarbons). HEM-3 requires an exact match in the chemical name in order to link emissions to the appropriate dose-response factors. The model will not process any pollutant that is not specifically listed in the chemical library. Therefore, all of the HAP names used in the NEI were linked to the appropriate chemical names in the HEM-3 reference file.

Pollutant-specific dose response values are used in the HEM-3 modeling whenever available, including when modeling POM pollutants. Pollutant groupings, such as POM groupings, are used for POMs without a chemical-specific unit URE's. These POMs are assigned a URE associated with various POM compounds having similar characteristics. "An Overview of Methods for EPA's National-Scale Air Toxics Assessment" 2011 document[16] provides more details regarding POM modeling, including:

> [S]ome emissions of POM were reported in [the] NEI as "7-PAH" or "16-PAH," representing subsets of certain POM, or simply as "total PAH" or "polycyclic organic matter." In other cases, individual POM compounds are reported for which no quantitative cancer dose-response value has been published in the sources used for NATA. As a result, simplifying assumptions that characterize emissions reported as POM are applied so that cancer risk can be quantitatively evaluated for these chemicals without substantially under- or overestimating risk (which can occur if all reported emissions of POM are assigned the same URE). To accomplish this, POM emissions as reported in NEI are grouped into categories. EPA assigns dose-response values based on the known or estimated toxicity for POM within each group and on information for the POM speciation of emission sources, such as wood fires and industrial processes involving combustion.

Emissions of metal compounds are also adjusted using algorithms developed for the Emissions Modeling System for Hazardous Air Pollutants (EMS-HAP) under the National-scale Air Toxics Assessment (NATA). A mass adjustment factor was applied to the emissions of metal compounds to account for a particular portion (e.g., the lead portion of lead sulfate) or to partition them among multiple pollutant categories (e.g. chromium arsenate into chromium VI compounds and arsenic compounds). In addition, where no specific compound information was available, metals were speciated into appropriate oxidation states (e.g. chromium compounds into chrome VI and chrome III) based on factors that have been developed for specific source categories and average factors that have been developed for the inventory as a whole. The adjustment factors and speciation factors were taken from the HAP Table module of EMS-HAP.[17,18]

3.3 Meteorological Data

Nationwide meteorological data files are accessed by HEM-3 and used for the RTR modeling. The current HEM-3 AERMOD Meteorological Library includes over 800 nationwide locations, depicted in Figure 3-1. This library contains surface and upper air meteorological data from National Weather Service (NWS) observation stations, which are named beginning with the state abbreviation for the state in which the station is located. AERMOD requires surface and upper air meteorological data that meet specific format requirements.[19,20] Appendix 2 discusses the preprocessing performed on the meteorological data used by AERMOD and includes a detailed listing of the 824 meteorological station pairs.

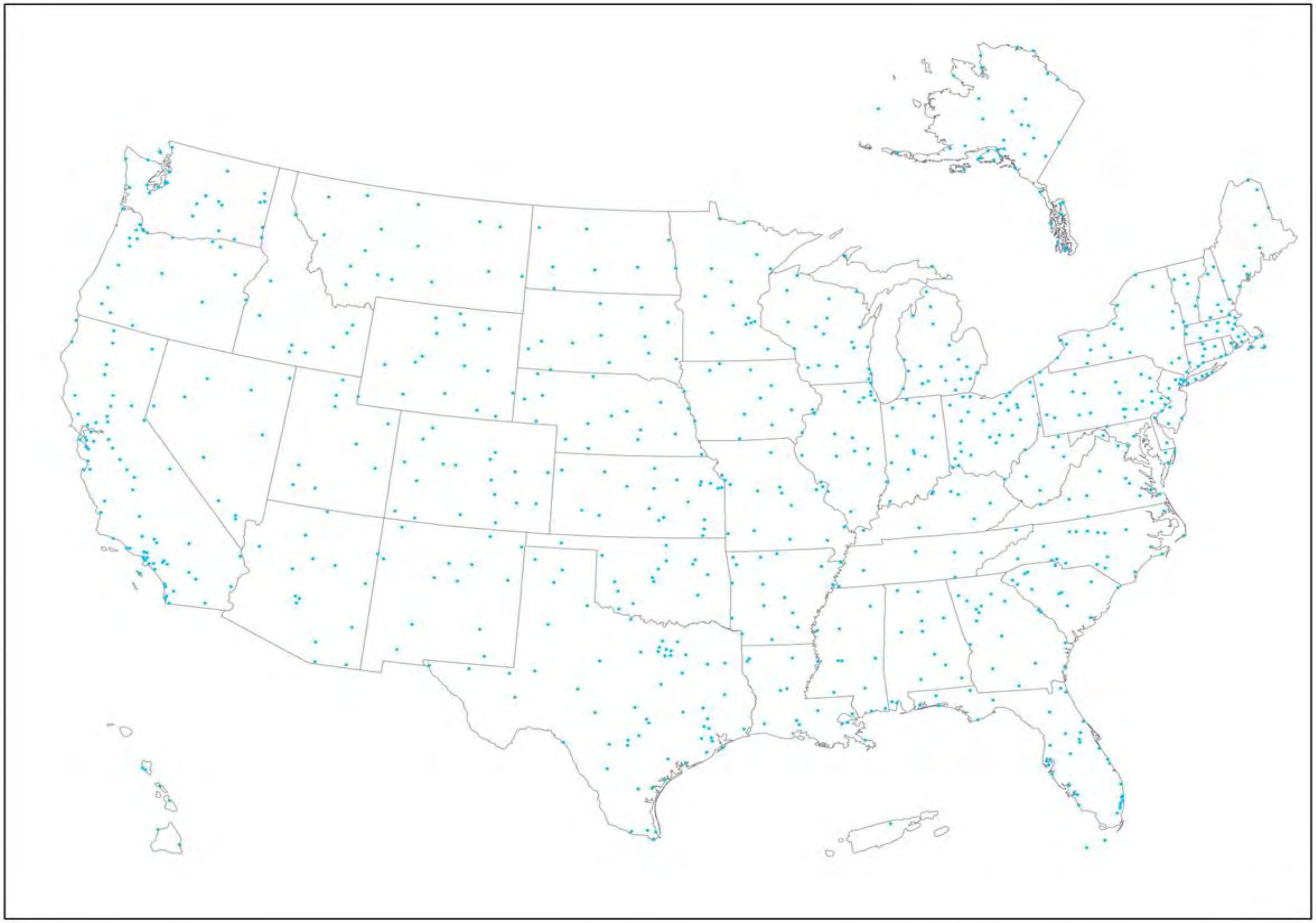

Figure 3-1. AERMOD Meteorological Stations

3.4 Model Options Selected

HEM-3 presents a number of options for characterizing the modeling domain and data sources. As many sources are generally modeled in RTR assessments, established defaults and common practices are relied on to make these choices. The choices available to a HEM-3 user and the selections that are made in most RTR assessments are presented in Table 3-1. Some of the key selections are discussed in more detail in the paragraphs below.

It should be noted that although routine emissions are not expected to vary significantly with time, nonroutine (upset) emissions can be significant relative to routine emissions. Upset emissions occur during periods of startup, shutdown, and malfunction. Upset emissions are not likely for equipment or storage tanks, but do result from malfunctioning control devices and leaks in cooling tower heat exchangers. There is some limited data on upset emissions available,[21] but no facility-specific analyses of these data were performed to characterize short-term emissions from these emission sources, and upset emissions are generally not modeled for the RTR risk assessments.

3.4.1 Urban or Rural Dispersion Characteristics

Current RTR source category assessments which use the 2010 Census are based on either urban or rural dispersion characteristics, depending on the land characteristics surrounding each modeled facility. The EPA provides guidance on whether to select urban or rural dispersion coefficients in its Guideline on Air Quality Models.[22] In general, the urban option is used 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.

Using the 2010 Census, the HEM-3 model determines, by default, whether to use rural or urban dispersion characteristics. HEM-3 will find the nearest census block to the facility center and determine whether that census block is in an urban area, as designated by the 2010 Census.[23] The population of the designated urban area will be used to specify the population input for AERMOD's urban mode. (Alternatively, a user may select the rural or urban option to override determination by the model. If a user selects an urban dispersion environment, then the user must provide the urban population as well.)

For the 2008 and prior screening-level RTR assessments of 51 source categories, the rural option was chosen to be most conservative (i.e., more likely to overestimate risk results). The rural option is also chosen by default by the HEM-3 model whenever the 2000 Census is selected by the user.

3.4.2 Deposition and Plume Depletion

The RTR modeling analysis to date has not taken into account the depletion of pollutant concentrations in the plume due to wet or dry deposition, although HEM-3 can model deposition and depletion using AERMOD. In addition, reactivity and decay have not been considered. It is possible that this approach may overestimate air concentrations and therefore risk. However, one of the main metrics used by EPA in the residual risk program is the risk to the individual most exposed (the maximum individual risk, or MIR). Because the maximum risk usually occurs at a receptor very close to the emission source, it is unlikely to be influenced by altered plume dispersion characteristics of this type. For more refined, multipathway assessments, EPA may consider deposition and depletion.

3.4.3 Cutoff Distance for Modeling of Individual Blocks

The cutoff distance for modeling individual Census blocks is initially set to 3 km by default. This distance generally ensures that the maximum individual cancer risk and the maximum TOSHI are modeled explicitly and not interpolated. Following a modeling run, the results for each facility are checked to determine whether the maximum impacts are located inside the modeling cutoff distance. If the maximum impacts are outside the cutoff distance, and if any of the impacts are significant, then HEM-3 is rerun for the facility with a cutoff distance greater than 3 km. In general, this is done if the cancer risk exceeds 1 in 1 million or any TOSHI exceeds 1. However, the risks for such facilities are generally very low, since the maximum impacts are in most cases only interpolated when the nearest Census block is more than 3 km from the facility (i.e., in sparsely populated areas).

3.4.4 Facility Boundary Assumptions

The main input mechanisms for incorporating facility boundary information in HEM-3 are the overlap distance, the distance to the innermost polar receptor ring, and user-specified receptor locations. The NEI does not provide information on facility boundaries. However, satellite/aerial images are used to locate residential populations that are closer to a facility than the Census block centroid. User-specified receptor locations are used in such assessments to avoid underestimating risk. Conservative default assumptions are used for the overlap distance and the innermost polar receptor ring. However, these are adjusted for some categories where facility sites are known to be large. In addition, satellite imagery is used to check the facility boundary assumptions for facilities with large projected impacts. These checks are discussed further in the section on Quality Assurance (Section 4).

Table 3-1. HEM-3 Domain and Set-Up Options As Used in the Residual Risk and Technology Review Assessments

Option	Selection
Dispersion model	AERMOD
Census database: 2010 or 2000	Based on date of analysis
Type of analysis: chronic, acute, or both	Both
Averaging time for short term impacts	1-hour
Multiplier for short term emissions	10 generally, although multiple source type-specific factors are also used if available
Dispersion characteristics: urban or rural, as determined by model, based on closest 2010 Census block to each facility (when using 2010 Census). Rural by default, when using the 2000 Census.	Urban or Rural based on facility location; (Rural for 2000 Census)
Include terrain impacts	Yes
Include building wake effects	No
Calculate deposition (wet, dry, or both) & include impacts of plume depletion	No
User-specified receptor locations (for residential population locations, facility boundary sites, or other sites of interest)	Yes, for some facilities
Modeling domain size – maximum distance to be modeled	50 km
Cutoff distance for modeling of individual blocks	3 km[a]
Overlap distance where receptors are considered to be on facility property – measured from each source measured from each source	30 m[b]
Polar receptor network specifications:	
Distance from the facility center to the innermost ring	≥ 100 m[c]
Number of rings	13
Number of directions	16
Meteorology data	Closest site

[a] The individual block modeling cutoff is increased for categories and for some facilities to ensure that the maximum individual risk values are not interpolated.

[b] The overlap distance is adjusted for some facilities to avoid modeling locations that are on facility property (see section 4.2).

[c] HEM-3 sets the innermost ring distance to be just outside the emission sources but not < 100 m.

3.5 Modeling of Multiple Facilities

HEM-3 models one facility at a time. However, clusters of nearby facilities may impact the same people, resulting in higher risk to those people. To account for this situation, risks are summed at each Census block for all facilities affecting the Census block.

As described earlier (Section 2.3.4), HEM-3 produces detailed output tables containing the risk and population for every Census block in the modeling domain. These detailed tables are combined for all facilities in a source category and the risk for each Census block is summed, using the RTR Summary Program add-on module to the Multi HEM-3 model.[3] Thus, the effect of multiple facilities in the same source category on the same receptor are estimated. The resulting “combined facility” or “cluster-effect” Census block risks are used to calculate population exposure to different cancer risk levels, noncancer hazard indices, and source category incidence.

4. Quality Assurance

The National Emissions Inventory (NEI) is subject to an extensive program of quality assurance (QA) and quality control (QC). The QA/QC program for the point source component of the NEI is documented in a separate report, available from the NEI website.[24] This section describes QA activities carried out under the RTR modeling analysis.

4.1 Engineering Review

In addition to the standardized QA steps taken for the entire NEI, EPA performs an engineering review of NEI data for the emission source categories included in the RTR analysis. This engineering review includes two main components. The first component addresses the list of facilities included in each source category. EPA engineers review independent sources of information to identify all sources in the category that are included in the NEI. In addition, EPA reviews the list of sources represented as part of each category in the NEI to make sure that the facilities actually manufacture products characteristic of the source category.

The second component of the engineering review focuses on the appropriateness of facility emissions. EPA reviews the list of HAPs reportedly emitted by each facility to make sure that the pollutants are appropriate to the source category. In addition, EPA engineers review the magnitude of those HAP emissions. In cases where new or better data are known to exist for a particular source category, that information is integrated into the data used in modeling for that category. In these cases, the source category specific documents provide additional details on the emissions inputs used.

4.2 Geographic Pre-Modeling Checks

The NEI QA process includes some basic checks on location data for point sources. The coordinates for each source are checked to ensure that they are in the county that has been specified for the source. If this is not the case, or if no geographic coordinates are available for the emission source, then the coordinates are set to a default location based on the nature of the emission source category.[25] In addition, coordinates for all emission sources at a given facility are checked to ensure that they are within 3 km of one another. These QA checks happen prior to HEM-3 modeling and the results of such checks are reflected in the HEM-3 input files.

Another pre-modeling geographic QA check regards the location of the census block receptors. As noted above, to estimate ambient concentrations for evaluating long-term exposures, the HEM-3 model uses the census block centroids as dispersion model receptors. The census block centroids are often good surrogates for where people live within a census block. A census block generally encompasses about 40 people or 10-15 households. However, in cases where a block centroid is located on industrial facility property, or where a census block is large and the centroid less likely to be representative of the block's residential locations, the block centroid may not be an appropriate surrogate.

Census block centroids that are on facility property can sometimes be identified by their proximity to emission sources. In cases where a census block centroid is within 300 meters of any emission source, aerial images of the facility are reviewed to determine whether the block centroid is likely located on facility property. The selection of the 300-meter distance reflects a compromise between too few and too many blocks identified as being potentially on facility property. Distances smaller than 300 meters would identify only block centroids very near the emission sources and could exclude some block centroids that are still within facility boundaries, particularly for large facilities. Distances significantly larger than 300 meters would identify many block centroids that are outside facility boundaries, particularly for small facilities. Block centroids confirmed to be located on facility property are moved to a location that best represents the residential locations in the block.

In addition, census block centroids for blocks with large areas may not be representative of residential locations. Risk estimates based on such centroids can be understated if there are residences nearer to a facility than the centroid, and overstated if the residences are farther from the facility than the centroid. To avoid understating the maximum individual risk associated with a facility, block centroids are relocated in some cases, or additional user-specified receptors are added to a block. Aerial images of all large census blocks within one kilometer of any emission source are examined. Experience from previous risks characterizations show that in most cases the MIR is generally located within 1 km of the facility boundary. If the block centroid does not represent the residential locations, it is relocated in the HEM-3 input files to better represent them. If residential locations cannot be represented by a single receptor (that is, the residences are spread out over the block), additional user-specified receptors are included in the HEM-3 input files to represent residences nearer to the facility than the centroid.

4.3 Geographic Post-Modeling Checks

As part of the RTR modeling analysis, additional geographical QA checks are made for some facilities, after initial HEM-3 modeling results are reviewed. Facilities subjected to these additional checks include:

- cases where the initial estimates of maximum risks are particularly high
    - maximum individual cancer risk of over 1 in 10,000
    - any maximum TOSHI above 10
- cases where no Census blocks are identified by the model within 3 km of the facility

HEM-3 produces a detailed Google Earth™ map of the modeled point and area emission sources and surrounding receptors (including Census block centroids, polar receptors and user-specified receptors) overlaying Google Earth™'s satellite imagery. This map allows a QA check of the specific source locations, as well as an approximate check of the facility boundaries. The emission source coordinates are reviewed for each of these facilities and compared with the address reported for the facility. If the address and the coordinates represent the same location, then the coordinates are taken to be correct. For more recent modeling of source categories, the emission coordinates initially modeled by HEM-3 tend to be correct, as they undergo pre-modeling scrutiny and QA checks (as discussed in Section 4.2).

More rarely, the modeled emission coordinates will be determined post initial modeling not to be located on facility property. If the facility and emission coordinate locations are different, then the satellite imagery for the address and the coordinate location are reviewed to determine whether either photograph includes an industrial facility. Generally for the 2008 and prior screening-level RTR assessments of 51 source categories, where the two locations were different, the facility address was found to be correct (and the emission source coordinates required correction). In some cases, this comparison could not be made because the reported address was a Post Office box or a headquarters address. Where this occurred, the aerial photograph for the coordinate location was reviewed to determine whether an industrial facility was located at or near the location. If emission source coordinates are found to be incorrect, HEM-3 is rerun using corrected coordinates. These changes are described in the source category documents.

For the high-risk facilities, the coordinates used to represent the most impacted Census blocks are also reviewed. This review draws on detailed Census block boundary maps and satellite imagery. Large industrial facilities will frequently occupy one or more entire Census blocks. However, these blocks may also include one or more residences on the periphery of the industrial land. Generally, the centroid coordinates listed for a Census block are near the center of the block. In these cases of mixed industrial and residential blocks, the coordinates may be on facility property.

In general, block coordinates are considered to be on facility property if they are located between the different emission source locations listed for the facility. In these situations, HEM-3 is rerun with an expanded overlap distance, in order to exclude the Census block coordinates that appear to be located on facility property. The distance to the innermost polar receptor ring is also adjusted to ensure that this ring is not on facility property, but as close to the apparent facility boundaries as possible.

5. Uncertainties

The RTR risk assessments using HEM-3 and AERMOD are subject to a number of uncertainties. For instance, model verification studies for AERMOD show predicted maximum annual concentrations ranging from 0.3 to 1.6 times measured values, with an average of 0.9. Predicted maximum short term (1 to 24 hours) concentrations were 0.25 to 2.5 times measured values, with an average of 1.0.[25]

In addition, a number of simplifying assumptions are made in these modeling analyses. First, the coordinates reported by the Department of Census for Census block internal points ("centroids") have been used as a surrogate for long-term population exposures. Locations of actual residences have not been modeled. In addition, the current version of HEM-3 does not take into account the movement of people from one Census block to another during the course of their lives, or commuting patterns during a given day. Nor does the model take into account the attenuation of pollutant from outside emission sources in indoor air. Ideally, risks to individuals would be modeled as they move through their communities and undertake different activities. However, such modeling is time-and resource-intensive and can only capture a portion of the uncertainty associated with the full range of human activities. In general, it is expected that long-term exposures will be overstated for high-end estimates (as most individuals will not spend all their time at their highly affected residences), but may understate the total population exposed (as some individuals living outside the modeled area may regularly commute into the area for work or school).

When considering long-term or lifetime exposures, it should be noted that relatively few people in the United States reside in one place for their entire lives. For the purposes of this assessment, cancer risk estimates are based on a lifetime exposure at the Census-identified place of residence. While it is impossible to know how this assumption affects the risk experiences by a particular individual (as people can move into higher- or lower-risk areas), it is likely that this assumption will overstate the exposure to those most exposed (i.e., people already living in high exposure areas are unlikely to move to yet higher exposure areas). However, this assumption will also tend to underestimate the total number of people exposed and population risk (i.e., incidence) because population levels are generally increasing.

In the current analyses, only direct inhalation is modeled. Other pathways such as the deposition of pollutants to drinking water, and to bioaccumulation of deposited pollutants in the food supply may be a significant source of exposure for persistent and bioaccumulative hazardous air pollutants (PB HAP). Screening level evaluations of the potential human health risks associated with emissions of PB HAP from the modeled facilities are used to determine if additional analyses are needed, but these analyses are outside the scope of this document. Because the HEM-3 AERMOD analyses are restricted to the inhalation pathway, the impacts of plume depletion due to deposition are not taken into account. Thus, inhalation impacts may be overestimated for some pollutants, but exposures through other pathways would be underestimated.

A number of other simplifications are made in the dispersion modeling analyses, as noted in Table 3-1. For instance, building wake effects are not considered. In addition, meteorological observations are based on the closest station in the HEM-3 meteorological library (see Figure 3-1). Alternative meteorological stations may be more appropriate for some facilities. Ideally, facility-specific meteorological observations would be used. A single year of meteorological data (2011) is currently used for AERMOD's dispersion modeling. (The 2008 and prior screening-level RTR assessments of 51 source categories used meteorological data based on the year 1991.) When considering off-site meteorological data most site specific dispersion modeling efforts will employ up to five years of data to capture variability in weather patterns from year to year. However, because of the large number of facilities in the analyses and the extent of the dispersion modeling analysis (national scale), it is not practical to model five years of data. Other national studies such as NATA also consider only a single year of meteorological data. A sensitivity analyses performed by the NATA assessment found that variability attributable to the selection of the meteorology location/time (both temporal and spatial) resulted in a 17-84% variation in predicted concentrations at a given station.[26]

Finally, risk and exposure factors are also subject to uncertainty. Not all individuals experience the same degree of exposure or internal dose of a given pollutant due to individual-specific parameters such as weight, age, and gender. While the health benchmarks used in the analyses crudely account for sensitive populations, a prototypical human (e.g., body weight, ventilation rate) is used to define the benchmark. Because of the variability of these parameters in the population, this factor will result in a degree of uncertainty in the resulting risk estimate.

Table 5-1 summarizes the general sources of uncertainty for the RTR modeling analyses. The table also gives a qualitative indication of the potential direction of bias on risk estimates. The sources of uncertainty in Table 5-1 are divided into four categories, based on the major components of the analyses:

- emissions inventory;
- fate and transport modeling;
- exposure assessment; and
- toxicity assessment.

It must also be noted that individual source categories may be subject to additional uncertainties. These are discussed in separate reports which are prepared for each emission source category included in the RTR assessments.

Table 5-1. Summary of General Uncertainties Associated with Risk and Technology Review Risk Assessments

Parameter	Assumption	Uncertainty/Variability Discussion	Potential Direction of Bias on Risk Estimates
Emissions Inventory			
Individual HAP emissions rates and facility characteristics (stack parameters, property boundaries)	Emissions and facility characteristics from the NEI provide an accurate characterization of actual source emissions.	Our current emissions inventory is based on the 2005 NEI, our internal review, and public comments received. The degree to which the data in our inventory represents actual emissions is likely to vary across sources. For the 2008 screening level assessments, nearly half of the sources in a given source category submitted a review of their emissions and facility characteristics data. Some detailed data, such as property boundary information is not available for most facilities. This is an important consideration in determining acute impacts.	Unbiased overall, magnitude variable
Multiplier for short-term emission rates	Generally, maximum short term emission rates are estimated by applying a simple multiplier (a factor of 10) to average annual emissions.	The ratio between short-term and long-term average emission rates may vary among the different emission sources at a facility. In addition, the use of a simple multiplier means that impacts of maximum short term emissions are modeled for all meteorological conditions, including the worst-case conditions for population exposure.	Potential overestimate due to the fact that worst-case emissions are assumed to occasionally coincide with worst-case meteorology. Overestimate due to lack of actual information on short-term emission rates.
Fate and Transport Modeling			
Atmospheric dispersion model choice	AERMOD is EPA's recommended dispersion model for assessing pollutant concentrations from industrial facilities	Field testing of dispersion models, including AERMOD, have shown results to generally be within a factor of 2 of measured concentrations.	Unbiased overall
Building downwash	Not included in assessments	Use of this algorithm in AERMOD could improve the dispersion calculations at individual facilities. However, data are not readily available to utilize this option.	Potential underestimate of maximum risks near facility. No effect on risks further out.
Plume deposition and depletion	Not included in assessments	Ignoring these impacts for pollutants that deposit minimally, and whose risks derive predominantly from inhalation, should have minimal effect on risk estimates.	Unbiased or minimal overestimate.

Table 5-1. Summary of General Uncertainties Associated with Risk and Technology Review Risk Assessments (continued)

Parameter	Assumption	Uncertainty/Variability Discussion	Potential Direction of Bias on Risk Estimates
Meteorology	One year of meteorological data from the nearest weather station (selected from 824 nationwide) is representative of long-term weather conditions at the facility.	The use of one year of data rather than the five or more adds uncertainty based on whether that year is representative of each location's climatology. Use of weather station data rather than on-site data can add to uncertainty. Additionally, the use of default surface parameters in the generation of the meteorological datasets imparts uncertainty to the results from any individual facility.	Minimal underestimate or overestimate.
Reactivity	Not included in the assessments	Chemical reactions and transformations of individual HAP into other compounds due to solar radiation and reactions with other chemicals happens in the atmosphere. However, in general, the HAP in this assessment do not react quickly enough for these transformations to be important near the sources, where the highest individual risks are estimated. Further, most of the HAP do not react quickly enough for these transformations to be important to risk estimates in the entire modeled domain (i.e., within 50 km of the source).	No impact on maximum risk estimates. Minimal impact on population risks and incidence.
Maximum modeling distance	50 kilometers from center of facility	This distance is considered to be the maximum downwind distance for a Gaussian plume model such as AERMOD. This is because, in general, winds cannot be considered to follow straight line trajectories beyond this distance.	No effect on maximum individual risks. Minimal underestimation of incidence.
Exposure Assessment			
Locations and short-term movements of individuals	Ambient concentration at centroid of each off-site census block is equal to the exposure concentration for all people living in that census block. Effect of human activity patterns on exposures is not included in the assessment.	People live at different areas within block that may have higher or lower exposures than at the centroid. Individuals also move from outdoors to indoors and from home to school/work to recreation, etc., and this can affect their total exposure from these sources.	Unbiased across population for most pollutants and individuals, likely overestimate for most exposed and underestimate for least exposed persons.

Table 5-1. Summary of General Uncertainties Associated with Risk and Technology Review Risk Assessments (continued)

Parameter	Assumption	Uncertainty/Variability Discussion	Potential Direction of Bias on Risk Estimates
Long-term movements of individuals	MIR individual is exposed continuously to the highest exposure concentration for a 70-year lifetime.	Maximum individual risk (MIR) is defined in this way to be a maximum theoretical risk at a point where a person can actually reside.	Unbiased for most individuals, likely overestimate for the actual individual most exposed and likely underestimate for the least exposed. Incidence remains unbiased unless population around facilities increases or decreases over 70 years.
Toxicity Assessment			
Reference concentrations (RfC)	Consistent with EPA guidance, RfCs are developed including uncertainty factors to be protective of sensitive subpopulations. Additionally, RfCs are developed based on the level producing an effect in the most sensitive target organ or system.	While other organ systems may be impacted at concentrations above the RfC, these are not included in the calculation of target organ-specific hazard indices.	In general, EPA derives RfCs using procedures whose goal is to avoid underestimating risks in light of uncertainty and variability. The greater the uncertainties, the greater the potential for overestimating risks.
Unit Risk Estimate (URE)	Use of unit risk estimates developed from dose-response models such as linear low-dose extrapolation.	Uncertainty in extrapolating the impacts from short-duration, high-dose animal or work-related exposures to longer duration, lower-dose environmental impacts.	Overestimate of risks for nonlinear carcinogens and for linear carcinogens with sparse health effects data. In general, EPA derives URE values using procedures aimed at overestimating risks in light of uncertainty and variability.
Toxicity of mixtures	Cancer risks and noncancer hazard quotients were calculated for each HAP individually and then summed into a total risk or hazard index (assumption of additivity).	Concurrent exposures to multiple chemicals may result in either increased or decreased toxicity due to chemical interactions but the data needed to quantify these effects are generally not available.	Unbiased overall. Some mixtures may have underestimated risks, some overestimated, and some correctly estimated.

Table 5-1. Summary of General Uncertainties Associated with Risk and Technology Review Risk Assessments (continued)

Parameter	Assumption	Uncertainty/Variability Discussion	Potential Direction of Bias on Risk Estimates
Surrogate dose- response values for HAPs without values	In the case of groups of HAPs such as glycol ethers, the most conservative dose-response value of the chemical group was used as a surrogate for missing dose-response values in the group. For others, such as unspeciated metals, we have applied speciation profiles appropriate to the source category to develop a composite dose-response value for the group. For HAP which are not in a group and for which no URE's or RfC's are available from credible sources, no assessment of risk is made.	Rather than neglecting the assessment of risks from some HAPs lacking dose response values, conservative assumptions allow the examination of whether these HAPs may pose an unacceptable risk and require further examination, or whether the conservative level examination with surrogates screens out the HAPs from further assessment.	Overestimate where most conservative values used. Unbiased where category-specific profiles applied. There is the potential to underestimate risks for pollutants which are not included in the assessment.

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Appendix 3
Meteorological Data for HEM3 Modeling

DRAFT

METEOROLOGICAL DATA PROCESSING
USING AERMET
FOR
HEM3

BACKGROUND

The AERMOD meteorological processor, AERMET, and its supporting modeling system (AERSURFACE and AERMINUTE) were used to process one year of meteorological data for over 800 observation stations across the continental United States, Alaska, Hawaii, and Puerto Rico.

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.

USEPA meteorologists obtained calendar year 2011 Integrated Surface Hourly Data (ISHD) for over 800 Automated Surface Observation System (ASOS) stations spanning the entire US, as well as Puerto Rico and the US Virgin Islands, from the National Climatic Data Center (NCDC). To support AERMET, ASOS 1-minute data for each surface station were also obtained from NCDC in a DSI 6405 format.

Further, upper air sounding data for the same time period for over 80 observation sites were obtained from the “NOAA/ESRL” online Radiosonde Database. These datasets were produced by ESRL in Forecast Systems Laboratory (FSL) format. Appendix 1 lists the surface stations, as well as the location, ground elevation, and anemometer height for each station. Figure 1 is a map that shows the locations of all the surface stations. Appendix 2 lists the upper air stations and their locations.

AERMET PROCESSING

Utilizing the AERMET meteorological data preprocessor, 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 preprocessor was used to process 1-minute ASOS wind data for input into AERMET. Table 1 outlines the approach/inputs each of the data preprocessors and tools used to generate the AERMOD meteorological data.

Figure 1. Surface Stations

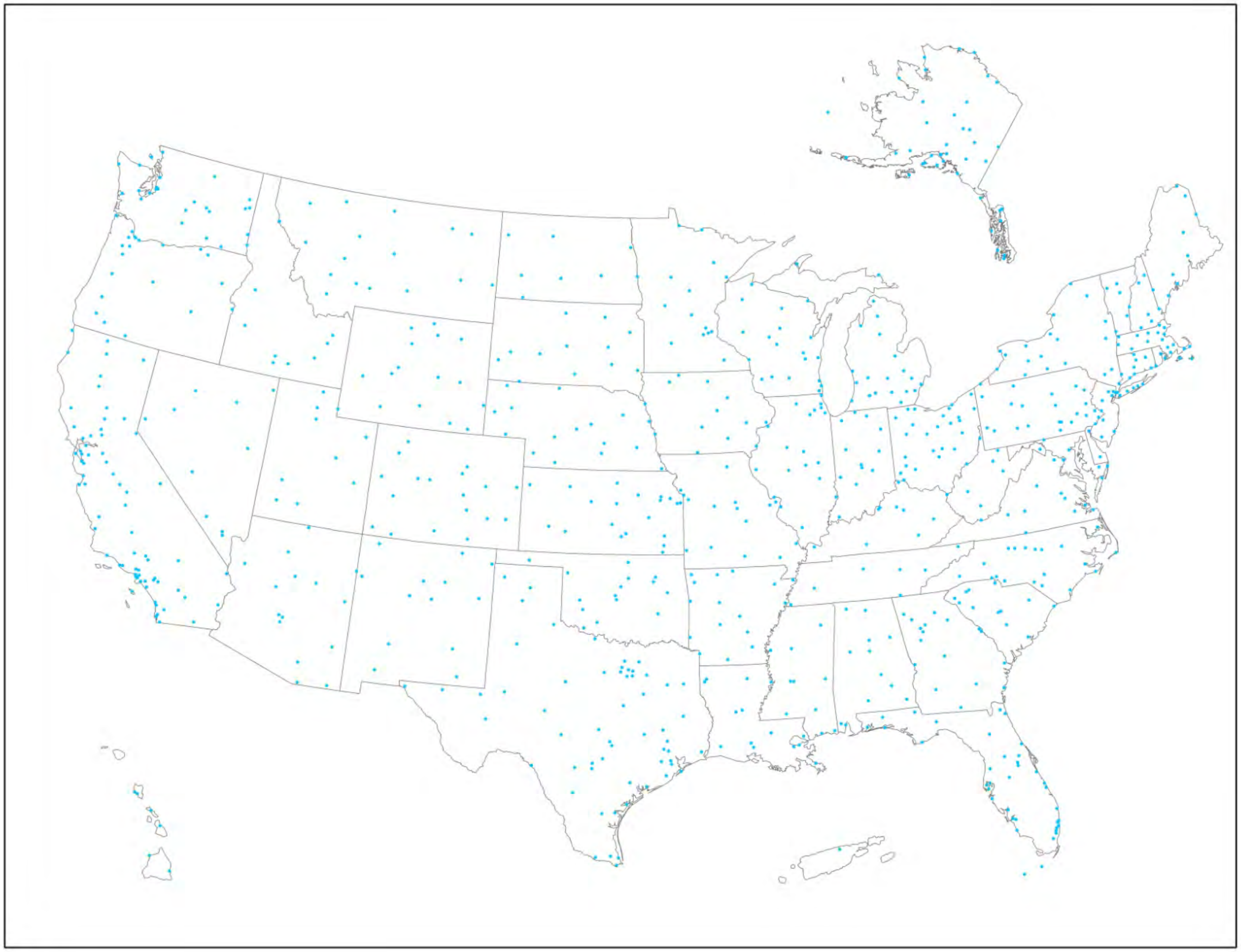

Table 1. AERMET Processing Options

AERMET Options	Version	12345
	ASOS Site	Yes
	Surface Data Format	NCDC TD-3505 (ISHD)
	Upper Air Data Format	FSL, all levels, tenths m/s
	Wind Speed Threshold	0.5 m/s
	Beta Option (U*)	Yes
AERMINUTE Options	Version	11325
	Include 1 minute ASOS Data	Yes, where available TD-6405 format
AERSURFACE Options	Version	13016
	Landcover data	USGS NLCD92 GeoTIFF format (except Alaska and Hawaii which used 2001 landcover data)
	Radius for Surface Roughness Calculations	1 km
	Site Characteristics	Airport Site (where applicable) Arid Regions for all sites in AZ, NM, UT only
	Temporal resolution	Monthly, 12 sectors
	Site Surface Moisture	Average
	Snow Cover	Late Winter/Winter without continuous snow cover – all states (except Alaska where we used continuous snow)

RESULTS

To assure that each surface and profile file would run properly, USEPA meteorologists ran AERMOD using a model plant. Further, the surface files were examined for completeness. If more than 10 percent of the data were missing, the station was not considered suitable for the HEM-3 meteorological database. In all, 824 met station pairs ran successfully and will be included in the HEM-3 meteorological library. A summary of these station pairs are presented in Appendix 3

Appendix 1
ASOS Surface Stations used for AERMET (2011)

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
AK	ANNETTE	25308	55.04333	-131.57000	33	10.05
AK	JUNEAU	25309	58.35500	-134.57500	7	10.05
AK	HAINES	25323	59.24500	-135.52000	7	10.05
AK	KETCHIKAN	25325	55.35667	-131.71167	26	10.05
AK	PALMER	25331	61.59611	-149.09167	70	10.05
AK	SITKA	25333	57.04833	-135.36000	5	10.05
AK	SKAGWAY	25335	59.46000	-135.31333	6	10.05
AK	YAKUTAT	25339	59.51028	-139.62778	12	10.05
AK	KALWOCK	25367	55.58000	-133.07500	20	10.05
AK	KODIAK	25501	57.75000	-152.49167	21	10.05
AK	KING SALMON	25503	58.68361	-156.65389	14	10.05
AK	ILIAMNA	25506	59.75333	-154.91500	52	10.05
AK	HOMER	25507	59.64667	-151.47667	17	10.05
AK	SELDOVIA	25516	59.44333	-151.70167	9	10.05
AK	COLD BAY	25624	55.20667	-162.72167	24	10.05
AK	ST PAUL ISLAND	25713	57.16333	-170.22000	11	10.05
AK	ANCHORAGE	26409	61.21694	-149.85500	42	10.05
AK	CORDOVA	26410	60.48889	-145.45111	13	10.05
AK	FAIRBANKS	26411	64.81667	-147.85500	132	10.05
AK	NORTHWAY	26412	62.96139	-141.94583	522	10.05
AK	DELTA JUNCTION/FT GREELY	26415	63.99500	-145.71833	391	10.05
AK	EAGLE	26422	64.77667	-141.14833	273	10.05
AK	GULKANA	26425	62.16028	-145.45750	479	10.05
AK	NENANA	26435	64.55000	-149.07167	109	10.05
AK	SEWARD	26438	60.12833	-149.41667	4	10.05
AK	ANCHORAGE	26451	61.17500	-149.99333	37	10.05
AK	ANCHORAGE	26491	61.17861	-149.96139	27	10.05
AK	PORTAGE GLACIER	26492	60.78500	-148.83889	31	10.05
AK	KALTAG	26502	64.32667	-158.74167	45	10.05
AK	MC GRATH	26510	62.95333	-155.60333	101	10.05
AK	KENAI	26523	60.57972	-151.23917	28	10.05
AK	TALKEETNA	26528	62.32167	-150.09167	107	10.05
AK	TANANA	26529	65.17444	-152.10694	67	10.05
AK	BETTLES	26533	66.91611	-151.50889	196	10.05
AK	KOTZEBUE	26616	66.88500	-162.59667	2	10.05
AK	NOME	26617	64.51333	-165.44333	6	10.05
AK	KIVALINA	26642	67.73167	-164.54833	4	10.05
AK	DEADHORSE	27406	70.19167	-148.47722	16	10.05
AK	BARROW	27502	71.28667	-156.76333	12	10.05
AK	WAINWRIGHT	27503	70.63917	-159.99500	8	10.05
AK	NUIQSUT	27515	70.21167	-151.00167	16	10.05
AL	HUNTSVILLE	03856	34.64361	-86.78556	190	10.05
AL	TROY	03878	31.86056	-86.01222	117	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
AL	MOBILE	13838	30.62639	-88.06806	5	10.05
AL	DOTHAN	13839	31.32139	-85.44972	113	10.05
AL	ANNISTON	13871	33.58806	-85.85806	182	10.05
AL	BIRMINGHAM	13876	33.56389	-86.75444	187	10.05
AL	MOBILE	13894	30.68833	-88.24556	66	10.05
AL	MONTGOMERY	13895	32.30056	-86.39417	38	10.05
AL	MUSCLE SHOALS	13896	34.74528	-87.61028	166	10.05
AL	EVERGREEN	53820	31.41556	-87.04417	77	10.05
AL	ALABASTER	53864	33.17833	-86.78167	172	10.05
AL	TUSCALOOSA	93806	33.21194	-87.61583	48	10.05
AR	JONESBORO	03953	35.83111	-90.64639	79	10.05
AR	HOT SPRINGS	03962	34.47806	-93.09611	155	10.05
AR	LITTLE ROCK	13963	34.74667	-92.23306	77	10.05
AR	FORT SMITH	13964	35.33361	-94.36500	136	10.05
AR	HARRISON	13971	36.26139	-93.15472	415	10.05
AR	TEXARKANA	13977	33.45361	-94.00750	116	10.05
AR	BLYTHEVILLE	53869	35.94028	-89.83083	77	10.05
AR	MOUNTAIN HOME	53918	36.36889	-92.47028	281	10.05
AR	MONTICELLO	53919	33.63833	-91.75083	85	10.05
AR	RUSSELLVILLE	53920	35.25778	-93.09472	117	10.05
AR	FAYETTEVILLE/SPRINGDALE	53922	36.28167	-94.30667	388	10.05
AR	De QUEEN	53925	34.04694	-94.39944	105	10.05
AR	WEST MEMPHIS	53959	35.13500	-90.23444	73	10.05
AR	PINE BLUFF	93988	34.17500	-91.93472	62	10.05
AR	EL DORADO	93992	33.22083	-92.81333	80	10.05
AR	FAYETTEVILLE	93993	36.00500	-94.17000	379	10.05
AZ	WINDOW ROCK	03029	35.65750	-109.06139	2052	7.92
AZ	FLAGSTAFF	03103	35.14028	-111.67222	2135	10.05
AZ	PAGE	03162	36.92611	-111.44778	1308	10.05
AZ	PHOENIX	03184	33.68833	-112.08167	453	10.05
AZ	SCOTTSDALE	03192	33.62278	-111.91056	449	10.05
AZ	GRAND CANYON	03195	35.94611	-112.15472	1991	10.05
AZ	NOGALES	03196	31.42083	-110.84583	1191	10.05
AZ	TUCSON	23160	32.13139	-110.95528	777	10.05
AZ	PHOENIX	23183	33.44306	-111.99028	337	10.05
AZ	PRESCOTT	23184	34.65167	-112.42083	1525	10.05
AZ	WINSLOW	23194	35.02194	-110.72194	1489	10.05
AZ	DOUGLAS BISBEE	93026	31.46917	-109.60361	1251	10.05
AZ	ST. JOHNS	93027	34.51833	-109.37917	1744	10.05
AZ	SAFFORD	93084	32.85472	-109.63528	966	10.05
AZ	KINGMAN	93167	35.25944	-113.93722	1042	10.05
CA	ONTARIO	03102	34.05611	-117.60028	281	10.05
CA	PALM SPRINGS	03104	33.62778	-116.16000	-37	10.05
CA	SAN DIEGO	03131	32.81583	-117.13944	128	10.05
CA	IMPERIAL	03144	32.83417	-115.57861	-18	10.05
CA	LANCASTER	03159	34.74083	-118.21889	713	10.05
CA	FULLERTON	03166	33.87194	-117.97889	26	10.05
CA	HAWTHORNE	03167	33.92278	-118.33417	18	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
CA	RIVERSIDE	03171	33.95194	-117.43861	229	10.05
CA	CARLSBAD	03177	33.12806	-117.27944	94	10.05
CA	SAN DIEGO	03178	32.57222	-116.97944	158	10.05
CA	CHINO	03179	33.97528	-117.63611	193	10.05
CA	LONG BEACH	23129	33.82833	-118.16306	9	10.05
CA	VAN NUYS	23130	34.20972	-118.48917	239	10.05
CA	CAMARILLO	23136	34.21667	-119.08333	84	10.05
CA	BURBANK	23152	34.20056	-118.35861	222	10.05
CA	BAKERSFIELD	23155	35.43361	-119.05583	149	10.05
CA	BISHOP	23157	37.37306	-118.36278	1250	10.05
CA	BLYTHE	23158	33.61917	-114.71694	120	10.05
CA	DAGGETT	23161	34.85361	-116.78667	584	10.05
CA	LOS ANGELES	23174	33.93806	-118.40556	34	10.05
CA	NEEDLES	23179	34.76611	-114.62333	271	10.05
CA	PALMDALE	23182	34.62944	-118.08361	764	10.05
CA	SANDBERG	23187	34.74361	-118.72444	1375	10.05
CA	SAN DIEGO	23188	32.73472	-117.16861	4	10.05
CA	SANTA BARBARA	23190	34.42611	-119.84361	3	10.05
CA	AVALON	23191	33.40500	-118.41583	487	10.05
CA	SANTA ROSA	23213	38.50917	-122.81167	36	10.05
CA	EMIGRANT GAP	23225	39.29167	-120.70833	1612	10.05
CA	OAKLAND	23230	37.75472	-122.22083	1	10.05
CA	SACRAMENTO	23232	38.51250	-121.49250	5	10.05
CA	SALINAS	23233	36.66333	-121.60528	23	10.05
CA	SAN FRANCISCO	23234	37.61972	-122.39806	2	10.05
CA	STOCKTON	23237	37.89417	-121.23722	8	10.05
CA	MOUNTAIN VIEW	23244	37.41472	-122.04750	10	10.05
CA	CONCORD	23254	37.99167	-122.05194	5	10.05
CA	MERCED	23257	37.28472	-120.51278	46	10.05
CA	MODESTO	23258	37.62583	-120.95333	22	10.05
CA	MONTEREY	23259	36.58806	-121.84528	50	10.05
CA	UKIAH	23275	39.12583	-123.20083	184	10.05
CA	WATSONVILLE	23277	36.93583	-121.78861	49	10.05
CA	LIVERMORE	23285	37.69389	-121.81722	120	10.05
CA	SAN JOSE	23293	37.36167	-121.92750	16	10.05
CA	MOUNT SHASTA	24215	41.33250	-122.33278	1077	10.05
CA	RED BLUFF	24216	40.15194	-122.25361	108	10.05
CA	REDDING	24257	40.51500	-122.31333	148	10.05
CA	MONTAGUE	24259	41.78139	-122.46806	803	10.05
CA	ARCATA/EUREKA	24283	40.97806	-124.10861	61	10.05
CA	CRESCENT CITY	24286	41.78028	-124.23667	17	10.05
CA	HANFORD	53119	36.31861	-119.62889	74	10.05
CA	RAMONA	53120	33.03333	-116.91667	423	10.05
CA	OCEANSIDE	53121	33.21944	-117.34944	7	10.05
CA	OXNARD	93110	34.20083	-119.20639	11	10.05
CA	LOS ANGELES	93134	34.02778	-118.29583	54	5.79
CA	PALM SPRINGS	93138	33.82806	-116.50528	124	10.05
CA	SANTA ANA	93184	33.68000	-117.86639	12	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
CA	FRESNO	93193	36.78000	-119.71944	101	10.05
CA	SANTA MONICA	93197	34.01583	-118.45139	43	10.05
CA	MARYSVILLE	93205	39.09778	-121.56972	19	10.05
CA	SAN LUIS OBISPO	93206	35.23722	-120.64139	61	10.05
CA	PASO ROBLES	93209	35.67278	-120.62694	247	10.05
CA	OROVILLE	93210	39.49000	-121.61833	55	10.05
CA	SACRAMENTO	93225	38.69556	-121.58972	7	10.05
CA	NAPA	93227	38.21333	-122.27972	4	10.05
CA	HAYWARD	93228	37.65944	-122.12139	10	10.05
CA	SOUTH LAKE TAHOE	93230	38.89389	-119.99528	1908	10.05
CA	VACAVILLE	93241	38.37694	-121.96139	33	10.05
CA	MADERA	93242	36.98778	-120.11056	75	10.05
CA	ALTURAS	94299	41.48333	-120.56667	1336	10.05
CO	LAMAR	03013	38.07000	-102.68806	1123	10.05
CO	DENVER	03017	39.83278	-104.65750	1657	10.05
CO	BURLINGTON	03026	39.24472	-102.28417	1278	10.05
CO	ALAMOSA	23061	37.43611	-105.86556	2296	10.05
CO	GRAND JUNCTION	23066	39.13417	-108.53750	1469	10.05
CO	LA JUNTA	23067	38.05139	-103.52694	1280	10.05
CO	TRINIDAD	23070	37.25917	-104.34056	1749	10.05
CO	CRAIG	24046	40.49528	-107.52111	1886	10.05
CO	DURANGO	93005	37.14306	-107.75972	2017	10.05
CO	LEADVILLE	93009	39.22806	-106.31611	3027	10.05
CO	LIMON	93010	39.18944	-103.71583	1631	10.05
CO	MONTROSE	93013	38.50500	-107.89750	1740	10.05
CO	COLORADO SPRINGS	93037	38.81194	-104.71111	1884	10.05
CO	PUEBLO	93058	38.29000	-104.49833	1424	10.05
CO	DENVER	93067	39.57028	-104.84889	1788	10.05
CO	CORTEZ	93069	37.30306	-108.62750	1796	10.05
CO	ASPEN	93073	39.22306	-106.86833	2341	10.05
CO	MEEKER	94050	40.04889	-107.88528	1939	10.05
CT	GROTON NEW LONDON	14707	41.32750	-72.04944	2	10.05
CT	WINDSOR LOCKS	14740	41.93806	-72.68250	52	10.05
CT	HARTFORD	14752	41.73611	-72.65056	4	10.05
CT	NEW HAVEN	14758	41.26389	-72.88722	2	10.05
CT	DANBURY	54734	41.37139	-73.48278	139	10.05
CT	WILLIMANTIC	54767	41.74194	-72.18361	74	10.05
CT	MERIDEN	54788	41.50972	-72.82778	32	10.05
CT	BRIDGEPORT	94702	41.17500	-73.14556	2	10.05
DC	WASHINGTON	13743	38.86500	-77.03417	3	10.05
DC	WASHINGTON	93738	38.93472	-77.44750	88	10.05
DE	GEORGETOWN	13764	38.68917	-75.35917	16	10.05
DE	WILMINGTON	13781	39.67278	-75.60083	23	10.05
FL	MARIANNA	03818	30.83556	-85.18389	33	10.05
FL	PUNTA GORDA	12812	26.91722	-81.99139	7	10.05
FL	ORLANDO	12815	28.43389	-81.32500	27	10.05
FL	GAINESVILLE	12816	29.68972	-82.27194	41	10.05
FL	BROOKSVILLE	12818	28.47361	-82.45444	20	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
FL	LEESBURG	12819	28.82083	-81.80972	23	10.05
FL	APALACHICOLA	12832	29.73333	-85.03333	6	10.05
FL	DAYTONA BEACH	12834	29.17722	-81.06000	9	10.05
FL	FORT MYERS	12835	26.58639	-81.86361	4	10.05
FL	KEY WEST	12836	24.55333	-81.75361	2	10.05
FL	MELBOURNE	12838	28.10278	-80.64583	8	10.05
FL	MIAMI	12839	25.82389	-80.29972	2	10.05
FL	ORLANDO	12841	28.54528	-81.33306	33	10.05
FL	TAMPA	12842	27.96139	-82.54028	2	10.05
FL	VERO BEACH	12843	27.65556	-80.41806	6	10.05
FL	WEST PALM BEACH	12844	26.68472	-80.09944	5	10.05
FL	FORT LAUDERDALE	12849	26.07194	-80.15361	3	10.05
FL	ORLANDO	12854	28.77972	-81.24361	16	10.05
FL	SARASOTA/BRADENTON	12871	27.40139	-82.55861	6	10.05
FL	ST PETERSBURG/ CLEARWATER	12873	27.91056	-82.68750	1	10.05
FL	WINTER HAVEN	12876	28.06222	-81.75417	44	10.05
FL	MIAMI	12882	25.90694	-80.28028	2	10.05
FL	FORT LAUDERDALE	12885	26.19694	-80.17083	3	10.05
FL	MIAMI	12888	25.64750	-80.43306	2	10.05
FL	FORT MYERS	12894	26.53611	-81.75500	8	10.05
FL	FORT PIERCE	12895	27.49806	-80.37667	7	10.05
FL	MARATHON	12896	24.72583	-81.05167	2	10.05
FL	NAPLES	12897	26.15250	-81.77500	2	10.05
FL	CRESTVIEW	13884	30.77972	-86.52250	49	10.05
FL	JACKSONVILLE	13889	30.49444	-81.69333	8	10.05
FL	PENSACOLA	13899	30.47306	-87.18750	34	10.05
FL	DESTIN	53853	30.40000	-86.47167	6	7.92
FL	JACKSONVILLE	53860	30.33611	-81.51472	14	10.05
FL	POMPANO BEACH	92805	26.25000	-80.10833	5	10.05
FL	ST PETERSBURG	92806	27.76472	-82.62750	2	10.05
FL	HOLLYWOOD	92809	25.99889	-80.24111	3	10.05
FL	TALLAHASSEE	93805	30.39306	-84.35333	17	10.05
GA	MACON	03813	32.68778	-83.65444	104	10.05
GA	AUGUSTA	03820	33.36972	-81.96472	40	10.05
GA	SAVANNAH	03822	32.11889	-81.20222	8	10.05
GA	ATLANTA	03888	33.77917	-84.52139	244	10.05
GA	AUGUSTA	13837	33.46694	-82.03861	126	10.05
GA	ALBANY	13869	31.53556	-84.19444	58	10.05
GA	ALMA	13870	31.53611	-82.50667	59	10.05
GA	ATHENS	13873	33.94833	-83.32667	244	10.05
GA	ATLANTA	13874	33.64028	-84.42694	304	10.05
GA	BRUNSWICK	13878	31.25167	-81.39139	6	10.05
GA	ATLANTA	53819	33.35528	-84.56694	243	10.05
GA	GAINESVILLE	53838	34.27194	-83.83028	386	10.05
GA	ATLANTA	53863	33.87500	-84.30222	298	10.05
GA	CARTERSVILLE	53873	34.12306	-84.84861	230	10.05
GA	ROME	93801	34.34778	-85.16111	211	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
GA	COLUMBUS	93842	32.51611	-84.94222	119	10.05
GA	VALDOSTA	93845	30.78250	-83.27667	60	10.05
HI	HILO	21504	19.72333	-155.05139	9	10.05
HI	KAILUA/KONA	21510	19.73556	-156.04889	12	10.05
HI	KAHULUI	22516	20.90194	-156.43306	16	10.05
HI	HONOLULU	22521	21.32750	-157.94306	2	10.05
HI	KAUNAKAKAI	22534	21.15722	-157.09861	134	10.05
HI	KAPOLEI	22551	21.31667	-158.06667	7	10.05
IA	BURLINGTON	14931	40.78333	-91.12528	207	10.05
IA	DES MOINES	14933	41.53778	-93.66611	277	10.05
IA	IOWA CITY	14937	41.63278	-91.54306	198	10.05
IA	MASON CITY	14940	43.15778	-93.33139	362	10.05
IA	SIOUX CITY	14943	42.39139	-96.37917	332	10.05
IA	OTTUMWA	14950	41.10667	-92.44806	255	10.05
IA	SPENCER	14972	43.16444	-95.20167	408	10.05
IA	WATERLOO	94910	42.55444	-92.40111	264	10.05
IA	ESTHERVILLE	94971	43.40750	-94.74611	401	10.05
IA	DAVENPORT	94982	41.61389	-90.59139	226	10.05
IA	MARSHALLTOWN	94988	42.11278	-92.91750	296	10.05
IA	LAMONI	94991	40.63306	-93.90194	84	10.05
ID	JEROME	04110	42.72667	-114.45639	1224	10.05
ID	CHALLIS	04114	41.52278	-114.21500	1536	10.05
ID	BOISE	24131	43.56500	-116.22000	858	10.05
ID	BURLEY	24133	42.54250	-113.77167	1261	10.05
ID	IDAHO FALLS	24145	43.51639	-112.06722	1442	10.05
ID	LEWISTON	24149	46.37472	-117.01444	434	10.05
ID	MULLAN PASS	24154	47.45694	-115.64500	1833	7.92
ID	POCATELLO	24156	42.92028	-112.57111	1353	10.05
ID	TWIN FALLS	94178	42.48194	-114.48694	1267	10.05
ID	McCALL	94182	44.88889	-116.10167	1526	10.05
ID	REXBURG	94194	43.83389	-111.88111	1481	10.05
IL	DECATUR	03887	39.98444	-88.86556	205	10.05
IL	CAHOKIA/ST.LOUIS	03960	38.57139	-90.15722	124	10.05
IL	CHICAGO/AURORA	04808	41.77000	-88.48139	214	10.05
IL	CHICAGO/PROSPECT HEIGHTS/WHEELING	04838	42.12083	-87.90472	194	10.05
IL	LAWRENCEVILLE	13809	38.76417	-87.60556	131	10.05
IL	CHICAGO	14819	41.78611	-87.75222	187	10.05
IL	PEORIA	14842	40.66750	-89.68389	199	10.05
IL	CHICAGO/WAUKEGAN	14880	42.42194	-87.86778	217	10.05
IL	MOLINE	14923	41.46528	-90.52333	180	10.05
IL	MATTOON/CHARLESTON	53802	39.47806	-88.28028	216	10.05
IL	BLOOMINGTON/NORMAL	54831	40.47778	-88.91583	259	10.05
IL	CARBONDALE/MURPHYBORO	93810	37.77972	-89.24972	124	10.05
IL	SPRINGFIELD	93822	39.84528	-89.68389	180	10.05
IL	QUINCY	93989	39.94250	-91.19444	231	10.05
IL	ROCKFORD	94822	42.19611	-89.09250	223	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
IL	CHICAGO	94846	41.98611	-87.91417	202	10.05
IL	CHAMPAIGN/URBANA	94870	40.03972	-88.27778	226	10.05
IL	CHICAGO/WEST CHICAGO	94892	41.91444	-88.24639	228	10.05
IN	TERRE HAUTE	03868	39.45194	-87.30889	174	10.05
IN	BLOOMINGTON	03893	39.14444	-86.61667	257	10.05
IN	VALPARAISO	04846	41.45250	-87.00583	235	10.05
IN	FORT WAYNE	14827	41.00611	-85.20556	252	7.92
IN	GOSHEN	14829	41.52722	-85.79222	251	10.05
IN	LAFAYETTE	14835	40.41222	-86.93694	182	10.05
IN	SOUTH BEND	14848	41.70722	-86.33306	237	10.05
IN	INDIANAPOLIS	53842	39.82500	-86.29583	249	10.05
IN	SHELBYVILLE	53866	39.57806	-85.80333	245	10.05
IN	EVANSVILLE	93817	38.04306	-87.53694	122	10.05
IN	INDIANAPOLIS	93819	39.71000	-86.27222	241	10.05
IN	MUNCIE	94895	40.23417	-85.39361	285	10.05
KS	SALINA	03919	38.81333	-97.66083	387	10.05
KS	WICHITA	03928	37.64722	-97.42944	402	10.05
KS	MANHATTAN	03936	39.13528	-96.67778	321	10.05
KS	OLATHE	03967	38.85000	-94.73917	329	10.05
KS	WICHITA	03974	37.74972	-97.21889	430	10.05
KS	LAWRENCE	03997	39.00833	-95.21167	252	10.05
KS	PARSONS	03998	37.32778	-95.50417	265	10.05
KS	TOPEKA	13920	38.95028	-95.66389	315	10.05
KS	CHANUTE	13981	37.67028	-95.48417	300	10.05
KS	CONCORDIA	13984	39.54917	-97.65194	448	10.05
KS	DODGE CITY	13985	37.77278	-99.96972	785	10.05
KS	HUTCHINSON	13986	38.06806	-97.86056	464	7.92
KS	EMPORIA	13989	38.33056	-96.18972	367	10.05
KS	TOPEKA	13996	39.07250	-95.62583	269	7.92
KS	GARDEN CITY	23064	37.92722	-100.72472	877	10.05
KS	GOODLAND	23065	39.36750	-101.69306	1112	10.05
KS	OLATHE	93909	38.83167	-94.88972	325	10.05
KS	COFFEYVILLE	93967	37.09111	-95.56639	228	7.92
KS	HILL CITY	93990	39.37556	-99.82972	669	10.05
KS	RUSSELL	93997	38.87222	-98.82806	568	10.05
KY	PADUCAH	03816	37.05639	-88.77389	123	10.05
KY	LONDON	03849	37.08722	-84.07694	360	10.05
KY	JACKSON	03889	37.59139	-83.31444	405	10.05
KY	LOUISVILLE	13810	38.22806	-85.66361	158	10.05
KY	FRANKFORT	53841	38.18472	-84.90333	236	10.05
KY	BOWLING GREEN	93808	36.98111	-86.43639	160	10.05
KY	LEXINGTON	93820	38.04083	-84.60583	294	10.05
KY	LOUISVILLE	93821	38.17722	-85.72972	146	10.05
LA	LAKE CHARLES	03937	30.12472	-93.22833	3	10.05
LA	BOOTHVILLE	12884	29.34972	-89.40750	0	10.05
LA	NEW ORLEANS	12916	29.99278	-90.25083	0	10.05
LA	ALEXANDRIA	13935	31.39472	-92.29556	28	10.05
LA	MONROE	13942	32.51083	-92.03750	23	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
LA	SHREVEPORT	13957	32.44694	-93.82417	70	10.05
LA	BATON ROUGE	13970	30.53722	-91.14694	20	10.05
LA	LAFAYETTE	13976	30.20500	-91.98750	12	7.92
LA	SLIDELL	53865	30.34500	-89.82083	8	10.05
LA	SHREVEPORT	53905	32.53972	-93.74444	53	10.05
LA	NEW IBERIA	53915	30.05278	-91.88750	5	10.05
LA	NEW ORLEANS	53917	30.04250	-90.02806	2	7.92
LA	ALEXANDRIA	93915	31.33472	-92.55861	24	10.05
MA	FITCHBURG	04780	42.55194	-71.75583	102	10.05
MA	BEDFORD	14702	42.47000	-71.28944	41	10.05
MA	BOSTON	14739	42.36056	-71.01056	6	10.05
MA	NANTUCKET	14756	41.25306	-70.06083	12	10.05
MA	PITTSFIELD	14763	42.42722	-73.28917	349	10.05
MA	WESTFIELD/SPRINGFIELD	14775	42.15778	-72.71611	81	10.05
MA	NORWOOD	54704	42.19083	-71.17361	14	10.05
MA	BEVERLY	54733	42.58417	-70.91750	26	10.05
MA	ORANGE	54756	42.57000	-72.29111	168	10.05
MA	NORTH ADAMS	54768	42.69622	-73.17021	198	1.21
MA	PLYMOUTH	54769	41.90972	-70.72944	44	10.05
MA	TAUNTON	54777	41.87556	-71.02111	8	10.05
MA	CHATHAM	94624	41.68750	-69.99333	19	10.05
MA	HYANNIS	94720	41.66861	-70.28000	12	10.05
MA	LAWRENCE	94723	42.71722	-71.12389	41	10.05
MA	VINEYARD HAVEN	94724	41.39306	-70.61500	18	10.05
MA	NEW BEDFORD	94726	41.67639	-70.95833	21	7.92
MA	WORCESTER	94746	42.26722	-71.87611	306	10.05
MD	HAGERSTOWN	93706	39.70778	-77.72972	211	10.05
MD	SALISBURY	93720	38.34056	-75.51028	15	10.05
MD	BALTIMORE	93721	39.17222	-76.68389	44	10.05
MD	OCEAN CITY	93786	38.30833	-75.12389	2	10.05
ME	FRENCHVILLE	04836	47.28556	-68.30722	299	10.05
ME	AUGUSTA	14605	44.32056	-69.79722	107	10.05
ME	BANGOR	14606	44.80750	-68.82417	45	10.05
ME	CARIBOU	14607	46.86694	-68.03278	189	10.05
ME	HOULTON	14609	46.12306	-67.79194	145	10.05
ME	MILLINOCKET	14610	45.64778	-68.68611	123	10.05
ME	PORTLAND	14764	43.64222	-70.30444	15	10.05
ME	FRYEBURG	54772	43.99056	-70.94750	137	10.05
ME	WISCASSET	94623	43.96361	-69.71167	16	10.05
MI	HOLLAND	04839	42.74611	-86.09667	207	10.05
MI	ADRIAN	04847	41.86778	-84.07944	243	7.92
MI	GAYLORD	04854	45.01333	-84.70139	406	10.05
MI	BATTLE CREEK	14815	42.30750	-85.25111	283	10.05
MI	DETROIT	14822	42.40917	-83.01000	190	10.05
MI	FLINT	14826	42.96667	-83.74944	235	10.05
MI	JACKSON	14833	42.25972	-84.45944	302	10.05
MI	LANSING	14836	42.78028	-84.57889	262	10.05
MI	MUSKEGON	14840	43.17111	-86.23667	191	10.05

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MI	PELLSTON	14841	45.57083	-84.79611	215	10.05
MI	SAGINAW	14845	43.53306	-84.07972	201	10.05
MI	SAULT STE MARIE	14847	46.46667	-84.36667	220	10.05
MI	TRAVERSE CITY	14850	44.74083	-85.58250	186	10.05
MI	DETROIT	14853	42.23667	-85.52611	216	10.05
MI	HANCOCK	14858	47.16861	-88.50556	323	7.92
MI	HOUGHTON LAKE	94814	44.36778	-84.69083	351	10.05
MI	KALAMAZOO	94815	42.23472	-85.55194	262	10.05
MI	PONTIAC	94817	42.66500	-83.41806	296	10.05
MI	DETROIT	94847	42.21528	-83.34861	192	10.05
MI	GRAND RAPTIDS	94860	42.88222	-85.52306	241	10.05
MI	BENTON HARBOR	94871	42.12917	-86.42222	191	10.05
MI	ANN ARBOR	94889	42.22300	-83.74400	253	10.05
MI	IRON MOUNTAIN/KINGSFORD	94893	45.81833	-88.11444	343	10.05
MN	ALEXANDRIA	14910	45.88306	-95.39306	433	10.05
MN	DULUTH	14913	46.84389	-92.19417	433	10.05
MN	INTERNATIONAL FALLS	14918	48.56639	-93.40306	361	10.05
MN	MINNEAPOLIS	14922	44.88306	-93.22889	248	10.05
MN	ROCHESTER	14925	43.90417	-92.49167	397	10.05
MN	ST CLOUD	14926	45.54472	-94.05194	310	10.05
MN	ST PAUL	14927	44.93028	-93.04806	214	10.05
MN	REDWOOD FALLS	14992	44.54722	-95.08222	312	10.05
MN	HIBBING	94931	47.38667	-92.83889	408	10.05
MN	BRAINERD	94938	46.40472	-94.13083	372	10.05
MN	MINNEAPOLIS	94960	45.06250	-93.35083	264	10.05
MN	BAUDETTE	94961	48.72750	-94.61028	330	7.92
MN	MINNEAPOLIS	94963	44.83222	-93.47028	276	10.05
MN	PARK RAPIDS	94967	46.90056	-95.06778	438	10.05
MO	CAPE GIRARDEAU	03935	37.22528	-89.57056	102	10.05
MO	COLUMBIA	03945	38.81694	-92.21833	272	10.05
MO	KANSAS CITY	03947	39.29917	-94.71778	297	10.05
MO	JEFFERSON CITY	03963	38.59111	-92.15583	168	10.05
MO	ST LOUIS	03966	38.65722	-90.65583	140	10.05
MO	POPLAR BLUFF	03975	36.77250	-90.32472	100	10.05
MO	SEDALIA	03994	38.70417	-93.18333	273	10.05
MO	JOPLIN	13987	37.14944	-94.49833	296	10.05
MO	KANSAS CITY	13988	39.12333	-94.59250	226	7.92
MO	ST LOUIS	13994	38.75250	-90.37361	199	10.05
MO	SPRINGFIELD	13995	37.23972	-93.38972	385	10.05
MO	ROLLA/VICHY	13997	38.12750	-91.76944	336	10.05
MO	KIRKSVILLE	14938	40.09722	-92.54333	293	10.05
MO	LEE'S SUMMIT	53879	38.95972	-94.37139	304	10.05
MO	WEST PLAINS	53901	36.87806	-91.90250	375	10.05
MO	ST CHARLES	53904	38.92861	-90.42806	134	10.05
MS	JACKSON	03940	32.31972	-90.07750	91	10.05
MS	TALLULAH/VICKSBURG	03996	32.34806	-91.03000	31	10.05
MS	HATTIESBURG	13833	31.26500	-89.25306	45	10.05

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MS	MERIDIAN	13865	32.33306	-88.75111	88	10.05
MS	JACKSON	13927	32.33472	-90.22250	103	10.05
MS	GREENVILLE	13939	33.48278	-90.98556	38	10.05
MS	GREENWOOD	13978	33.49556	-90.08417	45	10.05
MS	PASCAGOULA	53858	30.46361	-88.53194	4	10.05
MS	TUPELO	93862	34.26083	-88.77111	104	10.05
MS	GULFPORT	93874	30.40722	-89.07000	7	10.05
MS	MCCOMB	93919	31.17833	-90.47194	126	10.05
MT	BILLINGS	24033	45.80806	-108.54306	1091	10.05
MT	LEWISTOWN	24036	47.04917	-109.46667	1254	10.05
MT	MILES	24037	46.42806	-105.88611	800	10.05
MT	BOZEMAN	24132	45.79361	-111.15222	1349	10.05
MT	BUTTE	24135	45.95333	-112.51250	1678	10.05
MT	CUT BANK	24137	48.60833	-112.37611	1170	10.05
MT	DILLON	24138	45.25500	-112.55167	1585	10.05
MT	GREAT FALLS	24143	47.47333	-111.38222	1117	10.05
MT	HELENA	24144	46.60556	-111.96361	1167	10.05
MT	KALISPELL	24146	48.30417	-114.26361	901	10.05
MT	LIVINGSTON	24150	45.69944	-110.44833	1415	10.05
MT	MISSOULA	24153	46.92083	-114.09250	973	10.05
MT	GLASGOW	94008	48.21389	-106.62139	696	10.05
MT	HAVRE	94012	48.55944	-109.78000	788	10.05
MT	WOLF POINT	94017	48.09444	-105.57444	604	10.05
MT	BAKER	94055	46.35833	-104.25000	903	10.05
NC	HICKORY	03810	35.74111	-81.38972	357	7.92
NC	ASHEVILLE	03812	35.43194	-82.53750	645	10.05
NC	RALEIGH/DURHAM	13722	35.87056	-78.78639	121	10.05
NC	GREENSBORO	13723	36.09750	-79.94361	277	10.05
NC	WILMINGTON	13748	34.26833	-77.90611	7	7.92
NC	LUMBERTON	13776	34.61000	-79.05944	37	10.05
NC	ELIZABETH CITY	13786	36.26056	-76.17500	2	7.92
NC	CHARLOTTE	13881	35.21444	-80.94361	213	10.05
NC	GASTONIA	53870	35.19667	-81.15583	241	10.05
NC	MONROE	53872	35.01694	-80.62056	204	10.05
NC	NEW BERN	93719	35.06750	-77.04722	3	10.05
NC	CAPE HATTERAS	93729	35.23222	-75.62250	3	7.92
NC	FAYETTEVILLE	93740	34.99139	-78.88028	55	7.92
NC	ROCKY MOUNT	93759	35.85500	-77.89306	46	10.05
NC	BEAUFORT	93765	34.73361	-76.66056	2	10.05
NC	MAXTON	93782	34.79167	-79.36611	65	10.05
NC	BURLINGTON	93783	36.04667	-79.47694	183	7.92
NC	CHAPEL HILL	93785	35.93333	-79.06417	153	10.05
NC	WINSTON SALEM	93807	36.13361	-80.22222	290	10.05
ND	FARGO	14914	46.92528	-96.81111	273	10.05
ND	GRAND FORKS	14916	47.94917	-97.17583	256	10.05
ND	JAMESTOWN	14919	46.92972	-98.67833	455	10.05
ND	BISMARCK	24011	46.77417	-100.74750	503	10.05
ND	DICKINSON	24012	46.79722	-102.80194	786	10.05

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ND	MINOT	24013	48.25944	-101.28111	505	10.05
ND	WILLISTON	94014	48.19472	-103.64194	580	10.05
ND	HETTINGER	94038	46.01389	-102.65472	822	7.92
NE	GRAND ISLAND	14935	40.95833	-98.31250	564	7.92
NE	LINCOLN	14939	40.83111	-96.76444	357	10.05
NE	NORFOLK	14941	41.98056	-97.43694	476	10.05
NE	OMAHA	14942	41.31028	-95.89917	299	10.05
NE	CHADRON	24017	42.83750	-103.09528	1001	10.05
NE	NORTH PLATTE	24023	41.12194	-100.66833	842	7.92
NE	SCOTTSBLUFF	24028	41.87417	-103.59528	1203	7.92
NE	SIDNEY	24030	41.10139	-102.98472	1306	10.05
NE	VALENTINE	24032	42.85861	-100.55139	789	7.92
NE	ALLIANCE	24044	42.05722	-102.80000	1196	10.05
NE	IMPERIAL	24091	40.51000	-101.62000	996	10.05
NE	MC COOK	94040	40.20639	-100.59139	780	10.05
NE	BROKEN BOW	94946	41.43667	-99.63889	770	10.05
NE	HASTINGS	94949	40.60444	-98.42722	590	10.05
NE	FALLS CITY	94957	40.07889	-95.59194	299	10.05
NE	ORD	94958	41.62361	-98.95167	628	10.05
NE	TEKAMAH	94978	41.76361	-96.17778	312	10.05
NH	MANCHESTER	14710	42.93333	-71.43833	69	10.05
NH	CONCORD	14745	43.19528	-71.50111	104	10.05
NH	WHITEFIELD	54728	44.36750	-71.54500	318	7.92
NH	JAFFREY	54770	42.80500	-72.00361	309	7.92
NH	ROCHESTER	54791	43.27806	-70.92222	101	10.05
NH	BERLIN	94700	44.57611	-71.17861	343	10.05
NH	LEBANON	94765	43.62639	-72.30472	84	10.05
NJ	MILLVILLE	13735	39.36611	-75.07833	18	7.92
NJ	NEWARK	14734	40.71583	-74.16944	2	10.05
NJ	TRENTON	14792	40.27667	-74.81389	58	7.92
NJ	CALDWELL	54743	40.87639	-74.28306	53	10.05
NJ	SOMERVILLE	54785	40.62389	-74.66944	84	10.05
NJ	ATLANTIC CITY	93730	39.45750	-74.45667	20	7.92
NJ	MOUNT HOLLY	93780	39.94056	-74.84111	15	10.05
NJ	TETERBORO	94741	40.85000	-74.06139	2	7.92
NM	CLINES CORNERS	03027	35.00278	-105.66278	2160	10.05
NM	ROSWELL	23009	33.30806	-104.54111	1105	7.92
NM	TUCUMCARI	23048	35.18222	-103.60306	1230	10.05
NM	SANTA FE	23049	35.61694	-106.08889	1915	7.92
NM	ALBUQUERQUE	23050	35.04194	-106.61556	1618	10.05
NM	CLAYTON	23051	36.44583	-103.15417	1512	10.05
NM	RATON	23052	36.74139	-104.50167	1935	10.05
NM	LAS VEGAS	23054	35.65417	-105.14250	2093	10.05
NM	DEMING	23078	32.26222	-107.72056	1312	10.05
NM	GALLUP	23081	35.51111	-108.78944	1970	10.05
NM	FARMINGTON	23090	36.74361	-108.22917	1675	10.05
NM	CARLSBAD	93033	32.33750	-104.26333	992	10.05
NM	TRUTH OR CONSEQUENCES	93045	33.23667	-107.26806	1469	7.92

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
NV	MERCURY	03160	36.62056	-116.02778	985	10.05
NV	TONOPAH	23153	38.06028	-117.08722	1644	10.05
NV	ELY	23154	39.29500	-114.84528	1904	10.05
NV	LAS VEGAS	23169	36.07889	-115.15528	648	10.05
NV	RENO	23185	39.48389	-119.77111	1344	7.92
NV	ELKO	24121	40.82500	-115.79167	1539	7.92
NV	WINNEMUCCA	24128	40.90194	-117.80722	1309	10.05
NV	LOVELOCK	24172	40.06639	-118.56528	1189	10.05
NV	LAS VAGAS	53123	36.21167	-115.19583	666	10.05
NY	NIAGARA FALLS	04724	43.10722	-78.94528	178	10.05
NY	BINGHAMTON	04725	42.20778	-75.98139	486	10.05
NY	ISLIP	04781	40.79389	-73.10167	26	10.05
NY	MONTGOMERY	04789	41.50917	-74.26500	108	10.05
NY	WESTHAMPTON BEACH	14719	40.84361	-72.63222	13	10.05
NY	NEW YORK	14732	40.77889	-73.88083	3	10.05
NY	BUFFALO	14733	42.94083	-78.73583	216	10.05
NY	ALBANY	14735	42.74806	-73.80333	85	10.05
NY	DUNKIRK	14747	42.49333	-79.27222	203	7.92
NY	ELMIRA/CORNING	14748	42.15944	-76.89194	285	7.92
NY	GLEN FALLS	14750	43.34111	-73.61028	98	7.92
NY	POUGHKEEPSIE	14757	41.62667	-73.88417	48	7.92
NY	ROCHESTER	14768	43.11667	-77.67667	164	10.05
NY	SYRACUSE	14771	43.10917	-76.10333	125	10.05
NY	WELLSVILLE	54757	42.10944	-77.99194	636	10.05
NY	FULTON	54773	43.34972	-76.38472	143	7.92
NY	PENN YAN	54778	42.64250	-77.05639	268	10.05
NY	FARMINGDALE	54787	40.73417	-73.41694	23	10.05
NY	SHIRLEY	54790	40.82167	-72.86889	18	10.05
NY	DANSVILLE	94704	42.57083	-77.71306	197	10.05
NY	MASSENA	94725	44.93583	-74.84556	62	7.92
NY	NEW YORK	94728	40.78333	-73.96667	48	10.05
NY	SARANAC LAKE	94740	44.38528	-74.20667	505	10.05
NY	WHITE PLAINS	94745	41.06694	-73.70750	116	10.05
NY	NEW YORK	94789	40.65528	-73.79556	3	10.05
NY	WATERTOWN	94790	43.99222	-76.02167	94	7.92
OH	WOOSTER	04842	40.87472	-81.88694	338	10.05
OH	TOLEDO	04848	41.56306	-83.47639	189	10.05
OH	LORAIN/ELYRIA	04849	41.17944	-82.17944	241	7.92
OH	LIMA	04850	40.70833	-84.02667	297	7.92
OH	DEFIANCE	04851	41.33750	-84.42889	214	10.05
OH	NEW PHILADELPHIA	04852	40.47000	-81.42000	271	10.05
OH	CLEVELAND	04853	41.51750	-81.68361	177	10.05
OH	MARION	04855	40.61611	-83.06361	300	10.05
OH	ASHTABULA	04857	41.77806	-80.69583	280	7.92
OH	NEWARK	04858	40.02278	-82.46250	268	7.92
OH	WILMINGTON	13841	39.42028	-83.82167	322	10.05
OH	AKRON	14813	41.03750	-81.46417	318	10.05
OH	CLEVELAND	14820	41.40500	-81.85278	237	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
OH	COLUMBUS	14821	39.99139	-82.88083	247	10.05
OH	FINDLAY	14825	41.01361	-83.66861	247	10.05
OH	YOUNGSTOWN/WARREN	14852	41.25444	-80.67389	357	10.05
OH	MANSFIELD	14891	40.82028	-82.51778	394	10.05
OH	AKRON	14895	40.91806	-81.44250	368	10.05
OH	LANCASTER	53844	39.75556	-82.65722	258	10.05
OH	HAMILTON	53855	39.36444	-84.52472	185	10.05
OH	DAYTON	53859	39.59361	-84.22639	290	7.92
OH	CINCINNATI	93812	39.10333	-84.41889	145	10.05
OH	COVINGTON/CINCINNATI	93814	39.04306	-84.67167	262	10.05
OH	DAYTON	93815	39.90611	-84.21861	303	10.05
OH	ZANESVILLE	93824	39.94444	-81.89222	269	10.05
OH	TOLEDO	94830	41.58861	-83.80139	205	10.05
OK	GUYMON	03030	36.68167	-101.50528	949	7.92
OK	CLINTON	03932	35.33972	-99.20028	586	10.05
OK	LAWTON	03950	34.56778	-98.41639	328	10.05
OK	OKLAHOMA CITY	03954	35.53417	-97.64694	390	7.92
OK	STILLWATER	03965	36.16028	-97.08583	294	10.05
OK	FREDERICK	03981	34.35222	-98.98417	380	10.05
OK	OKLAHOMA CITY	13967	35.38861	-97.60028	388	10.05
OK	TULSA	13968	36.19750	-95.88639	195	10.05
OK	PONCA CITY	13969	36.73056	-97.09972	307	10.05
OK	GAGE	13975	36.29667	-99.77472	668	10.05
OK	TULSA	53908	36.03944	-95.98444	190	10.05
OK	GUTHRIE	53913	35.85028	-97.41556	328	10.05
OK	MC ALESTER	93950	34.89889	-95.78333	233	10.05
OK	MUSKOGEE	93953	35.65667	-95.36139	185	7.92
OK	HOBART	93986	35.00806	-99.05111	475	7.92
OR	HERMISTON	04113	45.82583	-119.26111	193	10.05
OR	SCAPPOOSE	04201	45.77278	-122.86111	13	10.05
OR	BAKER CITY	24130	44.83806	-117.80972	1024	10.05
OR	PENDLETON	24155	45.69833	-118.83417	451	10.05
OR	ONTARIO	24162	44.02056	-117.01278	666	10.05
OR	THE DALLES	24219	45.61861	-121.16722	72	10.05
OR	EUGENE	24221	44.13333	-123.21444	108	7.92
OR	MEDFORD	24225	42.38917	-122.87139	398	10.05
OR	PORTLAND	24229	45.59083	-122.60028	6	10.05
OR	REDMOND	24230	44.25417	-121.15000	928	10.05
OR	ROSEBURG	24231	43.23889	-123.35472	151	10.05
OR	SALEM	24232	44.90778	-122.99500	62	7.92
OR	SEXTON SUMMIT	24235	42.61694	-123.38083	1168	10.05
OR	PORTLAND	24242	45.54944	-122.40000	7	10.05
OR	BURNS	94185	43.59222	-118.95389	1262	10.05
OR	ASTORIA	94224	46.15806	-123.87750	3	10.05
OR	KLAMATH FALLS	94236	42.14694	-121.72417	1244	7.92
OR	PORTLAND	94261	45.54056	-122.94861	59	7.92
OR	MC MINNVILLE	94273	45.19472	-123.13389	47	7.92
OR	AURORA	94281	45.24861	-122.76861	59	7.92

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
PA	JOHNSTOWN	04726	40.30139	-78.83389	694	7.92
PA	BRADFORD	04751	41.80306	-78.64028	643	7.92
PA	DU BOIS	04787	41.17833	-78.89889	551	10.05
PA	MEADVILLE	04843	41.62639	-80.21500	429	10.05
PA	PHILADELPHIA	13739	39.86833	-75.23111	2	10.05
PA	HARRISBURG	14711	40.19361	-76.76333	91	7.92
PA	READING	14712	40.37333	-75.95944	101	7.92
PA	ALTOONA	14736	40.30000	-78.31694	447	10.05
PA	ALLENTOWN	14737	40.65083	-75.44917	117	7.92
PA	HARRISBURG	14751	40.21722	-76.85139	102	7.92
PA	PITTSBURGH	14762	40.35472	-79.92167	378	7.92
PA	SELINSGROVE	14770	40.82056	-76.86417	137	10.05
PA	WILKES-BARRE/SCRANTON	14777	41.33889	-75.72667	290	10.05
PA	WILLIAMSPORT	14778	41.24333	-76.92167	160	7.92
PA	ERIE	14860	42.08000	-80.18250	222	7.92
PA	LANCASTER	54737	40.12028	-76.29444	122	7.92
PA	POTTSTOWN	54782	40.23833	-75.55722	89	7.92
PA	DOYLESTOWN	54786	40.33000	-75.12250	116	10.05
PA	MOUNT POCONO	54789	41.13889	-75.37944	577	10.05
PA	CLEARFIELD	54792	41.04667	-78.41167	461	10.05
PA	YORK	93778	39.91806	-76.87417	144	10.05
PA	PHILADELPHIA	94732	40.08194	-75.01111	31	7.92
PA	PITTSBURGH	94823	40.50139	-80.23111	341	10.05
PR	SAN JUAN	11641	18.43000	-66.00000	2	5.79
RI	PROVIDENCE	14765	41.72194	-71.43250	16	10.05
RI	NEWPORT	14787	41.53000	-71.28361	44	7.92
RI	WESTERLY	14794	41.34972	-71.79889	20	10.05
SC	GREER	03870	34.89944	-82.21917	285	7.92
SC	FLORENCE	13744	34.18778	-79.73083	43	7.92
SC	CHARLESTON	13880	32.89861	-80.04083	12	10.05
SC	COLUMBIA	13883	33.94194	-81.11806	69	7.92
SC	GREENVILLE	13886	34.84611	-82.34611	307	10.05
SC	CLEMSON	53850	34.67194	-82.88639	271	7.92
SC	ORANGEBURG	53854	33.46167	-80.85806	60	7.92
SC	COLUMBIA	53867	33.97056	-80.99583	55	7.92
SC	ROCK HILL	53871	34.98694	-81.05750	196	7.92
SC	GREENWOOD	53874	34.24861	-82.15917	192	10.05
SC	NORTH MYRTLE BEACH	93718	33.81556	-78.72056	8	7.92
SC	ANDERSON	93846	34.49500	-82.70917	234	10.05
SD	ABERDEEN	14929	45.44972	-98.42139	395	10.05
SD	HURON	14936	44.38528	-98.22889	391	10.05
SD	SIOUX FALLS	14944	43.57694	-96.75361	433	10.05
SD	WATERTOWN	14946	44.93083	-97.15444	532	7.92
SD	PHILIP	24024	44.05111	-101.60111	673	7.92
SD	PIERRE	24025	44.38278	-100.28583	524	7.92
SD	RAPID CITY	24090	44.04556	-103.05389	963	10.05
SD	CUSTER	94032	43.73056	-103.62806	1699	7.92
SD	PINE RIDGE	94039	43.02056	-102.51833	1003	7.92

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
SD	MOBRIDGE	94052	45.54639	-100.40778	515	7.92
SD	MITCHELL	94950	43.77694	-98.03750	375	7.92
SD	WINNER	94990	43.39056	-99.84222	617	10.05
TN	JACKSON	03811	35.59306	-88.91667	131	7.92
TN	CROSSVILLE	03847	35.95139	-85.08500	566	7.92
TN	BRISTOL/JOHNSON CITY/KINGSPORT	13877	36.47972	-82.39889	457	10.05
TN	CHATTANOOGA	13882	35.03333	-85.20000	205	7.92
TN	KNOXVILLE	13891	35.81806	-83.98583	293	7.92
TN	MEMPHIS	13893	35.06111	-89.98500	93	7.92
TN	NASHVILLE	13897	36.11889	-86.68917	183	10.05
TX	BORGER	03024	35.70000	-101.39361	927	10.05
TX	LONGVIEW	03901	32.38472	-94.71139	106	10.05
TX	COLLEGE STATION	03904	30.58833	-96.36361	93	7.92
TX	DALLAS-FT WORTH	03927	32.89639	-97.04111	167	7.92
TX	DALLAS	03971	32.68083	-96.86806	198	7.92
TX	DENTON	03991	33.20611	-97.19889	198	10.05
TX	BURNET	03999	30.74056	-98.23528	389	10.05
TX	HARLINGEN	12904	26.22806	-97.65417	10	7.92
TX	VICTORIA	12912	28.86250	-96.92972	34	7.92
TX	BEAUMONT/PORT ARTHUR	12917	29.95056	-94.02056	4	7.92
TX	HOUSTON	12918	29.64528	-95.27861	13	10.05
TX	BROWNSVILLE	12919	25.90639	-97.42556	6	10.05
TX	SAN ANTONIO	12921	29.53278	-98.46361	236	10.05
TX	GALVESTON	12923	29.26500	-94.86028	2	7.92
TX	CORPUS CHRISTI	12924	27.77306	-97.51278	12	10.05
TX	ALICE	12932	27.74083	-98.02722	52	7.92
TX	PALACIOS	12935	28.72750	-96.25083	5	7.92
TX	COTULLA	12947	28.45806	-99.22000	140	10.05
TX	PORT ISABEL	12957	26.16583	-97.34583	4	7.92
TX	MC ALLEN	12959	26.17528	-98.23833	30	7.92
TX	HOUSTON	12960	29.99250	-95.36389	29	7.92
TX	HONDO	12962	29.35944	-99.17417	280	10.05
TX	SAN ANTONIO	12970	29.33667	-98.47083	174	7.92
TX	NEW BRAUNFELS	12971	29.70861	-98.04528	197	7.92
TX	ROCKPORT	12972	28.08361	-97.04639	8	7.92
TX	HOUSTON	12975	29.52111	-95.24028	12	7.92
TX	ANGLETON/LAKE JACKSON	12976	29.10972	-95.46194	7	7.92
TX	HOUSTON	12977	29.62222	-95.65639	23	10.05
TX	AUSTIN/BERGSTROM	13904	30.17944	-97.68056	148	7.92
TX	AUSTIN/CITY	13958	30.31667	-97.76667	200	10.05
TX	WACO	13959	31.61139	-97.22861	152	7.92
TX	DALLAS	13960	32.84694	-96.85139	145	7.92
TX	FORT WORTH	13961	32.81917	-97.36139	187	7.92
TX	ABILENE	13962	32.41111	-99.68167	544	7.92
TX	WICHITA FALLS	13966	33.97861	-98.49278	308	7.92
TX	TYLER	13972	32.35417	-95.40222	161	7.92
TX	JUNCTION	13973	30.51083	-99.76639	522	7.92

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TX	DEL RIO	22010	29.36694	-100.92167	307	7.92
TX	CHILDRESS	23007	34.43361	-100.28778	593	10.05
TX	MIDLAND	23023	31.93222	-102.20806	872	7.92
TX	SAN ANGELO	23034	31.35139	-100.49389	582	7.92
TX	WINK	23040	31.77972	-103.20139	858	7.92
TX	LUBBOCK	23042	33.66750	-101.82139	989	10.05
TX	EL PASO	23044	31.81111	-106.37583	1200	7.92
TX	AMARILLO	23047	35.21944	-101.70556	1095	7.92
TX	GUADALUPE PASS	23055	31.83111	-104.80889	1661	5.79
TX	FORT STOCKTON	23091	30.91500	-102.91194	917	10.05
TX	CONROE	53902	30.35167	-95.41417	72	7.92
TX	HUNTSVILLE	53903	30.74667	-95.58694	104	7.92
TX	ARLINGTON	53907	32.66361	-97.09389	187	7.92
TX	FORT WORTH	53909	32.97333	-97.31806	201	7.92
TX	HOUSTON	53910	30.06167	-95.55250	47	7.92
TX	TERRELL	53911	32.71000	-96.26722	143	7.92
TX	CORSICANA	53912	32.02722	-96.39778	135	7.92
TX	MC KINNEY	53914	33.18028	-96.59028	169	10.05
TX	DALHART	93042	36.02333	-102.54722	1216	7.92
TX	MINERAL WELLS	93985	32.78222	-98.06111	287	10.05
TX	LUFKIN	93987	31.23389	-94.75000	86	7.92
UT	BRYCE CANYON	23159	37.70639	-112.14556	2312	10.05
UT	MILFORD	23176	38.44333	-113.02833	1532	7.92
UT	OGDEN	24126	41.19611	-112.01139	1355	10.05
UT	SALT LAKE CITY	24127	40.78694	-111.96806	1286	10.05
UT	MOAB	93075	38.75500	-109.75417	1390	7.92
UT	CEDAR CITY	93129	37.70167	-113.09722	1703	7.92
UT	PRICE	93141	39.54528	-110.74972	1777	7.92
UT	VERNAL	94030	40.44111	-109.50917	1603	10.05
UT	LOGAN	94128	41.78722	-111.85333	1355	10.05
VA	DANVILLE	13728	36.57278	-79.33611	169	10.05
VA	LYNCHBURG	13733	37.33750	-79.20667	273	10.05
VA	NORFOLK	13737	36.90361	-76.19194	4	7.92
VA	RICHMOND	13740	37.51111	-77.32333	50	10.05
VA	ROANOKE	13741	37.31694	-79.97417	346	10.05
VA	CHARLOTTESVILLE	93736	38.13861	-78.45306	187	7.92
VA	WALLOPS ISLAND	93739	37.94056	-75.49639	11	7.92
VA	NEWPORT NEWS	93741	37.13194	-76.49306	12	7.92
VA	WAKEFIELD	93773	36.98389	-77.00722	32	7.92
VA	RICHMOND/ASHLAND	93775	37.70806	-77.43444	62	10.05
VT	BURLINGTON	14742	44.46806	-73.15028	101	7.92
VT	SPRINGFIELD	54740	43.34361	-72.51778	175	7.92
VT	MORRISVILLE	54771	44.53444	-72.61444	225	7.92
VT	BENNINGTON	54781	42.89139	-73.24694	244	10.05
VT	BARRE/MONTPELIER	94705	44.20333	-72.57944	336	7.92
WA	MOSES LAKE	24110	47.20778	-119.31917	355	7.92
WA	EPHRATA	24141	47.30444	-119.51361	381	7.92
WA	SPOKANE	24157	47.62139	-117.52778	717	10.05

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
WA	WALLA WALLA	24160	46.09472	-118.28694	356	7.92
WA	PASCO	24163	46.26472	-119.11806	122	7.92
WA	BELLINGHAM	24217	48.79389	-122.53722	47	7.92
WA	ELLENSBURG	24220	47.03389	-120.53028	531	7.92
WA	EVERETT	24222	47.90778	-122.28028	166	7.92
WA	OLYMPIA	24227	46.97333	-122.90333	57	7.92
WA	SEATTLE	24233	47.46139	-122.31361	113	7.62
WA	SEATTLE	24234	47.53028	-122.30083	5	7.92
WA	YAKIMA	24243	46.56417	-120.53361	320	7.92
WA	DEER PARK	94119	47.96861	-117.42139	670	10.05
WA	PULLMAN/MOSCOW	94129	46.74389	-117.10861	769	1.21
WA	SPOKANE	94176	47.68306	-117.32139	591	10.05
WA	OMAK	94197	48.46444	-119.51694	394	7.92
WA	HOQUIAM	94225	46.97111	-123.93667	4	7.92
WA	SHELTON	94227	47.23806	-123.14750	83	7.92
WA	WENATCHEE	94239	47.39889	-120.20667	375	7.92
WA	QUILLAYUTE	94240	47.93417	-124.56083	56	10.05
WA	RENTON	94248	47.49333	-122.21444	6	7.92
WA	PORT ANGELES	94266	48.12028	-123.49833	79	7.92
WA	TACOMA	94274	47.26750	-122.57611	88	7.92
WA	FRIDAY HARBOR	94276	48.52222	-123.02306	33	7.92
WA	VANCOUVER	94298	45.62083	-122.65722	8	7.92
WI	RHINELANDER	04803	45.63083	-89.46528	493	7.92
WI	WISCONSIN RAPTIDS	04826	44.35917	-89.83694	309	7.92
WI	FOND DU LAC	04840	43.77000	-88.48639	240	7.92
WI	SHEBOYGAN	04841	43.76944	-87.85139	226	7.92
WI	KENOSHA	04845	42.59500	-87.93806	223	7.92
WI	MADISON	14837	43.14056	-89.34528	262	7.92
WI	MILWAUKEE	14839	42.94667	-87.89694	206	7.92
WI	WAUSAU	14897	44.92861	-89.62667	366	7.92
WI	GREEN BAY	14898	44.51278	-88.12000	210	7.92
WI	LA CROSSE	14920	43.87600	-91.25890	199	7.92
WI	LONE ROCK	14921	43.21194	-90.18139	218	7.92
WI	EAU CLAIRE	14991	44.86528	-91.48500	270	7.92
WI	RACINE	94818	42.76111	-87.81361	203	5.79
WI	OSHKOSH	94855	43.98444	-88.55694	246	10.05
WI	ASHLAND	94929	46.54861	-90.91889	251	7.92
WI	HAYWARD	94973	46.02611	-91.44417	367	10.05
WI	MARSHFIELD	94985	44.63694	-90.18917	383	7.92
WI	B0SCOBEL	94994	43.15611	-90.67750	205	10.05
WV	CLARKSBURG	03802	39.29556	-80.22889	360	7.92
WV	PARKERSBURG	03804	39.34500	-81.43917	247	10.05
WV	BLUEFIELD	03859	37.29583	-81.20778	873	7.92
WV	HUNTINGTON	03860	38.38167	-82.55500	251	7.92
WV	BECKLEY	03872	37.79500	-81.12472	757	7.92
WV	ELKINS	13729	38.88528	-79.85278	603	7.92
WV	MARTINSBURG	13734	39.40194	-77.98444	164	7.92
WV	MORGANTOWN	13736	39.64278	-79.91639	372	7.92

State	City	WBAN #	Latitude	Longitude	Base Elevation (M)	Anemometer Ht (M)
WV	CHARLESTON	13866	38.37944	-81.59139	277	7.92
WV	WHEELING	14894	40.17639	-80.64722	366	7.92
WY	EVANSTON	04111	41.27306	-111.03056	2176	7.92
WY	CHEYENNE	24018	41.15778	-104.80694	1864	7.92
WY	LANDER	24021	42.81667	-108.73333	1704	10.05
WY	LARAMIE	24022	41.31250	-105.67444	2217	10.05
WY	ROCK SPRINGS	24027	41.59417	-109.06528	2055	4.87
WY	SHERIDAN	24029	44.77389	-106.97639	1209	7.92
WY	GREYBULL	24048	44.51694	-108.08222	1191	7.92
WY	RAWLINS	24057	41.80639	-107.20000	2065	7.92
WY	RIVERTON	24061	43.06417	-108.45889	1660	7.92
WY	WORLAND	24062	43.96583	-107.95083	1269	7.92
WY	CASPER	24089	42.89750	-106.47306	1621	7.92
WY	BIG PINEY	24164	42.58444	-110.10750	2116	7.92
WY	GILLETTE	94023	44.33944	-105.54194	1327	7.92
WY	TORRINGTON	94053	42.06472	-104.15278	1279	10.05
WY	BUFFALO	94054	44.38139	-106.72111	1502	10.05
WY	DOUGLAS	94057	42.79722	-105.38556	1500	7.92

Appendix 2
Upper Air Stations used for AERMET (2011)

State	City	WBAN #	Latitude	Longitude
AK	ANNETTE ISLAND	25308	55.03000	-131.57000
AK	YAKUTAT	25339	59.52000	-139.67000
AK	ANCHORAGE IAP/PT. CAMPBE	26409	61.17000	-150.02000
AK	KODIAK	25501	57.75000	-152.48000
AK	KING SALMON	25503	58.68000	-156.65000
AK	COLD BAY	25624	55.20000	-162.72000
AK	ST PAUL ISLAND	25713	57.15000	-170.22000
AK	FAIRBANKS	26411	64.82000	-147.87000
AK	MCGRATH	26510	62.97000	-155.62000
AK	KOTZEBUE	26616	66.87000	-162.63000
AK	NOME AP	26617	64.50000	-165.43000
AK	POINT BARROW	27502	71.30000	-156.78000
AL	BIRMINGHAM (SHELBY APT)	53823	34.60000	-86.62000
LA	SLIDELL	53813	30.33000	-89.82000
FL	TALLAHASEE	93805	30.52000	-86.58000
AR	N LITTLE ROCK	03952	34.83000	-92.27000
MO	SPRINGFIELD REGIONAL AP	13995	37.23000	-93.40000
LA	SHREVEPORT REGIONAL AP	13957	32.45000	-93.83000
NM	ALBUQUERQUE	23050	35.05000	-106.62000
AZ	FLAGSTAFF/BELLEMT (ARMY)	53103	35.23000	-111.82000
AZ	TUCSON	23160	32.23000	-110.96000
NV	LAS VEGAS	03120	36.05000	-115.18000
CA	MIRAMAR NAS	03190	32.87000	-117.15000
CA	VANDENBERG	93214	34.75000	-120.57000
NV	RENO	03198	39.57000	-119.80000
CA	OAKLAND INT AP	23230	37.75000	-122.22000
OR	MEDFORD	24225	42.37000	-122.87000
KS	DODGE CITY	13985	37.77000	-99.97000
CO	DENVER/STAPLETON ARPT	23062	39.77000	-104.88000
CO	GRAND JUNCTION	23066	39.12000	-108.53000
NY	BROOKHAVEN	94703	40.87000	-72.87000
VA	STERLING(WASH DULLES)	93734	38.98000	-77.47000
VA	WALLOPS ISLAND	93739	37.93000	-75.48000
FL	TAMPA BAY/RUSKIN	12842	27.70000	-82.40000
FL	JACKSONVILLE	13889	30.43000	-81.70000
FL	KEY WEST INT AP	12836	24.55000	-81.75000
FL	MIAMI/FL INTL UNIV	92803	25.75000	-80.38000
GA	PEACHTREE CITY	53819	33.35000	-84.56000
SC	CHARLESTON	13880	32.90000	-80.03000
HI	HILO	21504	19.72000	-155.07000
HI	LIHUE/KAUAI	22536	21.98000	-159.35000
IA	DAVENPORT MUNICIPAL AP	94982	41.60000	-90.57000
NE	OMAHA/VALLEY	94980	41.32000	-96.37000
MN	MINNEAPOLIS	94983	44.83000	-93.55000
ID	BOISE	24131	43.57000	-116.22000

State	City	WBAN #	Latitude	Longitude
NV	ELKO	04105	40.87000	-115.73000
WY	RIVERTON	24061	43.06000	-108.47000
WA	SPOKANE INTNL APT	04106	47.68000	-117.63000
UT	SALT LAKE CITY	24127	40.77000	-111.97000
IL	LINCOLN-LOGAN COUNTY AP	04833	40.15000	-89.33000
WI	GREEN BAY	14898	44.48000	-88.13000
OH	WILMINGTON	13841	39.42000	-83.82000
MI	DETROIT/PONTIAC	04830	42.70000	-83.47000
TN	NASHVILLE	13897	34.60000	-86.62000
KS	TOPEKA	13996	39.07000	-95.62000
NE	NORTH PLATTE	24023	41.13000	-100.68000
LA	LAKE CHARLES	03937	30.12000	-93.22000
NY	ALBANY	54775	42.69000	-73.83000
MA	CHATHAM	14684	41.67000	-69.97000
ME	GRAY	54762	43.89000	-70.25000
ME	CARIBOU	14607	46.87000	-68.02000
MI	GAYLORD / ALPENA	04837	44.55000	-84.43000
MN	INTERNATIONAL FALLS	14918	48.57000	-93.38000
MS	JACKSON/THOMPSON FLD	03940	32.32000	-90.07000
MT	GREAT FALLS	04102	47.45000	-111.38000
MT	GLASGOW	94008	48.20000	-106.62000
SD	RAPID CITY	94043	44.07000	-103.21000
NC	GREENSBORO	13723	36.08000	-79.95000
NC	MOREHEAD CITY/NEWPORT	93768	34.70000	-76.80000
SD	ABERDEEN	14929	45.45000	-98.42000
ND	BISMARCK	24011	46.77000	-100.75000
NM	SANTA TERESA	03020	31.90000	-106.70000
TX	AMARILLO	23047	35.23000	-101.70000
TX	MIDLAND	23023	31.93000	-102.20000
NY	BUFFALO/GRTR ARPT	14733	42.93000	-78.73000
PA	PITTSBURGH/MOON TOWNSHIP	94823	40.53000	-80.23000
OK	NORMAN	03948	35.23000	-97.47000
OR	SALEM	24232	44.92000	-123.02000
PR	SAN JUAN	11641	18.43000	-66.00000
VA	ROANOKE/BLACKSBURG	53829	37.20000	-80.41000
TX	FT WORTH	03990	32.80000	-97.30000
TX	BROWNSVILLE	12919	25.90000	-97.43000
TX	CORPUS CHRISTI	12924	27.77000	-97.50000
TX	DEL RIO	22010	29.37000	-100.92000
WA	QUILLAYUTE	94240	47.95000	-124.55000

Appendix 3
Station Pairs used for AERMET (2011)

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
AK	ANNETTE	25308	AK	ANNETTE ISLAND	25308
AK	JUNEAU	25309	AK	YAKUTAT	25339
AK	HAINES	25323	AK	YAKUTAT	25339
AK	KETCHIKAN	25325	AK	ANNETTE ISLAND	25308
AK	PALMER	25331	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	SITKA	25333	AK	ANNETTE ISLAND	25308
AK	SKAGWAY	25335	AK	YAKUTAT	25339
AK	YAKUTAT	25339	AK	YAKUTAT	25339
AK	KALWOCK	25367	AK	ANNETTE ISLAND	25308
AK	KODIAK	25501	AK	KODIAK	25501
AK	KING SALMON	25503	AK	KING SALMON	25503
AK	ILIAMNA	25506	AK	KING SALMON	25503
AK	HOMER	25507	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	SELDOVIA	25516	AK	KODIAK	25501
AK	COLD BAY	25624	AK	COLD BAY	25624
AK	ST PAUL ISLAND	25713	AK	ST PAUL ISLAND	25713
AK	ANCHORAGE	26409	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	CORDOVA	26410	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	FAIRBANKS	26411	AK	FAIRBANKS	26411
AK	NORTHWAY	26412	AK	FAIRBANKS	26411
AK	DELTA JUNCTION/FT GREELY	26415	AK	FAIRBANKS	26411
AK	EAGLE	26422	AK	FAIRBANKS	26411
AK	GULKANA	26425	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	NENANA	26435	AK	FAIRBANKS	26411
AK	SEWARD	26438	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	ANCHORAGE	26451	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	ANCHORAGE	26491	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	PORTAGE GLACIER	26492	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	KALTAG	26502	AK	MCGRATH	26510
AK	MC GRATH	26510	AK	MCGRATH	26510
AK	KENAI	26523	AK	ANCHORAGE IAP/PT. CAMPBE	26409
AK	TALKEETNA	26528	AK	ANCHORAGE IAP/PT. CAMPBE	26409

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
AK	TANANA	26529	AK	FAIRBANKS	26411
AK	BETTLES	26533	AK	FAIRBANKS	26411
AK	KOTZEBUE	26616	AK	KOTZEBUE	26616
AK	NOME	26617	AK	NOME AP	26617
AK	KIVALINA	26642	AK	KOTZEBUE	26616
AK	DEADHORSE	27406	AK	POINT BARROW	27502
AK	BARROW	27502	AK	POINT BARROW	27502
AK	WAINWRIGHT	27503	AK	POINT BARROW	27502
AK	NUIQSUT	27515	AK	POINT BARROW	27502
AL	HUNTSVILLE	03856	AL	BIRMINGHAM (SHELBY APT)	53823
AL	TROY	03878	AL	BIRMINGHAM (SHELBY APT)	53823
AL	MOBILE	13838	LA	SLIDELL	53813
AL	DOTHAN	13839	FL	TALLAHASEE	93805
AL	ANNISTON	13871	AL	BIRMINGHAM (SHELBY APT)	53823
AL	BIRMINGHAM	13876	AL	BIRMINGHAM (SHELBY APT)	53823
AL	MOBILE	13894	LA	SLIDELL	53813
AL	MONTGOMERY	13895	AL	BIRMINGHAM (SHELBY APT)	53823
AL	MUSCLE SHOALS	13896	AL	BIRMINGHAM (SHELBY APT)	53823
AL	EVERGREEN	53820	AL	BIRMINGHAM (SHELBY APT)	53823
AL	ALABASTER	53864	AL	BIRMINGHAM (SHELBY APT)	53823
AL	TUSCALOOSA	93806	AL	BIRMINGHAM (SHELBY APT)	53823
AR	JONESBORO	03953	AR	N LITTLE ROCK	03952
AR	HOT SPRINGS	03962	AR	N LITTLE ROCK	03952
AR	LITTLE ROCK	13963	AR	N LITTLE ROCK	03952
AR	FORT SMITH	13964	AR	N LITTLE ROCK	03952
AR	HARRISON	13971	MO	SPRINGFIELD REGIONAL AP	13995
AR	TEXARKANA	13977	LA	SHREVEPORT REGIONAL AP	13957
AR	BLYTHEVILLE	53869	AR	N LITTLE ROCK	03952
AR	MOUNTAIN HOME	53918	MO	SPRINGFIELD REGIONAL AP	13995
AR	MONTICELLO	53919	AR	N LITTLE ROCK	03952
AR	RUSSELLVILLE	53920	AR	N LITTLE ROCK	03952
AR	FAYETTEVILLE/SPRIN DALE	53922	MO	SPRINGFIELD REGIONAL AP	13995
AR	De QUEEN	53925	LA	SHREVEPORT REGIONAL AP	13957
AR	WEST MEMPHIS	53959	AR	N LITTLE ROCK	03952
AR	PINE BLUFF	93988	AR	N LITTLE ROCK	03952

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
AR	EL DORADO	93992	LA	SHREVEPORT REGIONAL AP	13957
AR	FAYETTEVILLE	93993	MO	SPRINGFIELD REGIONAL AP	13995
AZ	WINDOW ROCK	03029	NM	ALBUQUERQUE	23050
AZ	FLAGSTAFF	03103	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	PAGE	03162	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	PHOENIX	03184	AZ	TUCSON	23160
AZ	SCOTTSDALE	03192	AZ	TUCSON	23160
AZ	GRAND CANYON	03195	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	NOGALES	03196	AZ	TUCSON	23160
AZ	TUCSON	23160	AZ	TUCSON	23160
AZ	PHOENIX	23183	AZ	TUCSON	23160
AZ	PRESCOTT	23184	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	WINSLOW	23194	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	DOUGLAS BISBEE	93026	AZ	TUCSON	23160
AZ	ST. JOHNS	93027	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
AZ	SAFFORD	93084	AZ	TUCSON	23160
AZ	KINGMAN	93167	NV	LAS VEGAS	03120
CA	ONTARIO	03102	CA	MIRAMAR NAS	03190
CA	PALM SPRINGS	03104	CA	MIRAMAR NAS	03190
CA	SAN DIEGO	03131	CA	MIRAMAR NAS	03190
CA	IMPERIAL	03144	CA	MIRAMAR NAS	03190
CA	LANCASTER	03159	CA	VANDENBERG	93214
CA	FULLERTON	03166	CA	MIRAMAR NAS	03190
CA	HAWTHORNE	03167	CA	MIRAMAR NAS	03190
CA	RIVERSIDE	03171	CA	MIRAMAR NAS	03190
CA	CARLSBAD	03177	CA	MIRAMAR NAS	03190
CA	SAN DIEGO	03178	CA	MIRAMAR NAS	03190
CA	CHINO	03179	CA	MIRAMAR NAS	03190
CA	LONG BEACH	23129	CA	MIRAMAR NAS	03190
CA	VAN NUYS	23130	CA	MIRAMAR NAS	03190
CA	CAMARILLO	23136	CA	VANDENBERG	93214
CA	BURBANK	23152	CA	MIRAMAR NAS	03190
CA	BAKERSFIELD	23155	CA	VANDENBERG	93214
CA	BISHOP	23157	NV	RENO	03198
CA	BLYTHE	23158	CA	MIRAMAR NAS	03190
CA	DAGGETT	23161	NV	LAS VEGAS	03120
CA	LOS ANGELES	23174	CA	MIRAMAR NAS	03190
CA	NEEDLES	23179	NV	LAS VEGAS	03120
CA	PALMDALE	23182	CA	MIRAMAR NAS	03190
CA	SANDBERG	23187	CA	VANDENBERG	93214
CA	SAN DIEGO	23188	CA	MIRAMAR NAS	03190

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
CA	SANTA BARBARA	23190	CA	VANDENBERG	93214
CA	AVALON	23191	CA	MIRAMAR NAS	03190
CA	SANTA ROSA	23213	CA	OAKLAND INT AP	23230
CA	EMIGRANT GAP	23225	NV	RENO	03198
CA	OAKLAND	23230	CA	OAKLAND INT AP	23230
CA	SACRAMENTO	23232	CA	OAKLAND INT AP	23230
CA	SALINAS	23233	CA	OAKLAND INT AP	23230
CA	SAN FRANCISCO	23234	CA	OAKLAND INT AP	23230
CA	STOCKTON	23237	CA	OAKLAND INT AP	23230
CA	MOUNTAIN VIEW	23244	CA	OAKLAND INT AP	23230
CA	CONCORD	23254	CA	OAKLAND INT AP	23230
CA	MERCED	23257	CA	OAKLAND INT AP	23230
CA	MODESTO	23258	CA	OAKLAND INT AP	23230
CA	MONTEREY	23259	CA	OAKLAND INT AP	23230
CA	UKIAH	23275	CA	OAKLAND INT AP	23230
CA	WATSONVILLE	23277	CA	OAKLAND INT AP	23230
CA	LIVERMORE	23285	CA	OAKLAND INT AP	23230
CA	SAN JOSE	23293	CA	OAKLAND INT AP	23230
CA	MOUNT SHASTA	24215	OR	MEDFORD	24225
CA	RED BLUFF	24216	NV	RENO	03198
CA	REDDING	24257	OR	MEDFORD	24225
CA	MONTAGUE	24259	OR	MEDFORD	24225
CA	ARCATA/EUREKA	24283	OR	MEDFORD	24225
CA	CRESCENT CITY	24286	OR	MEDFORD	24225
CA	HANFORD	53119	CA	VANDENBERG	93214
CA	RAMONA	53120	CA	MIRAMAR NAS	03190
CA	OCEANSIDE	53121	CA	MIRAMAR NAS	03190
CA	OXNARD	93110	CA	VANDENBERG	93214
CA	LOS ANGELES	93134	CA	MIRAMAR NAS	03190
CA	PALM SPRINGS	93138	CA	MIRAMAR NAS	03190
CA	SANTA ANA	93184	CA	MIRAMAR NAS	03190
CA	FRESNO	93193	CA	VANDENBERG	93214
CA	SANTA MONICA	93197	CA	MIRAMAR NAS	03190
CA	MARYSVILLE	93205	CA	OAKLAND INT AP	23230
CA	SAN LUIS OBISPO	93206	CA	VANDENBERG	93214
CA	PASO ROBLES	93209	CA	VANDENBERG	93214
CA	OROVILLE	93210	NV	RENO	03198
CA	SACRAMENTO	93225	CA	OAKLAND INT AP	23230
CA	NAPA	93227	CA	OAKLAND INT AP	23230
CA	HAYWARD	93228	CA	OAKLAND INT AP	23230
CA	SOUTH LAKE TAHOE	93230	NV	RENO	03198
CA	VACAVILLE	93241	CA	OAKLAND INT AP	23230
CA	MADERA	93242	CA	OAKLAND INT AP	23230
CA	ALTURAS	94299	OR	MEDFORD	24225
CO	LAMAR	03013	KS	DODGE CITY	13985
CO	DENVER	03017	CO	DENVER/STAPLETON ARPT	23062

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
CO	BURLINGTON	03026	CO	DENVER/STAPLETON ARPT	23062
CO	ALAMOSA	23061	CO	DENVER/STAPLETON ARPT	23062
CO	GRAND JUNCTION	23066	CO	GRAND JUNCTION	23066
CO	LA JUNTA	23067	CO	DENVER/STAPLETON ARPT	23062
CO	TRINIDAD	23070	CO	DENVER/STAPLETON ARPT	23062
CO	CRAIG	24046	CO	GRAND JUNCTION	23066
CO	DURANGO	93005	CO	GRAND JUNCTION	23066
CO	LEADVILLE	93009	CO	DENVER/STAPLETON ARPT	23062
CO	LIMON	93010	CO	DENVER/STAPLETON ARPT	23062
CO	MONTROSE	93013	CO	GRAND JUNCTION	23066
CO	COLORADO SPRINGS	93037	CO	DENVER/STAPLETON ARPT	23062
CO	PUEBLO	93058	CO	DENVER/STAPLETON ARPT	23062
CO	DENVER	93067	CO	DENVER/STAPLETON ARPT	23062
CO	CORTEZ	93069	CO	GRAND JUNCTION	23066
CO	ASPEN	93073	CO	GRAND JUNCTION	23066
CO	MEEKER	94050	CO	GRAND JUNCTION	23066
CT	GROTON NEW LONDON	14707	NY	BROOKHAVEN	94703
CT	WINDSOR LOCKS	14740	NY	BROOKHAVEN	94703
CT	HARTFORD	14752	NY	BROOKHAVEN	94703
CT	NEW HAVEN	14758	NY	BROOKHAVEN	94703
CT	DANBURY	54734	NY	BROOKHAVEN	94703
CT	WILLIMANTIC	54767	NY	BROOKHAVEN	94703
CT	MERIDEN	54788	NY	BROOKHAVEN	94703
CT	BRIDGEPORT	94702	NY	BROOKHAVEN	94703
DC	WASHINGTON	13743	VA	STERLING(WASH DULLES)	93734
DC	WASHINGTON	93738	VA	STERLING(WASH DULLES)	93734
DE	GEORGETOWN	13764	VA	WALLOPS ISLAND	93739
DE	WILMINGTON	13781	VA	STERLING(WASH DULLES)	93734
FL	MARIANNA	03818	FL	TALLAHASEE	93805
FL	PUNTA GORDA	12812	FL	TAMPA BAY/RUSKIN	12842
FL	ORLANDO	12815	FL	TAMPA BAY/RUSKIN	12842
FL	GAINESVILLE	12816	FL	JACKSONVILLE	13889
FL	BROOKSVILLE	12818	FL	TAMPA BAY/RUSKIN	12842
FL	LEESBURG	12819	FL	TAMPA BAY/RUSKIN	12842
FL	APALACHICOLA	12832	FL	TALLAHASEE	93805
FL	DAYTONA BEACH	12834	FL	JACKSONVILLE	13889

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
FL	FORT MYERS	12835	FL	TAMPA BAY/RUSKIN	12842
FL	KEY WEST	12836	FL	KEY WEST INT AP	12836
FL	MELBOURNE	12838	FL	TAMPA BAY/RUSKIN	12842
FL	MIAMI	12839	FL	MIAMI/FL INTL UNIV	92803
FL	ORLANDO	12841	FL	TAMPA BAY/RUSKIN	12842
FL	TAMPA	12842	FL	TAMPA BAY/RUSKIN	12842
FL	VERO BEACH	12843	FL	TAMPA BAY/RUSKIN	12842
FL	WEST PALM BEACH	12844	FL	MIAMI/FL INTL UNIV	92803
FL	FORT LAUDERDALE	12849	FL	MIAMI/FL INTL UNIV	92803
FL	ORLANDO	12854	FL	TAMPA BAY/RUSKIN	12842
FL	SARASOTA/BRADENTON	12871	FL	TAMPA BAY/RUSKIN	12842
FL	ST PETERSBURG/ CLEARWATER	12873	FL	TAMPA BAY/RUSKIN	12842
FL	WINTER HAVEN	12876	FL	TAMPA BAY/RUSKIN	12842
FL	MIAMI	12882	FL	MIAMI/FL INTL UNIV	92803
FL	FORT LAUDERDALE	12885	FL	MIAMI/FL INTL UNIV	92803
FL	MIAMI	12888	FL	MIAMI/FL INTL UNIV	92803
FL	FORT MYERS	12894	FL	TAMPA BAY/RUSKIN	12842
FL	FORT PIERCE	12895	FL	TAMPA BAY/RUSKIN	12842
FL	MARATHON	12896	FL	KEY WEST INT AP	12836
FL	NAPLES	12897	FL	MIAMI/FL INTL UNIV	92803
FL	CRESTVIEW	13884	FL	TALLAHASEE	93805
FL	JACKSONVILLE	13889	FL	JACKSONVILLE	13889
FL	PENSACOLA	13899	LA	SLIDELL	53813
FL	DESTIN	53853	FL	TALLAHASEE	93805
FL	JACKSONVILLE	53860	FL	JACKSONVILLE	13889
FL	POMPANO BEACH	92805	FL	MIAMI/FL INTL UNIV	92803
FL	ST PETERSBURG	92806	FL	TAMPA BAY/RUSKIN	12842
FL	HOLLYWOOD	92809	FL	MIAMI/FL INTL UNIV	92803
FL	TALLAHASSEE	93805	FL	TALLAHASEE	93805
GA	MACON	03813	GA	PEACHTREE CITY	53819
GA	AUGUSTA	03820	SC	CHARLESTON	13880
GA	SAVANNAH	03822	SC	CHARLESTON	13880
GA	ATLANTA	03888	GA	PEACHTREE CITY	53819
GA	AUGUSTA	13837	SC	CHARLESTON	13880
GA	ALBANY	13869	FL	TALLAHASEE	93805
GA	ALMA	13870	FL	JACKSONVILLE	13889
GA	ATHENS	13873	GA	PEACHTREE CITY	53819
GA	ATLANTA	13874	GA	PEACHTREE CITY	53819
GA	BRUNSWICK	13878	FL	JACKSONVILLE	13889
GA	ATLANTA	53819	GA	PEACHTREE CITY	53819
GA	GAINESVILLE	53838	GA	PEACHTREE CITY	53819
GA	ATLANTA	53863	GA	PEACHTREE CITY	53819
GA	CARTERSVILLE	53873	GA	PEACHTREE CITY	53819
GA	ROME	93801	GA	PEACHTREE CITY	53819

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
GA	COLUMBUS	93842	GA	PEACHTREE CITY	53819
GA	VALDOSTA	93845	FL	TALLAHASEE	93805
HI	HILO	21504	HI	HILO	21504
HI	KAILUA/KONA	21510	HI	HILO	21504
HI	KAHULUI	22516	HI	HILO	21504
HI	HONOLULU	22521	HI	LIHUE/KAUAI	22536
HI	KAUNAKAKAI	22534	HI	LIHUE/KAUAI	22536
HI	KAPOLEI	22551	HI	LIHUE/KAUAI	22536
IA	BURLINGTON	14931	IA	DAVENPORT MUNICIPAL AP	94982
IA	DES MOINES	14933	NE	OMAHA/VALLEY	94980
IA	IOWA CITY	14937	IA	DAVENPORT MUNICIPAL AP	94982
IA	MASON CITY	14940	MN	MINNEAPOLIS	94983
IA	SIOUX CITY	14943	NE	OMAHA/VALLEY	94980
IA	OTTUMWA	14950	IA	DAVENPORT MUNICIPAL AP	94982
IA	SPENCER	14972	NE	OMAHA/VALLEY	94980
IA	WATERLOO	94910	IA	DAVENPORT MUNICIPAL AP	94982
IA	ESTHERVILLE	94971	MN	MINNEAPOLIS	94983
IA	DAVENPORT	94982	IA	DAVENPORT MUNICIPAL AP	94982
IA	MARSHALLTOWN	94988	IA	DAVENPORT MUNICIPAL AP	94982
IA	LAMONI	94991	NE	OMAHA/VALLEY	94980
ID	JEROME	04110	ID	BOISE	24131
ID	CHALLIS	04114	NV	ELKO	04105
ID	BOISE	24131	ID	BOISE	24131
ID	BURLEY	24133	ID	BOISE	24131
ID	IDAHO FALLS	24145	WY	RIVERTON	24061
ID	LEWISTON	24149	WA	SPOKANE INTNL APT	04106
ID	MULLAN PASS	24154	WA	SPOKANE INTNL APT	04106
ID	POCATELLO	24156	UT	SALT LAKE CITY	24127
ID	TWIN FALLS	94178	ID	BOISE	24131
ID	McCALL	94182	ID	BOISE	24131
ID	REXBURG	94194	WY	RIVERTON	24061
IL	DECATUR	03887	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	CAHOKIA/ST.LOUIS	03960	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	CHICAGO/AURORA	04808	IA	DAVENPORT MUNICIPAL AP	94982
IL	CHICAGO/PROSPECT HEIGHTS/WHEELING	04838	IA	DAVENPORT MUNICIPAL AP	94982
IL	LAWRENCEVILLE	13809	IL	LINCOLN-LOGAN COUNTY AP	04833

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
IL	CHICAGO	14819	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	PEORIA	14842	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	CHICAGO/WAUKEGAN	14880	WI	GREEN BAY	14898
IL	MOLINE	14923	IA	DAVENPORT MUNICIPAL AP	94982
IL	MATTOON/CHARLESTON	53802	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	BLOOMINGTON/NORMAL	54831	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	CARBONDALE/MURPHYBORO	93810	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	SPRINGFIELD	93822	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	QUINCY	93989	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	ROCKFORD	94822	IA	DAVENPORT MUNICIPAL AP	94982
IL	CHICAGO	94846	IA	DAVENPORT MUNICIPAL AP	94982
IL	CHAMPAIGN/URBANA	94870	IL	LINCOLN-LOGAN COUNTY AP	04833
IL	CHICAGO/WEST CHICAGO	94892	IA	DAVENPORT MUNICIPAL AP	94982
IN	TERRE HAUTE	03868	IL	LINCOLN-LOGAN COUNTY AP	04833
IN	BLOOMINGTON	03893	OH	WILMINGTON	13841
IN	VALPARAISO	04846	IL	LINCOLN-LOGAN COUNTY AP	04833
IN	FORT WAYNE	14827	OH	WILMINGTON	13841
IN	GOSHEN	14829	MI	DETROIT/PONTIAC	04830
IN	LAFAYETTE	14835	IL	LINCOLN-LOGAN COUNTY AP	04833
IN	SOUTH BEND	14848	MI	DETROIT/PONTIAC	04830
IN	INDIANAPOLIS	53842	OH	WILMINGTON	13841
IN	SHELBYVILLE	53866	OH	WILMINGTON	13841
IN	EVANSVILLE	93817	TN	NASHVILLE	13897
IN	INDIANAPOLIS	93819	OH	WILMINGTON	13841
IN	MUNCIE	94895	OH	WILMINGTON	13841
KS	SALINA	03919	KS	TOPEKA	13996
KS	WICHITA	03928	KS	TOPEKA	13996
KS	MANHATTAN	03936	KS	TOPEKA	13996
KS	OLATHE	03967	KS	TOPEKA	13996
KS	WICHITA	03974	KS	TOPEKA	13996
KS	LAWRENCE	03997	KS	TOPEKA	13996
KS	PARSONS	03998	MO	SPRINGFIELD REGIONAL AP	13995

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
KS	TOPEKA	13920	KS	TOPEKA	13996
KS	CHANUTE	13981	KS	TOPEKA	13996
KS	CONCORDIA	13984	KS	TOPEKA	13996
KS	DODGE CITY	13985	KS	DODGE CITY	13985
KS	HUTCHINSON	13986	KS	DODGE CITY	13985
KS	EMPORIA	13989	KS	TOPEKA	13996
KS	TOPEKA	13996	KS	TOPEKA	13996
KS	GARDEN CITY	23064	KS	DODGE CITY	13985
KS	GOODLAND	23065	NE	NORTH PLATTE	24023
KS	OLATHE	93909	KS	TOPEKA	13996
KS	COFFEYVILLE	93967	MO	SPRINGFIELD REGIONAL AP	13995
KS	HILL CITY	93990	KS	DODGE CITY	13985
KS	RUSSELL	93997	KS	DODGE CITY	13985
KY	PADUCAH	03816	TN	NASHVILLE	13897
KY	LONDON	03849	TN	NASHVILLE	13897
KY	JACKSON	03889	OH	WILMINGTON	13841
KY	LOUISVILLE	13810	OH	WILMINGTON	13841
KY	FRANKFORT	53841	OH	WILMINGTON	13841
KY	BOWLING GREEN	93808	TN	NASHVILLE	13897
KY	LEXINGTON	93820	OH	WILMINGTON	13841
KY	LOUISVILLE	93821	OH	WILMINGTON	13841
LA	LAKE CHARLES	03937	LA	LAKE CHARLES	03937
LA	BOOTHVILLE	12884	LA	SLIDELL	53813
LA	NEW ORLEANS	12916	LA	SLIDELL	53813
LA	ALEXANDRIA	13935	LA	LAKE CHARLES	03937
LA	MONROE	13942	LA	SHREVEPORT REGIONAL AP	13957
LA	SHREVEPORT	13957	LA	SHREVEPORT REGIONAL AP	13957
LA	BATON ROUGE	13970	LA	SLIDELL	53813
LA	LAFAYETTE	13976	LA	LAKE CHARLES	03937
LA	SLIDELL	53865	LA	SLIDELL	53813
LA	SHREVEPORT	53905	LA	SHREVEPORT REGIONAL AP	13957
LA	NEW IBERIA	53915	LA	LAKE CHARLES	03937
LA	NEW ORLEANS	53917	LA	SLIDELL	53813
LA	ALEXANDRIA	93915	LA	LAKE CHARLES	03937
MA	FITCHBURG	04780	NY	ALBANY	54775
MA	BEDFORD	14702	MA	CHATHAM	14684
MA	BOSTON	14739	MA	CHATHAM	14684
MA	NANTUCKET	14756	MA	CHATHAM	14684
MA	PITTSFIELD	14763	NY	ALBANY	54775
MA	WESTFIELD/SPRINGFI LD	14775	NY	ALBANY	54775
MA	NORWOOD	54704	MA	CHATHAM	14684
MA	BEVERLY	54733	MA	CHATHAM	14684
MA	ORANGE	54756	NY	ALBANY	54775
MA	NORTH ADAMS	54768	NY	ALBANY	54775

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
MA	PLYMOUTH	54769	MA	CHATHAM	14684
MA	TAUNTON	54777	MA	CHATHAM	14684
MA	CHATHAM	94624	MA	CHATHAM	14684
MA	HYANNIS	94720	MA	CHATHAM	14684
MA	LAWRENCE	94723	ME	GRAY	54762
MA	VINEYARD HAVEN	94724	MA	CHATHAM	14684
MA	NEW BEDFORD	94726	MA	CHATHAM	14684
MA	WORCESTER	94746	NY	ALBANY	54775
MD	HAGERSTOWN	93706	VA	STERLING(WASH DULLES)	93734
MD	SALISBURY	93720	VA	WALLOPS ISLAND	93739
MD	BALTIMORE	93721	VA	STERLING(WASH DULLES)	93734
MD	OCEAN CITY	93786	VA	WALLOPS ISLAND	93739
ME	FRENCHVILLE	04836	ME	CARIBOU	14607
ME	AUGUSTA	14605	ME	GRAY	54762
ME	BANGOR	14606	ME	GRAY	54762
ME	CARIBOU	14607	ME	CARIBOU	14607
ME	HOULTON	14609	ME	CARIBOU	14607
ME	MILLINOCKET	14610	ME	CARIBOU	14607
ME	PORTLAND	14764	ME	GRAY	54762
ME	FRYEBURG	54772	ME	GRAY	54762
ME	WISCASSET	94623	ME	GRAY	54762
MI	HOLLAND	04839	MI	DETROIT/PONTIAC	04830
MI	ADRIAN	04847	MI	DETROIT/PONTIAC	04830
MI	GAYLORD	04854	MI	GAYLORD / ALPENA	04837
MI	BATTLE CREEK	14815	MI	DETROIT/PONTIAC	04830
MI	DETROIT	14822	MI	DETROIT/PONTIAC	04830
MI	FLINT	14826	MI	DETROIT/PONTIAC	04830
MI	JACKSON	14833	MI	DETROIT/PONTIAC	04830
MI	LANSING	14836	MI	DETROIT/PONTIAC	04830
MI	MUSKEGON	14840	WI	GREEN BAY	14898
MI	PELLSTON	14841	MI	GAYLORD / ALPENA	04837
MI	SAGINAW	14845	MI	DETROIT/PONTIAC	04830
MI	SAULT STE MARIE	14847	MI	GAYLORD / ALPENA	04837
MI	TRAVERSE CITY	14850	MI	GAYLORD / ALPENA	04837
MI	DETROIT	14853	MI	DETROIT/PONTIAC	04830
MI	HANCOCK	14858	WI	GREEN BAY	14898
MI	HOUGHTON LAKE	94814	MI	GAYLORD / ALPENA	04837
MI	KALAMAZOO	94815	MI	DETROIT/PONTIAC	04830
MI	PONTIAC	94817	MI	DETROIT/PONTIAC	04830
MI	DETROIT	94847	MI	DETROIT/PONTIAC	04830
MI	GRAND RAPTIDS	94860	MI	DETROIT/PONTIAC	04830
MI	BENTON HARBOR	94871	MI	DETROIT/PONTIAC	04830
MI	ANN ARBOR	94889	MI	DETROIT/PONTIAC	04830
MI	IRON MOUNTAIN/KINGSFORD	94893	WI	GREEN BAY	14898
MN	ALEXANDRIA	14910	MN	MINNEAPOLIS	94983

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
MN	DULUTH	14913	MN	INTERNATIONAL FALLS	14918
MN	INTERNATIONAL FALLS	14918	MN	INTERNATIONAL FALLS	14918
MN	MINNEAPOLIS	14922	MN	MINNEAPOLIS	94983
MN	ROCHESTER	14925	MN	MINNEAPOLIS	94983
MN	ST CLOUD	14926	MN	MINNEAPOLIS	94983
MN	ST PAUL	14927	MN	MINNEAPOLIS	94983
MN	REDWOOD FALLS	14992	MN	MINNEAPOLIS	94983
MN	HIBBING	94931	MN	INTERNATIONAL FALLS	14918
MN	BRAINERD	94938	MN	MINNEAPOLIS	94983
MN	MINNEAPOLIS	94960	MN	MINNEAPOLIS	94983
MN	BAUDETTE	94961	MN	INTERNATIONAL FALLS	14918
MN	MINNEAPOLIS	94963	MN	MINNEAPOLIS	94983
MN	PARK RAPIDS	94967	MN	INTERNATIONAL FALLS	14918
MO	CAPE GIRARDEAU	03935	TN	NASHVILLE	13897
MO	COLUMBIA	03945	MO	SPRINGFIELD REGIONAL AP	13995
MO	KANSAS CITY	03947	KS	TOPEKA	13996
MO	JEFFERSON CITY	03963	MO	SPRINGFIELD REGIONAL AP	13995
MO	ST LOUIS	03966	IL	LINCOLN-LOGAN COUNTY AP	04833
MO	POPLAR BLUFF	03975	MO	SPRINGFIELD REGIONAL AP	13995
MO	SEDALIA	03994	MO	SPRINGFIELD REGIONAL AP	13995
MO	JOPLIN	13987	MO	SPRINGFIELD REGIONAL AP	13995
MO	KANSAS CITY	13988	KS	TOPEKA	13996
MO	ST LOUIS	13994	IL	LINCOLN-LOGAN COUNTY AP	04833
MO	SPRINGFIELD	13995	MO	SPRINGFIELD REGIONAL AP	13995
MO	ROLLA/VICHY	13997	MO	SPRINGFIELD REGIONAL AP	13995
MO	KIRKSVILLE	14938	IA	DAVENPORT MUNICIPAL AP	94982
MO	LEE'S SUMMIT	53879	KS	TOPEKA	13996
MO	WEST PLAINS	53901	MO	SPRINGFIELD REGIONAL AP	13995
MO	ST CHARLES	53904	IL	LINCOLN-LOGAN COUNTY AP	04833
MS	JACKSON	03940	MS	JACKSON/THOMPSON FLD	03940

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
MS	TALLULAH/VICKSBURG	03996	MS	JACKSON/THOMPSON FLD	03940
MS	HATTIESBURG	13833	LA	SLIDELL	53813
MS	MERIDIAN	13865	MS	JACKSON/THOMPSON FLD	03940
MS	JACKSON	13927	MS	JACKSON/THOMPSON FLD	03940
MS	GREENVILLE	13939	MS	JACKSON/THOMPSON FLD	03940
MS	GREENWOOD	13978	MS	JACKSON/THOMPSON FLD	03940
MS	PASCAGOULA	53858	LA	SLIDELL	53813
MS	TUPELO	93862	AL	BIRMINGHAM (SHELBY APT)	53823
MS	GULFPORT	93874	LA	SLIDELL	53813
MS	MCCOMB	93919	LA	SLIDELL	53813
MT	BILLINGS	24033	MT	GREAT FALLS	04102
MT	LEWISTOWN	24036	MT	GREAT FALLS	04102
MT	MILES	24037	MT	GLASGOW	94008
MT	BOZEMAN	24132	MT	GREAT FALLS	04102
MT	BUTTE	24135	MT	GREAT FALLS	04102
MT	CUT BANK	24137	MT	GREAT FALLS	04102
MT	DILLON	24138	MT	GREAT FALLS	04102
MT	GREAT FALLS	24143	MT	GREAT FALLS	04102
MT	HELENA	24144	MT	GREAT FALLS	04102
MT	KALISPELL	24146	MT	GREAT FALLS	04102
MT	LIVINGSTON	24150	MT	GREAT FALLS	04102
MT	MISSOULA	24153	MT	GREAT FALLS	04102
MT	GLASGOW	94008	MT	GLASGOW	94008
MT	HAVRE	94012	MT	GREAT FALLS	04102
MT	WOLF POINT	94017	MT	GLASGOW	94008
MT	BAKER	94055	SD	RAPID CITY	94043
NC	HICKORY	03810	NC	GREENSBORO	13723
NC	ASHEVILLE	03812	NC	GREENSBORO	13723
NC	RALEIGH/DURHAM	13722	NC	GREENSBORO	13723
NC	GREENSBORO	13723	NC	GREENSBORO	13723
NC	WILMINGTON	13748	NC	MOREHEAD CITY/NEWPORT	93768
NC	LUMBERTON	13776	NC	GREENSBORO	13723
NC	ELIZABETH CITY	13786	NC	MOREHEAD CITY/NEWPORT	93768
NC	CHARLOTTE	13881	NC	GREENSBORO	13723
NC	GASTONIA	53870	NC	GREENSBORO	13723
NC	MONROE	53872	NC	GREENSBORO	13723
NC	NEW BERN	93719	NC	MOREHEAD CITY/NEWPORT	93768
NC	CAPE HATTERAS	93729	NC	MOREHEAD CITY/NEWPORT	93768
NC	FAYETTEVILLE	93740	NC	GREENSBORO	13723

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
NC	ROCKY MOUNT	93759	NC	MOREHEAD CITY/NEWPORT	93768
NC	BEAUFORT	93765	NC	MOREHEAD CITY/NEWPORT	93768
NC	MAXTON	93782	NC	GREENSBORO	13723
NC	BURLINGTON	93783	NC	GREENSBORO	13723
NC	CHAPEL HILL	93785	NC	GREENSBORO	13723
NC	WINSTON SALEM	93807	NC	GREENSBORO	13723
ND	FARGO	14914	SD	ABERDEEN	14929
ND	GRAND FORKS	14916	MN	INTERNATIONAL FALLS	14918
ND	JAMESTOWN	14919	ND	BISMARCK	24011
ND	BISMARCK	24011	ND	BISMARCK	24011
ND	DICKINSON	24012	ND	BISMARCK	24011
ND	MINOT	24013	ND	BISMARCK	24011
ND	WILLISTON	94014	MT	GLASGOW	94008
ND	HETTINGER	94038	ND	BISMARCK	24011
NE	GRAND ISLAND	14935	NE	OMAHA/VALLEY	94980
NE	LINCOLN	14939	NE	OMAHA/VALLEY	94980
NE	NORFOLK	14941	NE	OMAHA/VALLEY	94980
NE	OMAHA	14942	NE	OMAHA/VALLEY	94980
NE	CHADRON	24017	SD	RAPID CITY	94043
NE	NORTH PLATTE	24023	NE	NORTH PLATTE	24023
NE	SCOTTSBLUFF	24028	SD	RAPID CITY	94043
NE	SIDNEY	24030	NE	NORTH PLATTE	24023
NE	VALENTINE	24032	NE	NORTH PLATTE	24023
NE	ALLIANCE	24044	NE	NORTH PLATTE	24023
NE	IMPERIAL	24091	NE	NORTH PLATTE	24023
NE	MC COOK	94040	NE	NORTH PLATTE	24023
NE	BROKEN BOW	94946	NE	NORTH PLATTE	24023
NE	HASTINGS	94949	NE	OMAHA/VALLEY	94980
NE	FALLS CITY	94957	KS	TOPEKA	13996
NE	ORD	94958	NE	NORTH PLATTE	24023
NE	TEKAMAH	94978	NE	OMAHA/VALLEY	94980
NH	MANCHESTER	14710	ME	GRAY	54762
NH	CONCORD	14745	ME	GRAY	54762
NH	WHITEFIELD	54728	ME	GRAY	54762
NH	JAFFREY	54770	NY	ALBANY	54775
NH	ROCHESTER	54791	ME	GRAY	54762
NH	BERLIN	94700	ME	GRAY	54762
NH	LEBANON	94765	NY	ALBANY	54775
NJ	MILLVILLE	13735	VA	WALLOPS ISLAND	93739
NJ	NEWARK	14734	NY	BROOKHAVEN	94703
NJ	TRENTON	14792	NY	BROOKHAVEN	94703
NJ	CALDWELL	54743	NY	BROOKHAVEN	94703
NJ	SOMERVILLE	54785	NY	BROOKHAVEN	94703
NJ	ATLANTIC CITY	93730	VA	WALLOPS ISLAND	93739
NJ	MOUNT HOLLY	93780	NY	BROOKHAVEN	94703
NJ	TETERBORO	94741	NY	BROOKHAVEN	94703

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
NM	CLINES CORNERS	03027	NM	ALBUQUERQUE	23050
NM	ROSWELL	23009	NM	SANTA TERESA	03020
NM	TUCUMCARI	23048	TX	AMARILLO	23047
NM	SANTA FE	23049	NM	ALBUQUERQUE	23050
NM	ALBUQUERQUE	23050	NM	ALBUQUERQUE	23050
NM	CLAYTON	23051	TX	AMARILLO	23047
NM	RATON	23052	NM	ALBUQUERQUE	23050
NM	LAS VEGAS	23054	NM	ALBUQUERQUE	23050
NM	DEMING	23078	NM	SANTA TERESA	03020
NM	GALLUP	23081	NM	ALBUQUERQUE	23050
NM	FARMINGTON	23090	NM	ALBUQUERQUE	23050
NM	CARLSBAD	93033	TX	MIDLAND	23023
NM	TRUTH OR CONSEQUENCES	93045	NM	SANTA TERESA	03020
NV	MERCURY	03160	NV	LAS VEGAS	03120
NV	TONOPAH	23153	NV	LAS VEGAS	03120
NV	ELY	23154	NV	ELKO	04105
NV	LAS VEGAS	23169	NV	LAS VEGAS	03120
NV	RENO	23185	NV	RENO	03198
NV	ELKO	24121	NV	ELKO	04105
NV	WINNEMUCCA	24128	NV	ELKO	04105
NV	LOVELOCK	24172	NV	RENO	03198
NV	LAS VAGAS	53123	NV	LAS VEGAS	03120
NY	NIAGARA FALLS	04724	NY	BUFFALO/GRTR ARPT	14733
NY	BINGHAMTON	04725	NY	ALBANY	54775
NY	ISLIP	04781	NY	BROOKHAVEN	94703
NY	MONTGOMERY	04789	NY	ALBANY	54775
NY	WESTHAMPTON BEACH	14719	NY	BROOKHAVEN	94703
NY	NEW YORK	14732	NY	BROOKHAVEN	94703
NY	BUFFALO	14733	NY	BUFFALO/GRTR ARPT	14733
NY	ALBANY	14735	NY	ALBANY	54775
NY	DUNKIRK	14747	NY	BUFFALO/GRTR ARPT	14733
NY	ELMIRA/CORNING	14748	NY	BUFFALO/GRTR ARPT	14733
NY	GLEN FALLS	14750	NY	ALBANY	54775
NY	POUGHKEEPSIE	14757	NY	ALBANY	54775
NY	ROCHESTER	14768	NY	BUFFALO/GRTR ARPT	14733
NY	SYRACUSE	14771	NY	ALBANY	54775
NY	WELLSVILLE	54757	NY	BUFFALO/GRTR ARPT	14733
NY	FULTON	54773	NY	BUFFALO/GRTR ARPT	14733
NY	PENN YAN	54778	NY	BUFFALO/GRTR ARPT	14733
NY	FARMINGDALE	54787	NY	BROOKHAVEN	94703
NY	SHIRLEY	54790	NY	BROOKHAVEN	94703
NY	DANSVILLE	94704	NY	BUFFALO/GRTR ARPT	14733
NY	MASSENA	94725	NY	ALBANY	54775
NY	NEW YORK	94728	NY	BROOKHAVEN	94703
NY	SARANAC LAKE	94740	NY	ALBANY	54775
NY	WHITE PLAINS	94745	NY	BROOKHAVEN	94703
NY	NEW YORK	94789	NY	BROOKHAVEN	94703

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
NY	WATERTOWN	94790	NY	ALBANY	54775
OH	WOOSTER	04842	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	TOLEDO	04848	MI	DETROIT/PONTIAC	04830
OH	LORAIN/ELYRIA	04849	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	LIMA	04850	OH	WILMINGTON	13841
OH	DEFIANCE	04851	MI	DETROIT/PONTIAC	04830
OH	NEW PHILADELPHIA	04852	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	CLEVELAND	04853	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	MARION	04855	OH	WILMINGTON	13841
OH	ASHTABULA	04857	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	NEWARK	04858	OH	WILMINGTON	13841
OH	WILMINGTON	13841	OH	WILMINGTON	13841
OH	AKRON	14813	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	CLEVELAND	14820	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	COLUMBUS	14821	OH	WILMINGTON	13841
OH	FINDLAY	14825	OH	WILMINGTON	13841
OH	YOUNGSTOWN/WARREN	14852	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	MANSFIELD	14891	OH	WILMINGTON	13841
OH	AKRON	14895	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	LANCASTER	53844	OH	WILMINGTON	13841
OH	HAMILTON	53855	OH	WILMINGTON	13841
OH	DAYTON	53859	OH	WILMINGTON	13841
OH	CINCINNATI	93812	OH	WILMINGTON	13841
OH	COVINGTON/CINCINNATI	93814	OH	WILMINGTON	13841
OH	DAYTON	93815	OH	WILMINGTON	13841
OH	ZANESVILLE	93824	PA	PITTSBURGH/MOON TOWNSHIP	94823
OH	TOLEDO	94830	MI	DETROIT/PONTIAC	04830
OK	GUYMON	03030	TX	AMARILLO	23047
OK	CLINTON	03932	OK	NORMAN	03948
OK	LAWTON	03950	OK	NORMAN	03948
OK	OKLAHOMA CITY	03954	OK	NORMAN	03948
OK	STILLWATER	03965	OK	NORMAN	03948
OK	FREDERICK	03981	OK	NORMAN	03948
OK	OKLAHOMA CITY	13967	OK	NORMAN	03948
OK	TULSA	13968	OK	NORMAN	03948
OK	PONCA CITY	13969	OK	NORMAN	03948
OK	GAGE	13975	KS	DODGE CITY	13985
OK	TULSA	53908	OK	NORMAN	03948

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
OK	GUTHRIE	53913	OK	NORMAN	03948
OK	MC ALESTER	93950	OK	NORMAN	03948
OK	MUSKOGEE	93953	OK	NORMAN	03948
OK	HOBART	93986	OK	NORMAN	03948
OR	HERMISTON	04113	WA	SPOKANE INTNL APT	04106
OR	SCAPPOOSE	04201	OR	SALEM	24232
OR	BAKER CITY	24130	ID	BOISE	24131
OR	PENDLETON	24155	WA	SPOKANE INTNL APT	04106
OR	ONTARIO	24162	ID	BOISE	24131
OR	THE DALLES	24219	OR	SALEM	24232
OR	EUGENE	24221	OR	SALEM	24232
OR	MEDFORD	24225	OR	MEDFORD	24225
OR	PORTLAND	24229	OR	SALEM	24232
OR	REDMOND	24230	OR	SALEM	24232
OR	ROSEBURG	24231	OR	MEDFORD	24225
OR	SALEM	24232	OR	SALEM	24232
OR	SEXTON SUMMIT	24235	OR	MEDFORD	24225
OR	PORTLAND	24242	OR	SALEM	24232
OR	BURNS	94185	ID	BOISE	24131
OR	ASTORIA	94224	OR	SALEM	24232
OR	KLAMATH FALLS	94236	OR	MEDFORD	24225
OR	PORTLAND	94261	OR	SALEM	24232
OR	MC MINNVILLE	94273	OR	SALEM	24232
OR	AURORA	94281	OR	SALEM	24232
PA	JOHNSTOWN	04726	PA	PITTSBURGH/MOON TOWNSHIP	94823
PA	BRADFORD	04751	NY	BUFFALO/GRTR ARPT	14733
PA	DU BOIS	04787	PA	PITTSBURGH/MOON TOWNSHIP	94823
PA	MEADVILLE	04843	PA	PITTSBURGH/MOON TOWNSHIP	94823
PA	PHILADELPHIA	13739	VA	STERLING(WASH DULLES)	93734
PA	HARRISBURG	14711	VA	STERLING(WASH DULLES)	93734
PA	READING	14712	VA	STERLING(WASH DULLES)	93734
PA	ALTOONA	14736	VA	STERLING(WASH DULLES)	93734
PA	ALLENTOWN	14737	NY	BROOKHAVEN	94703
PA	HARRISBURG	14751	VA	STERLING(WASH DULLES)	93734
PA	PITTSBURGH	14762	PA	PITTSBURGH/MOON TOWNSHIP	94823
PA	SELINSGROVE	14770	VA	STERLING(WASH DULLES)	93734
PA	WILKES-BARRE/SCRANTON	14777	NY	ALBANY	54775

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
PA	WILLIAMSPORT	14778	NY	BUFFALO/GRTR ARPT	14733
PA	ERIE	14860	NY	BUFFALO/GRTR ARPT	14733
PA	LANCASTER	54737	VA	STERLING(WASH DULLES)	93734
PA	POTTSTOWN	54782	VA	STERLING(WASH DULLES)	93734
PA	DOYLESTOWN	54786	NY	BROOKHAVEN	94703
PA	MOUNT POCONO	54789	NY	BROOKHAVEN	94703
PA	CLEARFIELD	54792	PA	PITTSBURGH/MOON TOWNSHIP	94823
PA	YORK	93778	VA	STERLING(WASH DULLES)	93734
PA	PHILADELPHIA	94732	NY	BROOKHAVEN	94703
PA	PITTSBURGH	94823	PA	PITTSBURGH/MOON TOWNSHIP	94823
PR	SAN JUAN	11641	PR	SAN JUAN	11641
RI	PROVIDENCE	14765	MA	CHATHAM	14684
RI	NEWPORT	14787	MA	CHATHAM	14684
RI	WESTERLY	14794	NY	BROOKHAVEN	94703
SC	GREER	03870	NC	GREENSBORO	13723
SC	FLORENCE	13744	SC	CHARLESTON	13880
SC	CHARLESTON	13880	SC	CHARLESTON	13880
SC	COLUMBIA	13883	SC	CHARLESTON	13880
SC	GREENVILLE	13886	NC	GREENSBORO	13723
SC	CLEMSON	53850	GA	PEACHTREE CITY	53819
SC	ORANGEBURG	53854	SC	CHARLESTON	13880
SC	COLUMBIA	53867	SC	CHARLESTON	13880
SC	ROCK HILL	53871	NC	GREENSBORO	13723
SC	GREENWOOD	53874	GA	PEACHTREE CITY	53819
SC	NORTH MYRTLE BEACH	93718	SC	CHARLESTON	13880
SC	ANDERSON	93846	GA	PEACHTREE CITY	53819
SD	ABERDEEN	14929	SD	ABERDEEN	14929
SD	HURON	14936	SD	ABERDEEN	14929
SD	SIOUX FALLS	14944	SD	ABERDEEN	14929
SD	WATERTOWN	14946	SD	ABERDEEN	14929
SD	PHILIP	24024	SD	RAPID CITY	94043
SD	PIERRE	24025	SD	ABERDEEN	14929
SD	RAPID CITY	24090	SD	RAPID CITY	94043
SD	CUSTER	94032	SD	RAPID CITY	94043
SD	PINE RIDGE	94039	SD	RAPID CITY	94043
SD	MOBRIDGE	94052	ND	BISMARCK	24011
SD	MITCHELL	94950	SD	ABERDEEN	14929
SD	WINNER	94990	SD	ABERDEEN	14929
TN	JACKSON	03811	TN	NASHVILLE	13897
TN	CROSSVILLE	03847	TN	NASHVILLE	13897
TN	BRISTOL/JOHNSON CITY/KINGSPORT	13877	VA	ROANOKE/BLACKSBURG	53829

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
TN	CHATTANOOGA	13882	TN	NASHVILLE	13897
TN	KNOXVILLE	13891	TN	NASHVILLE	13897
TN	MEMPHIS	13893	AR	N LITTLE ROCK	03952
TN	NASHVILLE	13897	TN	NASHVILLE	13897
TX	BORGER	03024	TX	AMARILLO	23047
TX	LONGVIEW	03901	LA	SHREVEPORT REGIONAL AP	13957
TX	COLLEGE STATION	03904	TX	FT WORTH	03990
TX	DALLAS-FT WORTH	03927	TX	FT WORTH	03990
TX	DALLAS	03971	TX	FT WORTH	03990
TX	DENTON	03991	TX	FT WORTH	03990
TX	BURNET	03999	TX	FT WORTH	03990
TX	HARLINGEN	12904	TX	BROWNSVILLE	12919
TX	VICTORIA	12912	TX	CORPUS CHRISTI	12924
TX	BEAUMONT/PORT ARTHUR	12917	LA	LAKE CHARLES	03937
TX	HOUSTON	12918	LA	LAKE CHARLES	03937
TX	BROWNSVILLE	12919	TX	BROWNSVILLE	12919
TX	SAN ANTONIO	12921	TX	CORPUS CHRISTI	12924
TX	GALVESTON	12923	LA	LAKE CHARLES	03937
TX	CORPUS CHRISTI	12924	TX	CORPUS CHRISTI	12924
TX	ALICE	12932	TX	CORPUS CHRISTI	12924
TX	PALACIOS	12935	TX	CORPUS CHRISTI	12924
TX	COTULLA	12947	TX	CORPUS CHRISTI	12924
TX	PORT ISABEL	12957	TX	BROWNSVILLE	12919
TX	MC ALLEN	12959	TX	BROWNSVILLE	12919
TX	HOUSTON	12960	LA	LAKE CHARLES	03937
TX	HONDO	12962	TX	DEL RIO	22010
TX	SAN ANTONIO	12970	TX	CORPUS CHRISTI	12924
TX	NEW BRAUNFELS	12971	TX	CORPUS CHRISTI	12924
TX	ROCKPORT	12972	TX	CORPUS CHRISTI	12924
TX	HOUSTON	12975	LA	LAKE CHARLES	03937
TX	ANGLETON/LAKE JACKSON	12976	LA	LAKE CHARLES	03937
TX	HOUSTON	12977	LA	LAKE CHARLES	03937
TX	AUSTIN/BERGSTROM	13904	TX	CORPUS CHRISTI	12924
TX	AUSTIN/CITY	13958	TX	FT WORTH	03990
TX	WACO	13959	TX	FT WORTH	03990
TX	DALLAS	13960	TX	FT WORTH	03990
TX	FORT WORTH	13961	TX	FT WORTH	03990
TX	ABILENE	13962	TX	FT WORTH	03990
TX	WICHITA FALLS	13966	OK	NORMAN	03948
TX	TYLER	13972	LA	SHREVEPORT REGIONAL AP	13957
TX	JUNCTION	13973	TX	DEL RIO	22010
TX	DEL RIO	22010	TX	DEL RIO	22010
TX	CHILDRESS	23007	TX	AMARILLO	23047

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
TX	MIDLAND	23023	TX	MIDLAND	23023
TX	SAN ANGELO	23034	TX	MIDLAND	23023
TX	WINK	23040	TX	MIDLAND	23023
TX	LUBBOCK	23042	TX	AMARILLO	23047
TX	EL PASO	23044	NM	SANTA TERESA	03020
TX	AMARILLO	23047	TX	AMARILLO	23047
TX	GUADALUPE PASS	23055	NM	SANTA TERESA	03020
TX	FORT STOCKTON	23091	TX	MIDLAND	23023
TX	CONROE	53902	LA	LAKE CHARLES	03937
TX	HUNTSVILLE	53903	LA	LAKE CHARLES	03937
TX	ARLINGTON	53907	TX	FT WORTH	03990
TX	FORT WORTH	53909	TX	FT WORTH	03990
TX	HOUSTON	53910	LA	LAKE CHARLES	03937
TX	TERRELL	53911	TX	FT WORTH	03990
TX	CORSICANA	53912	TX	FT WORTH	03990
TX	MC KINNEY	53914	TX	FT WORTH	03990
TX	DALHART	93042	TX	AMARILLO	23047
TX	MINERAL WELLS	93985	TX	FT WORTH	03990
TX	LUFKIN	93987	LA	SHREVEPORT REGIONAL AP	13957
UT	BRYCE CANYON	23159	AZ	FLAGSTAFF/BELLEMT (ARMY)	53103
UT	MILFORD	23176	UT	SALT LAKE CITY	24127
UT	OGDEN	24126	UT	SALT LAKE CITY	24127
UT	SALT LAKE CITY	24127	UT	SALT LAKE CITY	24127
UT	MOAB	93075	CO	GRAND JUNCTION	23066
UT	CEDAR CITY	93129	NV	LAS VEGAS	03120
UT	PRICE	93141	UT	SALT LAKE CITY	24127
UT	VERNAL	94030	CO	GRAND JUNCTION	23066
UT	LOGAN	94128	UT	SALT LAKE CITY	24127
VA	DANVILLE	13728	NC	GREENSBORO	13723
VA	LYNCHBURG	13733	VA	ROANOKE/BLACKSBURG	53829
VA	NORFOLK	13737	VA	WALLOPS ISLAND	93739
VA	RICHMOND	13740	VA	STERLING(WASH DULLES)	93734
VA	ROANOKE	13741	VA	ROANOKE/BLACKSBURG	53829
VA	CHARLOTTESVILLE	93736	VA	STERLING(WASH DULLES)	93734
VA	WALLOPS ISLAND	93739	VA	WALLOPS ISLAND	93739
VA	NEWPORT NEWS	93741	VA	WALLOPS ISLAND	93739
VA	WAKEFIELD	93773	VA	WALLOPS ISLAND	93739
VA	RICHMOND/ASHLAND	93775	VA	STERLING(WASH DULLES)	93734
VT	BURLINGTON	14742	NY	ALBANY	54775
VT	SPRINGFIELD	54740	NY	ALBANY	54775
VT	MORRISVILLE	54771	ME	GRAY	54762
VT	BENNINGTON	54781	NY	ALBANY	54775

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
VT	BARRE/MONTPELIER	94705	ME	GRAY	54762
WA	MOSES LAKE	24110	WA	SPOKANE INTNL APT	04106
WA	EPHRATA	24141	WA	SPOKANE INTNL APT	04106
WA	SPOKANE	24157	WA	SPOKANE INTNL APT	04106
WA	WALLA WALLA	24160	WA	SPOKANE INTNL APT	04106
WA	PASCO	24163	WA	SPOKANE INTNL APT	04106
WA	BELLINGHAM	24217	WA	QUILLAYUTE	94240
WA	ELLENSBURG	24220	WA	SPOKANE INTNL APT	04106
WA	EVERETT	24222	WA	QUILLAYUTE	94240
WA	OLYMPIA	24227	WA	QUILLAYUTE	94240
WA	SEATTLE	24233	WA	QUILLAYUTE	94240
WA	SEATTLE	24234	WA	QUILLAYUTE	94240
WA	YAKIMA	24243	WA	SPOKANE INTNL APT	04106
WA	DEER PARK	94119	WA	SPOKANE INTNL APT	04106
WA	PULLMAN/MOSCOW	94129	WA	SPOKANE INTNL APT	04106
WA	SPOKANE	94176	WA	SPOKANE INTNL APT	04106
WA	OMAK	94197	WA	SPOKANE INTNL APT	04106
WA	HOQUIAM	94225	WA	QUILLAYUTE	94240
WA	SHELTON	94227	WA	QUILLAYUTE	94240
WA	WENATCHEE	94239	WA	SPOKANE INTNL APT	04106
WA	QUILLAYUTE	94240	WA	QUILLAYUTE	94240
WA	RENTON	94248	WA	QUILLAYUTE	94240
WA	PORT ANGELES	94266	WA	QUILLAYUTE	94240
WA	TACOMA	94274	WA	QUILLAYUTE	94240
WA	FRIDAY HARBOR	94276	WA	QUILLAYUTE	94240
WA	VANCOUVER	94298	OR	SALEM	24232
WI	RHINELANDER	04803	WI	GREEN BAY	14898
WI	WISCONSIN RAPTIDS	04826	WI	GREEN BAY	14898
WI	FOND DU LAC	04840	WI	GREEN BAY	14898
WI	SHEBOYGAN	04841	WI	GREEN BAY	14898
WI	KENOSHA	04845	WI	GREEN BAY	14898
WI	MADISON	14837	WI	GREEN BAY	14898
WI	MILWAUKEE	14839	WI	GREEN BAY	14898
WI	WAUSAU	14897	WI	GREEN BAY	14898
WI	GREEN BAY	14898	WI	GREEN BAY	14898
WI	LA CROSSE	14920	MN	MINNEAPOLIS	94983
WI	LONE ROCK	14921	IA	DAVENPORT MUNICIPAL AP	94982
WI	EAU CLAIRE	14991	MN	MINNEAPOLIS	94983
WI	RACINE	94818	WI	GREEN BAY	14898
WI	OSHKOSH	94855	WI	GREEN BAY	14898
WI	ASHLAND	94929	MN	MINNEAPOLIS	94983
WI	HAYWARD	94973	MN	MINNEAPOLIS	94983
WI	MARSHFIELD	94985	WI	GREEN BAY	14898
WI	B0SCOBEL	94994	IA	DAVENPORT MUNICIPAL AP	94982

Surface			Upper Air		
State	City	WBAN #	State	City	WBAN #
WV	CLARKSBURG	03802	PA	PITTSBURGH/MOON TOWNSHIP	94823
WV	PARKERSBURG	03804	PA	PITTSBURGH/MOON TOWNSHIP	94823
WV	BLUEFIELD	03859	VA	ROANOKE/BLACKSBURG	53829
WV	HUNTINGTON	03860	OH	WILMINGTON	13841
WV	BECKLEY	03872	VA	ROANOKE/BLACKSBURG	53829
WV	ELKINS	13729	PA	PITTSBURGH/MOON TOWNSHIP	94823
WV	MARTINSBURG	13734	VA	STERLING(WASH DULLES)	93734
WV	MORGANTOWN	13736	PA	PITTSBURGH/MOON TOWNSHIP	94823
WV	CHARLESTON	13866	VA	ROANOKE/BLACKSBURG	53829
WV	WHEELING	14894	PA	PITTSBURGH/MOON TOWNSHIP	94823
WY	EVANSTON	04111	UT	SALT LAKE CITY	24127
WY	CHEYENNE	24018	CO	DENVER/STAPLETON ARPT	23062
WY	LANDER	24021	WY	RIVERTON	24061
WY	LARAMIE	24022	CO	DENVER/STAPLETON ARPT	23062
WY	ROCK SPRINGS	24027	WY	RIVERTON	24061
WY	SHERIDAN	24029	WY	RIVERTON	24061
WY	GREYBULL	24048	WY	RIVERTON	24061
WY	RAWLINS	24057	WY	RIVERTON	24061
WY	RIVERTON	24061	WY	RIVERTON	24061
WY	WORLAND	24062	WY	RIVERTON	24061
WY	CASPER	24089	WY	RIVERTON	24061
WY	BIG PINEY	24164	WY	RIVERTON	24061
WY	GILLETTE	94023	SD	RAPID CITY	94043
WY	TORRINGTON	94053	SD	RAPID CITY	94043
WY	BUFFALO	94054	WY	RIVERTON	24061
WY	DOUGLAS	94057	SD	RAPID CITY	94043

APPENDIX 4: Technical Support Document for the TRIM-Based Multipathway Tiered Screening Methodology for RTR

Technical Support Document
for the TRIM-Based Multipathway
Tiered Screening Methodology for RTR

December 2013

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CONTENTS

1. Introduction and Background

Section 112 of the Clean Air Act (CAA) directs the U.S. Environmental Protection Agency (EPA) to assess the risk remaining (i.e., residual risk) from emissions of hazardous air pollutants (HAPs) following the implementation of maximum achievable control technology (MACT) standards for emission sources. This risk assessment is a major component of EPA's Risk and Technology Review (RTR) program. As part of this program, EPA must consider additional emission standards for a source category if the current emission standards—with MACT regulations in place—do not provide an "ample margin of safety" for human health. One aspect of human health that EPA must consider under RTR is the potential for health effects resulting from exposures to persistent and bioaccumulative HAPs (PB-HAPs) via non-inhalation pathways, namely ingestion and dermal exposure. EPA's assessment for RTR focuses on specific PB-HAPs that the Office of Air Quality Planning and Standards (OAQPS) has identified as candidates for multipathway risk assessments (selection of the PB-HAPs is discussed in Attachment A, Section A.2.2). These non-inhalation human health risks are considered in combination with estimated inhalation human health risks, potential ecological impacts, and other factors to support decisions about residual risk for RTR source categories. For PB-HAPs, exposures via ingestion are anticipated to be significantly higher than any dermal exposures that might occur as a result of the same emissions (see below and Addendum 3 to Attachment A). Consequently, a methodology has been developed to evaluate ingestion exposure and risk for PB-HAPs efficiently in the context of EPA's RTR program.

To evaluate ingestion exposures and human health risks for RTR on a source category basis, an iterative approach was developed that enables EPA to confidently screen out PB-HAP emissions unlikely to pose health risks above levels of concern (i.e., a cancer risk of 1 in 1 million or a noncancer hazard of 1.0) and to focus additional resources on sources of greater concern within the category. To estimate exposure and risk, two models are used: the Fate, Transport, and Ecological Exposure module of EPA's Total Risk Integrated Methodology (TRIM.FaTE) to model the fate and transport of pollutants released to the environment and the Multimedia Ingestion Risk Calculator (MIRC) to estimate transfer and uptake into the food chain and exposure to receptors consuming contaminated food products and soil. This approach is divided into three tiers of increasing refinement, as follows.

- Tier 1 of the approach begins by identifying the facility-level emissions of PB-HAPs within a source category and comparing them to risk-based emission thresholds. The risk-based thresholds are derived using the aforementioned models applied for a hypothetical environmental and exposure scenario, assuming ingestion of locally caught fish, locally grown produce and livestock, and local soil. This hypothetical "screening scenario" is intended to represent a situation in which the ingestion exposure is unlikely to be exceeded at any actual facility evaluated through the RTR program. The thresholds for Tier 1 are derived by estimating the emission rate that corresponds to a lifetime cancer risk of 1 in 1 million or a chronic non-cancer hazard quotient (HQ) of 1 for an individual exposed according to the characteristics associated with the screening scenario. For a facility, if the emission rate of each PB-HAP is less than the Tier 1 threshold emission rate, risks are assumed to be low and no additional multipathway screening is done. If, however, the emission rate of any PB-HAP exceeds the Tier 1 threshold emission rate, the facility can be evaluated further in Tier 2.
- In Tier 2, the actual location of the facility emitting PB-HAPs is used to refine some of the assumptions associated with the environmental scenario while maintaining the Tier 1 ingestion exposure scenario assumptions. The environmental scenario assumptions are refined by incorporating binned site-specific meteorological data and and locations of fishable lakes near the facility (see below). The risk-based threshold for each PB-HAP is

then adjusted for that facility based on an understanding of how exposure concentrations estimated for the screening scenario change with meteorology and lake location. PB-HAP emissions that do not exceed the adjusted threshold are assumed to pose risks below levels of concern and no additional multipathway assessment for RTR is required. Facilities having emissions that exceed the adjusted thresholds for Tier 2 may require additional analysis.

- For facilities emitting PB-HAPs at levels that cannot be ruled out as being above levels of concern based on the screening analyses, a refined, site-specific, multipathway risk assessment can be conducted. Such an assessment would incorporate location- or facility-specific characteristics regarding the environment to which PB-HAPs are emitted, relevant exposure pathways, ingestion rates or other exposure factors, and other parameters. A range of exposure scenarios could be evaluated as part of a site-specific assessment, resulting in a range of risk estimates.

The key processes and decisions that make up this approach are summarized in Exhibit 1. In the remainder of this overview, each of the tiers in the multipathway assessment approach is described in additional detail. Attachments to this appendix provide a comprehensive record of the characteristics and methods associated with Tier 1 (Attachment A) and Tier 2 (Attachment B). If a site-specific analysis is conducted, a separate report detailing that analysis will be prepared.

2. Tier 1

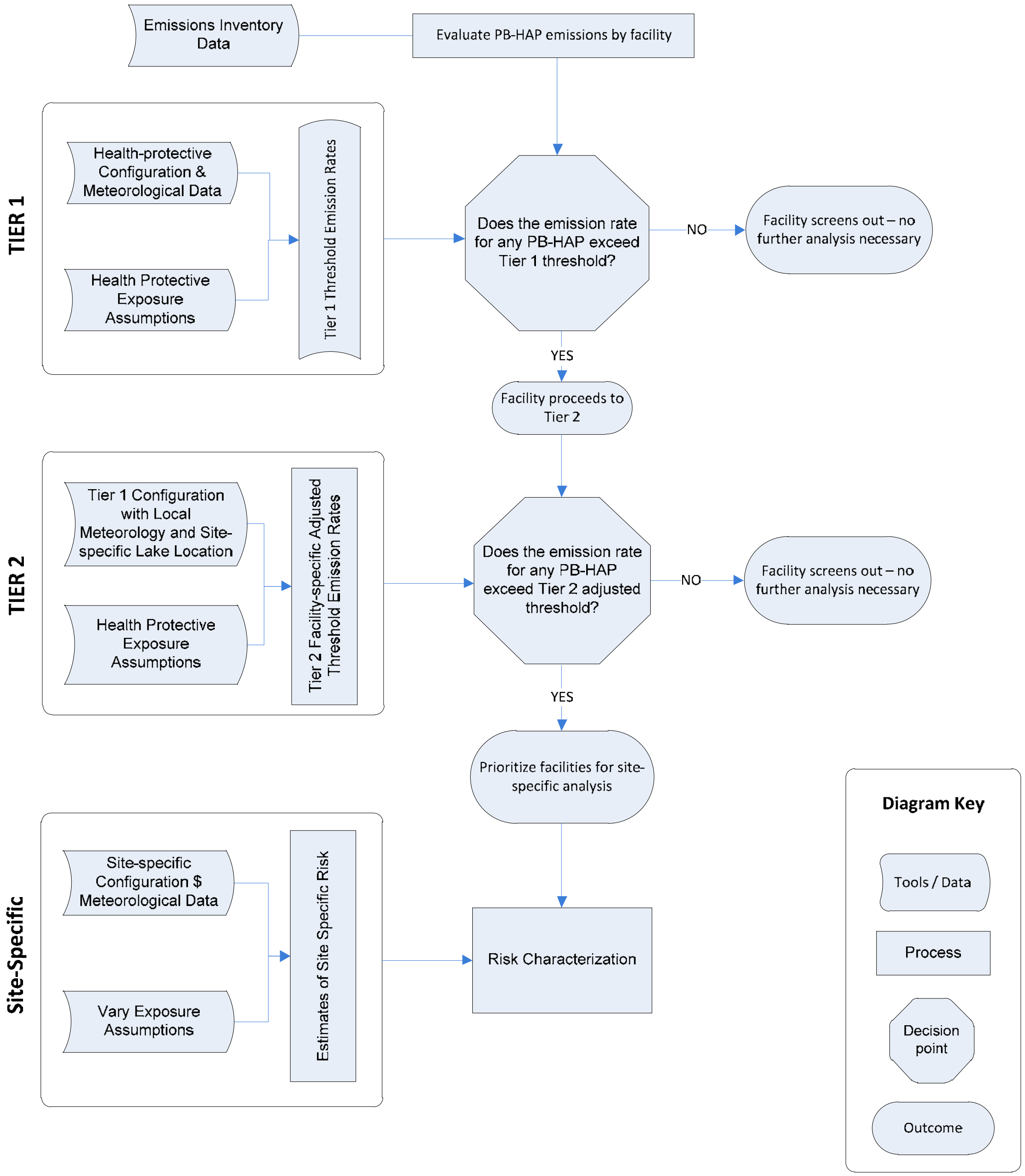
The methods used in Tier 1 are intended to enable EPA to evaluate PB-HAP emissions from multiple sources in a particular category quickly and efficiently and to remove from consideration those that are unlikely to pose risks above levels of concern, while also minimizing the possibility of EPA's failing to identify risks that exceed levels of concern. The hypothetical scenario used to estimate Tier 1 thresholds is designed to be health-protective in estimating exposures and risks; specifically, it is intended to avoid underestimating exposures to PB-HAPS that might be encountered for any location throughout the United States. The scenario also is intended to avoid grossly overestimating risk to the point where no emissions screen out (i.e., overprotective, resulting in too many "false positives").

2.1 Chemicals of Concern

The assessment of risk from multipathway exposures begins with a review of data for sources in a particular category to determine if emissions of any of the following PB-HAPs are reported:

- Cadmium compounds,
- Chlorinated dibenzodioxins and furans (dioxins),
- Mercury compounds, and
- Polycyclic organic matter (POM).

Exhibit 1. Conceptual Decision Tree for Evaluating Non-Inhalation Exposures for PB-HAPs



Based on current emissions, bioaccumulation potential, and toxicity considerations, emissions of these four PB-HAPs are expected to pose the majority of the non-inhalation risks to humans from air emissions at sources subject to residual risk provisions of the CAA[1] Thus, although EPA has identified nine other PB-HAPs that should be evaluated as part of residual risk assessments, the methods for multipathway assessment described here encompass only these four at this time.

If emissions of any of the four PB-HAPs listed above are reported for a facility, the emission rate for that PB-HAP is compared to the threshold emissions rate derived for that chemical using the hypothetical TRIM-based screening scenario. This threshold is the emission rate that, when input to the models used in evaluating multipathway risk for RTR, results in a specified cancer risk or non-cancer HQ threshold level of concern. For the screening scenario, threshold emission rates were calculated for a cancer risk of 1 in 1 million or an HQ of 1.0, depending on the more sensitive health effect of the PB-HAP. However, due to the hypothetical nature of the screening scenario, exceeding the threshold emissions rate by 60 times, for dioxins for example, does not imply a resulting cancer risk of 60 in 1 million. Rather, exceeding the threshold emissions rate by 60 times for dioxin implies that it is highly unlikely that the actual risk would exceed 60 in 1 million.

Important to note for dioxins and POM is that the screening methodology assesses individual congeners, taking into account differences in both the fate and transport and the toxicity among the various congeners. The details of the methods for assessing dioxins and POM are provided in Attachment A to this appendix.

2.2 Development of Emission Thresholds

Generally, the approach used to assess ingestion exposures and resulting risks for RTR has four components (Exhibit 2):

1. **Fate and transport modeling** of PB-HAPs emitted to air that partition into soil, water, and other environmental media (including fish uptake);
2. **Modeling of uptake** of PB-HAPs by farm food chain media from soil and air;
3. **Estimating ingestion exposures** in terms of average daily dose for consumption of farm food items by a hypothetical exposed human; and
4. **Calculating lifetime cancer risk estimates or chronic non-cancer HQs** for each HAP and corresponding screening threshold emission rates.

The TRIM.FaTE model is used in the first component, and the MIRC model is used to conduct calculations for the other three components.[2] To derive the emission thresholds used in Tier 1, these models are used to estimate the emission rate corresponding to a cancer risk of 1 in

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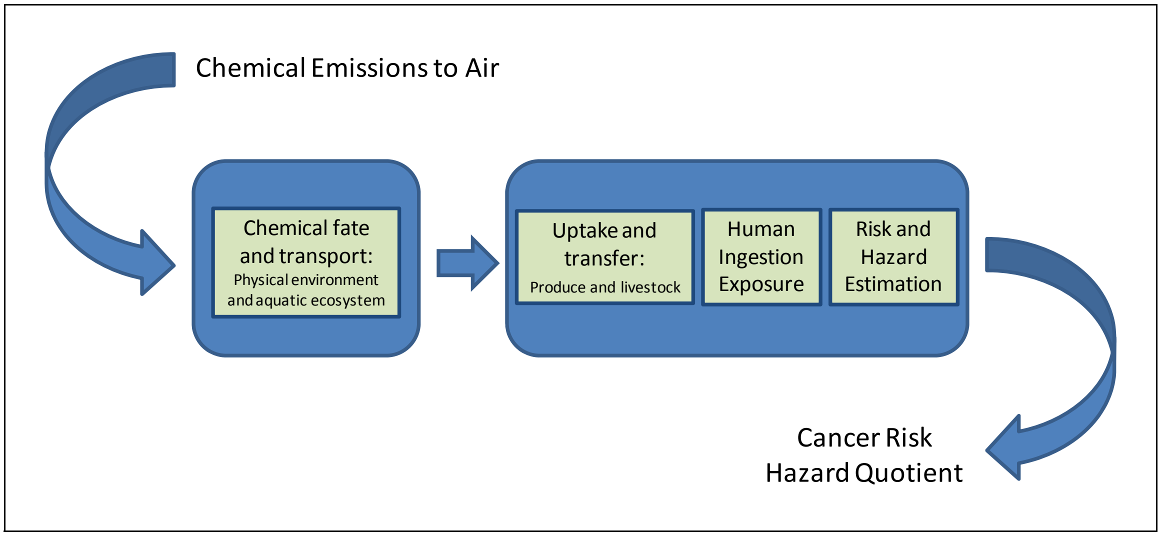
[1] Potential impacts on human health from non-inhalation exposures to lead are evaluated for RTR using the National Ambient Air Quality Standard for lead, which takes into account multipathway risks.

[2] EPA's TRIM methodology was conceived as a comprehensive modeling framework for evaluating risks from air toxics. It was designed to address each of the four steps in screening ingestion risk; however, only the fate and transport module currently is available for use. For the RTR screening scenario, the Multimedia Ingestion Risk Calculator (MIRC) was constructed to complete the calculations required for estimating PB-HAP concentrations in farm food chain media, average daily ingestion doses, and cancer risks and chronic non-cancer HQs. The framework is conceptually identical to the ingestion exposure and risk analyses that TRIM intended to cover. Information about the current status of TRIM modules and documentation of modules developed thus far can be accessed on EPA's Technology Transfer Network (TTN) on the Fate, Exposure, and Risk Analysis website (http://www.epa.gov/ttn/fera/).

1 million or a noncancer HQ of 1 (depending on the PB-HAP) for each PB-HAP within the hypothetical environmental scenario, as described in more detail in the following sections.

Exhibit 2. Overview of Ingestion Exposure and Risk Screening Evaluation Method



2.2.1 Modeling Fate and Transport

To model chemical fate and transport in the environment when deriving emission thresholds for Tier 1, the TRIM.FaTE module of the TRIM system was used.[3] The two main components of the fate and transport modeling are (1) the modeled domain, including the meteorological data and (2) the environmental and chemical-specific properties associated with fate and transport through the environment. The hypothetical modeled domain includes a farm homestead and a fishable lake near (i.e., 2 km) an emissions source, which are assumed to be the primary food sources for exposed individuals. The spatial layout and other physical aspects of the modeled domain configuration are designed to be health-protective, which results in an ingestion exposure situation that is unlikely to be exceeded at any actual facility evaluated under the RTR program. The environmental and chemical-specific properties governing fate and transport of PB-HAPs are parameterized with either conservative (i.e., health protective) values or central-tendency values. The mix of health protective and central-tendency assumptions and parameterization is expected to result in a scenario configuration that, on average, is likely to overpredict environmental concentrations of PB-HAPs in media of interest for this evaluation. The inclusion of central-tendency values where warranted is intended to minimize the number of false positives. (See Attachment A and Addenda 1 and 2 for additional discussion on parameter values and their selection.)

Based on sensitivity analyses and model testing it is generally recognized that the spatial layout of the modeled domain (e.g, distance to a fishable lake) and the meteorological data used (or a combination of these two factors) are more influential than physical/chemical parameters in dictating the resulting chemical concentrations in air, soil, water, sediment, and fish within TRIM.FaTE. The Tier 1 assumptions about these two components of fate and transport modeling are refined with relatively more site-specific data in subsequent tiers. The spatial

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[3] http://www.epa.gov/ttn/fera/trim_fate.html

layout used to develop the threshold emission levels in Tier 1 and other details of the Tier 1 methodology are presented in Attachment A to this appendix.

2.2.2 Modeling Transfer and Uptake

MIRC was developed to conduct the required calculations involving farm food chain transfer, ingestion exposure, and risk. TRIM.FaTE outputs that are used as inputs to MIRC include:

- PB-HAP concentrations in air,
- Air-to-surface deposition rates for PB-HAPs in both particle and vapor phases,
- PB-HAP concentrations in fish tissue for fish consumed, and
- PB-HAP concentrations in surface soil and root zone soil.

From these inputs, MIRC calculates the transfer and uptake of PB-HAPs through the farm food chain using algorithms based on those included in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 2005) and biotransfer factors (e.g., soil-to-plant factors, which are the ratios of the concentrations in plants to concentrations in soil). The outputs of MIRC are PB-HAP concentrations in contaminated food items.

2.2.3 Estimating Ingestion Exposure

MIRC is also used to estimate exposure in terms of average daily doses (ADDs), normalized to body weight for the following exposure pathways:

- Incidental ingestion of soil
- Ingestion of homegrown produce
- Ingestion of homegrown beef
- Ingestion of milk from homegrown cows
- Ingestion of homegrown poultry/eggs
- Ingestion of homegrown pork
- Ingestion of fish
- Ingestion of breast milk (children <1 year old; dioxins only)[4]

Chemicals are modeled separately to evaluate the potential for risks, with exposures (in terms of ADD) for each PB-HAP summed across all ingestion exposure pathways. For the screening scenario used in Tiers 1 and 2 of this analysis, exposure characteristics were selected that result in a highly health protective estimate of total exposure. The ingestion rate for each exposure pathway listed above was set (as feasible) equal to an upper percentile value (99th percentile for fish and 90th percentile for all other food types) based on EPA's *Exposure Factors Handbook* (EPA 2011a) or other sources as appropriate. All media were assumed to be obtained from a location impacted by the modeled source. This approach results in an overestimate of total chemical exposure for a hypothetical exposure scenario. For example, the resulting total food ingestion rate is extremely high for a hypothetical consumer, with ingestion rates at the 99th percentile for fish and the 90th percentile for every other farm food type. These health protective exposure assumptions can be replaced in a site-specific assessment as appropriate (e.g., with distributions of the data for key exposure factors).

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[4] Breast milk ingestion is an important exposure pathway for lipophilic compounds like dioxins and has been shown not to contribute meaningfully for exposures to mercury, cadmium, and POM. See Section A.4.2.3 of Attachment A and Section 3.4 of Addendum 2 for full discussions of infant exposures via breast milk ingestion.

Dermal absorption of chemicals that are originally airborne is generally relatively minor and this pathway was not included in the scenario used to calculate Tier 1 emission thresholds (this topic is discussed further in Attachment A and Addendum 3).

2.2.4 Calculating Lifetime Cancer Risk and Non-Cancer HQs

Lifetime cancer risks and the potential for chronic non-cancer effects are estimated using chemical-specific oral cancer slope factors and oral reference doses. Lifetime cancer risk estimates are calculated separately for each PB-HAP. As provided in Section 5.1 of Addendum 2, age-group specific cancer risk estimates are calculated and the estimated lifetime cancer risk equals the sum of these age-group specific risks. Similarly, HQs are calculated separately for each PB-HAP and for each age group. However, as detailed in Section 5.2 of Addendum 2, the HQ for the most sensitive age group is used to determine the screening threshold emission rate.

2.2.5 Determining Threshold Emission Rates

Tier 1 emission thresholds were calculated by conducting iterative model simulations in TRIM.FaTE and MIRC using the screening scenario described above to determine emission rates for cadmium, mercury, dioxins, and POM that correspond to a cancer risk of 1 in 1 million or a chronic non-cancer HQ of 1. Given the generally health protective nature of the scenario inputs, these thresholds are assumed to be appropriate for screening facilities emitting these PB-HAPs.

3. Tier 2

The Tier 1 screening approach is, by design, generic and health protective. It was constructed for quick application to a large number of facilities in a source category with the least chance of returning false negatives for risk. Once the initial screen is complete, however, facilities that “fail” for any PB-HAPs can be scrutinized further. Based on screening analyses conducted for RTR to date, many facilities could “fail” the Tier 1 screen for some source categories. However, conducting a full site-specific analysis of all facilities that cannot be screened out in Tier 1 would not be practical.

Site-specific values for some influential variables, however, can be determined without intensive effort during the assessment. The use of these site-specific values instead of the generic values used in Tier 1 can be used to justify adjusting the screening threshold for a given PB-HAP at that facility, potentially eliminating the facility from concern while maintaining a high degree of confidence that risks above levels of concern have not been overlooked. Specifically, for Tier 2, location-specific data on two types of variables are taken into account:

- Meteorological characteristics, including the fraction of time the wind blows toward the farm and lake (using wind direction), wind speed, precipitation rate, and mixing height; and
- Location of the nearest fishable lake(s) relative to the facility[5] (including the absence of a fishable lake).

These variables affect the PB-HAP concentrations in environmental media estimated by TRIM.FaTE, but they are not related to specific exposure assumptions. The exposure

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[5] The lake size also was changed for each lake distance allowing for a constant ratio between watershed and erosion area compared with lake area within the TRIM modeling structure.

assumptions, such as ingestion rate and fraction of diet derived from the lake and farm remain at fixed, health-protective values in Tier 2. In selecting the fate and transport variables to include in Tier 2, a balance was struck between the degree of impact on the risk estimate, the ease of implementation in TRIM.FaTE, and the ease of obtaining relatively certain site-specific values for all facilities that might be evaluated under the RTR program.

For efficient Tier 2 evaluation of the impacts these parameters could have on specific facilities, a series of TRIM.FaTE simulations was performed that systematically varied the values used in the screening scenario for four of the five selected variables (lake location, wind speed, precipitation rate, and mixing height). Wind direction affects only whether the chemical mass advects toward the farm and lake, so the effect of site-specific wind directions can be evaluated outside TRIM.FaTE simulations. The values of each of the four variables were changed, independent of any other changes. The values (four to six for each variable, including the original screening scenario values) were selected using statistics on U.S. meteorological data or professional judgment to capture the expected range in the facility data. Four to six values were selected to result in a total number of runs that was reasonable. This set of values was used to develop “bins” for each variable.

Based on the TRIM.FaTE results of these simulations (and the subsequent exposure and risk characterization, conducted using MIRC), threshold adjustment factors were calculated for each unique combination of the five parameters, for each PB-HAP. These adjustment factors represent the ratio between the risk metric (i.e., cancer risk or HQ) obtained using the baseline Tier 1 screening scenario and the risk metric obtained from the adjusted run. For a given facility and PB-HAP, an adjusted Tier 2 emission threshold can be estimated by multiplying the Tier 1 emission threshold by the adjustment factor that best corresponds to the meteorological conditions present at the site and the presence and location of lakes at the site.

To facilitate the implementation of this approach without requiring facility-specific data searches for each new source category evaluated, databases of the relevant U.S. meteorological and lake data were created that could be accessed readily during a Tier 2 evaluation. These databases are described in more detail in Attachment B. The meteorological database is based on the same hourly meteorology data used for RTR inhalation assessments. The meteorology database includes annual summary statistics on wind direction, wind speed, precipitation, and mixing heights for more than 800 surface stations located throughout the United States and is paired with their closest upper-air station with available data (data available from the National Oceanic and Atmospheric Administration). The lake database, based on U.S. Geological Survey (USGS) data and including location and size information, consisted of hundreds of thousands of water bodies classified as “Lake/Pond” or “Reservoir” but not designated for disposal, evaporation, or treatment. To focus on lakes that can support angling of upper trophic level fish, only lakes greater than 100 acres were included. Very large lakes and bays (i.e., those larger than 100,000 acres) are not included because their watersheds are too large and their lake dynamics are too complex to realistically model in the TRIM.FaTE system. Lakes and bays larger than 100,000 acres include the Great Lakes, the Great Salt Lake, Lake Okeechobee, Lake Pontchartrain, Lake Champlain, Green Bay, and Galveston Bay. These databases are described in more detail in Attachment B.

When the Tier 2 screening is conducted, three additional processing steps are completed for each facility and PB-HAP that will be analyzed in Tier 2 before looking up the appropriate adjustment factors. First, using GIS software, each relevant lake within a 50-km of the facility is identified and matched to its respective directional “octant” relative to the facility. For the purposes of Tier 2, a “relevant” lake meets the size and designation criteria discussed in the previous paragraph. Second, the lakes are manually screened to remove lakes whose names indicate uses related to disposal, evaporation, or treatment (sometimes the name indicates one of these uses while the USGS designations do not). Third, the lakes around the facility that remain after the first two processing steps are screened to include only the closest lake for each octant.

To access these databases, a Microsoft® Excel™ tool was created that merges the TRIM.FaTE Tier 2 adjustment factors with the lake and meteorology information relevant to a specific facility from the databases. In the tool, each facility is matched with the same meteorology station used in RTR inhalation assessments, and the values for the four relevant meteorological parameters at that station are recorded. The distances from the facility to the nearest lakes estimated using GIS are also imported. These five values become the set of facility-specific parameters. Then, the adjustment factors for each chemical for the combination of these five variables are determined. As described above, the Tier 1 screening emission threshold is then multiplied by the appropriate adjustment factor to obtain an updated, Tier 2 emission threshold for that PB-HAP. More information about Tier 2 assessment methods can be found in Attachment B.

4. Refined Multipathway Assessment

If, based on results of the screening analyses, a risk assessor concludes that there is a reasonable probability that individuals could be adversely affected by the facility emissions, a refined site-specific multipathway analysis might be performed. Examples of recent refined multipathway analyses include residual risk assessments of a petroleum refinery facility (EPA 2013), two secondary lead smelting facilities (EPA 2011b), assessments of two coal-fired electric utility units conducted in support of EPA's utility rule (EPA 2011c), and a case study evaluation of a Portland cement facility included with other RTR materials presented to the Science Advisory Board for review (Appendix I of EPA 2009).

Whereas a Tier 2 analysis incorporates some binned site-specific and regional information on meteorology and water bodies, a refined multipathway analysis uses detailed site-specific data to parameterize more accurately (to the extent possible) each important parameter that affects pollutant fate and transport. These site-specific properties are incorporated into model scenarios configured in TRIM.FaTE and MIRC. Important site-specific properties likely would include emission release height and plume buoyancy, hourly meteorology (e.g., wind flow, temperature, mixing height, and precipitation), surface compartments based on watershed and terrain data, local farms and water bodies, land use, soil, erosion, runoff, surface water and sediment, water transfer, and aquatic ecosystems.

The outputs from the site-specific run of TRIM.FaTE (i.e., chemical concentrations in environmental media and fish) are used in MIRC to produce estimates of exposure and health risk (i.e., risk and/or HQ values). Additional analyses of the media concentrations, exposure estimates, and risk estimates for the various ingested media using a range of ingestion rates for each modeled PB-HAP allows the risk assessor to understand, based on TRIM.FaTE and MIRC, the sources and pathways of possible human health risk from emissions of PB-HAPs.

5. References

EPA (U.S. Environmental Protection Agency) (2005) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. EPA Office of Solid Waste. EPA-530/R-05-006. 09/2005.

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Sources and Portland Cement Manufacturing. EPA Office of Air Quality Planning and Standards. EPA-452/R-09-006. 06/2009.

EPA. (2011a) Exposure Factors Handbook: 2011 edition. National Center for Environmental Assessment, Washington, DC; EPA/600/R-09/052F. Available from the National Technical Information Service, Springfield, VA, and online at http://www.epa.gov/ncea/efh.

EPA. (2011b) Human Health Multipathway Residual Risk Assessment for the Secondary Lead Smelting Source Category. Draft Report. Prepared by ICF International for EPA Risk and Exposure Assessment Group. 02/15/2011.

EPA. (2011c) Technical Support Document: Case Study Analyses of Potential Local-scale Human Health Risks Associated with Mercury Emissions from Electric Utility Steam-generating Units. Draft. Prepared by ICF International for EPA Office of Air Quality Planning and Standards. 02/17/2011.

EPA. (2013) Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Petroleum Refineries Sector. Draft. Prepared by ICF International for EPA Office of Air Quality Planning and Standards. 04/10/2013.

Attachment A. Tier 1 Screening Methodology

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CONTENTS, ATTACHMENT A

EXHIBITS, ATTACHMENT A

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A.1 Introduction

As discussed in the Overview Document, the U.S. Environmental Protection Agency (EPA) will implement a tiered approach to evaluate multipathway exposures and human health risks for the Risk and Technology Review (RTR) program. EPA's assessment for RTR focuses on persistent and bioaccumulative hazardous air pollutants (PB-HAPs) that the Office of Air Quality Planning and Standards (OAQPS) has identified as candidates for multipathway risk assessments (selection of the PB-HAPs is discussed in Section A.2.2). In the first tier, a screen is conducted that focuses on the identity and magnitude of emissions of PB-HAPs,from a given facility to determine whether a facility passes certain human health risk-based criteria. Sources that are "screened out" in the Tier 1 analysis are assumed to pose no risks to human health above levels of concern and and are not considered in further analyses. For sources that do not pass the Tier 1 screen, more refined assessments, up to and including site-specific multipathway assessments, can be conducted as appropriate.

This Attachment describes the technical basis for the first, screening-level tier of EPA's multipathway human health evaluation of PB-HAP emissions from RTR sources. Specifically, the scenarios, models, configurations, and inputs used to derive screening threshold emission rates in the first tier of the approach are described in detail in the following sections.

- Section A.2 presents an overview of how screening is conducted in Tier 1, the chemicals and exposure scenario evaluated in Tier 1, and the models and methods used to conduct the screen.
- Sections A.3 and A.4 present technical descriptions of the hypothetical environmental setting and the exposure modeling scenario used in Tier 1 as well as the models used in the screen.
- Section A.5 provides a brief discussion of the screening threshold emissions for each of the chemicals assessed. References cited in this report are listed in Section A.6.

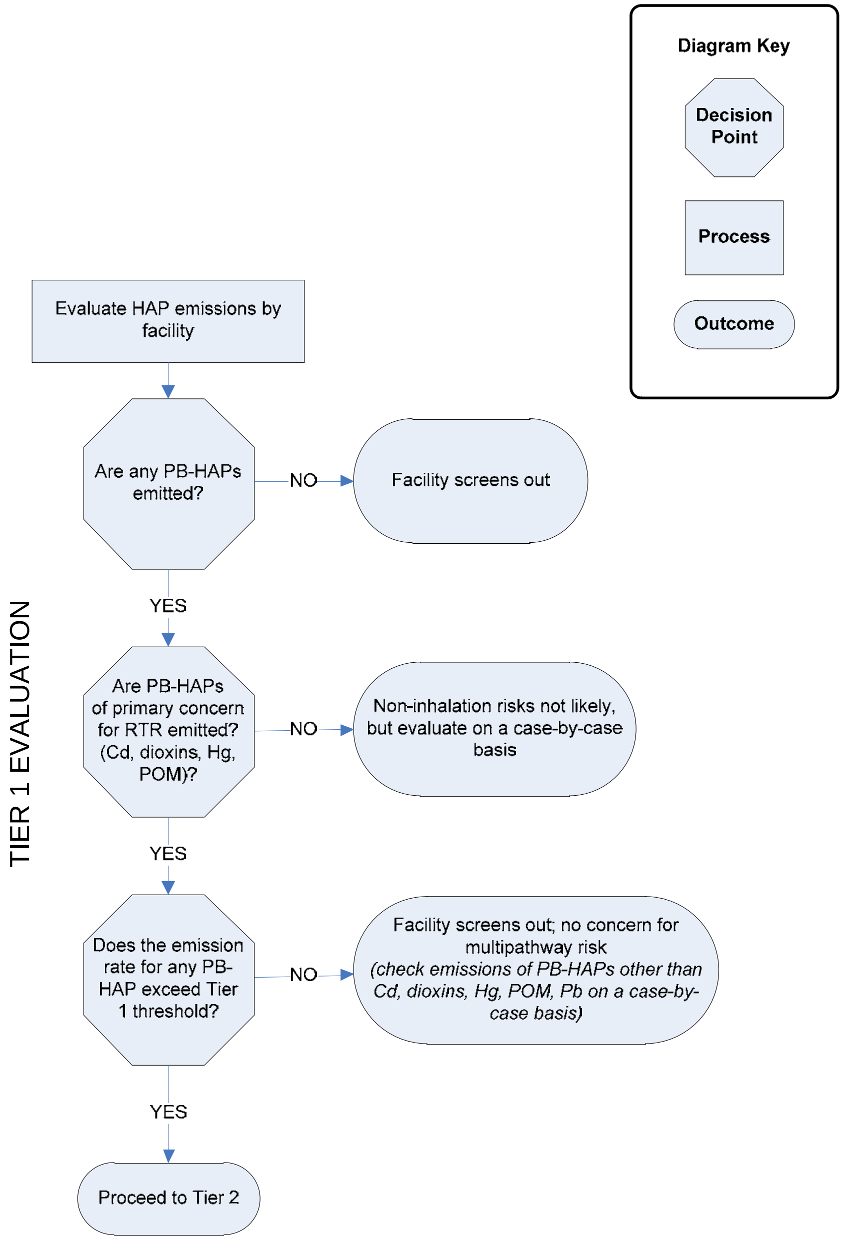
The Tier 2 screen is discussed separately in Attachment B.

A.2 Summary of Approach

A.2.1 Overview

The Tier 1 approach for evaluating non-inhalation, multipathway exposures to PB-HAPs for RTR is diagrammed in Exhibit_Att A-1. Air toxics emitted by a source under consideration are reviewed to determine, first, whether emissions are reported for any of the four PB-HAPs of concern for non-inhalation pathways. If such emissions are reported, the emission rates are compared to Tier 1 threshold-screening emission rates that have been derived using the TRIM-based Tier 1 scenario described in this document (see Exhibit_Att A-2 for threshold screening emission rates).

Exhibit_Att A-1. Conceptual Decision Tree for Evaluation of Non-Inhalation Exposures of PB-HAPs



The TRIM-based multipathway modeling configuration, referred to in this document as the Tier 1 scenario, forms the technical basis for determining the Tier 1 emission thresholds. The term, Tier 1 scenario, is used to refer collectively to the specific TRIM.FaTE and exposure modeling configuration described herein, including the set of assumptions and input values associated with a hypothetical watershed and the exposure and risk scenarios evaluated for this watershed. The Tier 1 scenario is a static configuration, and its primary purpose is as a modeling tool to calculate the Tier 1 emission rate thresholds for PB-HAPs of concern.

The two potential outcomes of the Tier 1 evaluation are:

- Non-inhalation exposures are unlikely to pose a human health problem (i.e., the emissions evaluated “pass” the screen); or
- Risks above the levels of concern from non-inhalation exposures cannot be ruled out.

An ideal screening approach strikes a balance between being *health-protective*—to ensure that risks above levels of concern are identified, and being *accurate*—to minimize results suggesting that additional analysis is required when in fact the actual risk is low. Typically, gains in accuracy in environmental modeling are accompanied by additional resource requirements. Stated another way, a suitable approach minimizes both false negatives and false positives. False negatives (i.e., results that suggest that the risk is acceptable when in fact the actual risk is high) can lead to inappropriate and non-protective health or environmental policy decisions. False positives (i.e., results that suggest more assessment is required when in fact the actual risk is low) can result in wasted resources by leading to additional, unnecessary analysis. For the evaluation of multipathway human health exposures to PB-HAPs, the methods for screening described in this document are intended to achieve this balance.

Because the Tier 1 evaluation enables EPA to confidently eliminate from consideration those facilities where risks from non-inhalation exposures are projected to be minimal, resources can be targeted toward those facilities that do not pass the screening test. For facilities that do not pass the Tier 1 screening, in additional tiers of analysis, some of the Tier 1 parameters are reassessed, and if appropriate, are changed to more accurately reflect site-specific characteristics. With each successive tier of the assessment, additional Tier 1 assumptions are evaluated and refined to better reflect site-specific characteristics of the facility being modeled.

The Tier 1 screening evaluation for RTR compares reported air emission rates of PB-HAPs (summed by PB-HAP for each facility) to screening threshold emission rates derived using the Tier 1 scenario. A threshold emission rate is the level that, when input to a risk model using emissions as a parameter, corresponds to a specified cancer risk or non-cancer hazard quotient (HQ) that, for the purposes of the evaluation being conducted, is assumed to be below a level of concern. Tier 1 threshold emission rates were calculated for a cancer risk of 1 in 1 million or an HQ of 1.0 and are presented in Exhibit_Att A-2.[6] Conceptually, a threshold level for the RTR multipathway screening evaluation could be obtained by back-calculating the emission rate that results in the specified cancer risk or HQ level, taking into account the exposure and fate and transport calculations included in the model. Because the models used in this assessment are not designed to run “backwards,” the rates instead were derived from regression equations established following a series of TRIM.FaTE and exposure/risk model runs spanning a wide

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[6] For chemicals known to cause both cancer and chronic non-cancer impacts, *and* for which acceptable quantitative dose-response values are available for both cancer and non-cancer endpoints, the endpoint that results in the lower threshold emission level is used for screening (i.e., the threshold will be based on the effect that occurs at the lower exposure level). For the set of PB-HAPs for which screening threshold levels have been derived, only chlorinated dibenzo-dioxins and -furans meet both criteria. Because the cancer dose-response value is lower than that for non-cancer effects, the screening threshold value is based on the cancer endpoint.

range of emission rates for each chemical. The estimated screening-level emission rates are verified by performing model runs using the estimated threshold emission rate to confirm that the emission rates result in a cancer risk of 1 in 1 million or an HQ of 1.0.

Exhibit_Att A-2. Emission Thresholds for Screening of Multipathway Exposures

Chemical	Screening Threshold Emission Rate (TPY)	Basis of Threshold (Type of Health Endpoint)
POM (as benzo(a)pyrene equivalents)[a]	2.58E-03	Cancer
Dioxins (as 2,3,7,8-TCDD equivalents)[a]	2.81E-09	Cancer
Cadmium	1.18E-02	Non-cancer
Mercury (as divalent mercury emissions)	3.16E-04	Non-cancer

TPY = U.S. short tons per year
[a]See Section A.2.7 for a discussion on the derivation of equivalent emissions.

The more probable risk for each emission rate would be lower than the level corresponding to the screening threshold risk quantities in nearly all circumstances, given the health protective and hypothetical nature of the Tier 1 screening configuration. It is considered very unlikely that the estimated risk at a real site would be greater than the estimated risk for the simulated Tier 1 scenario at equivalent emission rates. This is because the Tier 1 scenario assumes, for many of the most risk influential parameters in the model, parameter values that result in high-end risk estimates. In the real world, the probability of such risk-maximizing conditions prevailing across multiple parameters is very low. For example, the Tier 1 scenario assumes a fishable lake approximately 2 km from any given facility, when in reality, a lake may be more than 50 km away. Additional conservative assumptions used in the Tier 1 screen are described in Section A.4.4 of this Attachment.

Tier 1 emission thresholds were developed individually for elemental and divalent mercury. Both were based on the lower of the thresholds associated with multipathway exposures to divalent mercury and methyl mercury.[7] Only speciated emissions of divalent mercury are screened because the sum of elemental mercury emissions across all National Emission Inventory (NEI) facilities is less than the elemental mercury screening threshold level. See Section A.5.3 for a detailed discussion of mercury.

A.2.2 Chemicals of Potential Concern

EPA's assessment of multipathway human exposures for RTR focuses on PB-HAPs [8] that the Office of Air Quality Planning and Standards (OAQPS) has identified as candidates for multipathway risk assessments. OAQPS developed a list of 14 chemicals and chemical groups that are PB-HAPs based on a two-step process taking into account the following (EPA 2004a):

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[7] Note that TRIM.FaTE models the transformation of mercury within the environment; thus, emissions of both divalent and elemental mercury will result in multipathway exposures to elemental mercury, methyl mercury, and divalent mercury.

[8] Although POM (polycyclic organic matter) is the name of the HAP listed in the Clean Air Act, the term "polycyclic aromatic hydrocarbons" or PAHs is used in many cases. Much of the literature regarding toxicity and fate and transport of this chemical group refers to PAHs rather than POM. In addition, the individual POM species that are of concern with respect to health risk for RTR evaluations are all PAHs (i.e., there are no POM species explicitly evaluated for RTR that do not include an aromatic ring). The terms are used interchangeably throughout this text.

- their presence on three existing EPA lists of persistent, bioaccumulative, and toxic substances, and
- a semiquantitative ranking of toxicity and bioaccumulation potential of the entire list of HAPs.

The list's development and utility in hazard identification for multipathway risk assessment are explained further in Chapter 14 and Appendix D of Volume I of EPA's *Air Toxics Risk Assessment (ATRA) Reference Library* (EPA 2004a). Exhibit_Att A-3 presents the 14 chemicals and groups that are PB-HAPs.

Exhibit_Att A-3. OAQPS PB-HAP Compounds

PB-HAP Compound[a]	Addressed by Screening Scenario?
Cadmium compounds	Yes
Chlordane	No
Chlorinated dibenzodioxins and furans	Yes
DDE (1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene)	No
Heptachlor	No
Hexachlorobenzene	No
Hexachlorocyclohexane (all isomers)	No
Lead compounds	No
Mercury compounds	Yes
Methoxychlor	No
Polychlorinated biphenyls	No
Polycyclic organic matter (POM)	Yes
Toxaphene	No
Trifluralin	No

[a] Source of list: EPA (2004a).

The screening scenario described in this document is not configured for evaluating the risk potential for all 14 PB-HAPs on the list. Currently, the scenario can only be used to estimate exposures and risks quantitatively for 4 of the 14 PB-HAPs (as indicated in Exhibit_Att A-3). These four PB-HAPs are the focus of the current scenario because, based on current emissions, bioaccumulation potential, and toxicity considerations, they are expected to pose the vast majority of the non-inhalation risks to humans from air emissions at sources subject to residual risk provisions of the Clean Air Act.[9]

A.2.3 Conceptual Exposure Scenario

A conceptual exposure scenario was developed that encompasses the specific exposure routes and pathways of interest for the four PB-HAPs that are assessed in the Tier 1 analysis. Exposure routes and pathways describe the movement of air toxics from the point of release to the point where exposure occurs and generally consist of the following elements:

- Release to the environment (i.e., emissions);

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[9] Potential impacts on human health from non-inhalation exposures to lead are evaluated for RTR using the National Ambient Air Quality Standard for lead, which takes into account multipathway risks. Non-inhalation exposures to the other nine PB-HAPs not addressed by the modeling scenario discussed in this report will be evaluated on an individual facility or source category basis as appropriate.

- A retention medium, or a transport mechanism and subsequent retention medium in cases involving media transfer of chemicals;
- A point of potential human contact with the contaminated medium; and
- An exposure route.

An exposure route is the particular means of entry into the body. Receptors are exposed to chemicals emitted to the atmosphere via two primary routes: either directly via inhalation, or indirectly via ingestion or dermal contact with various media that have been contaminated with the emitted PB-HAPs. (Inhalation pathways are assessed separately and are not considered in the Tier 1 assessment presented here.)

PB-HAPs can persist in the environment for long periods of time and also build up in soil and in the food chain, including fish, fruits and vegetables, and animal products (e.g., meat, dairy, eggs). For this reason, ingestion of foods grown within an area impacted by RTR sources can be an important source of exposure to PB-HAPs.

To assess risks from hazardous waste combustion facilities, EPA identified several hypothetical receptor scenarios, noting that these scenarios are considered appropriate for a broad range of situations, rather than to represent any actual scenario. These scenarios are described in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities,* or HHRAP (EPA 2005a). In this document, EPA recommends assessment of the following hypothetical receptors: a Farmer, Farmer Child, Resident, Resident Child, Fisher, Fisher Child, Acute Receptor, and Nursing Infant. These receptors are distinguished by their pathways of exposures. EPA further notes in HHRAP that some exposure settings might warrant including additional exposure pathways; such as including exposure through fish ingestion for the farmer receptor. For the RTR screening scenario, risks are assessed for a single hypothetical receptor. Based on the guidance provided in HHRAP, a health protective exposure scenario was developed whereby the hypothetical receptor receives ingestion exposure via both the farm food chain and the fish ingestion pathways. The exposure scenario for the RTR Tier 1 analysis includes the following ingestion pathways:

- Incidental ingestion of soil,
- Ingestion of homegrown fruits and vegetables,
- Ingestion of homegrown beef,
- Ingestion of dairy products from homegrown cows,
- Ingestion of homegrown poultry and eggs,
- Ingestion of homegrown pork,
- Ingestion of locally caught fish, and
- Ingestion of breast milk (for children less than 1 year old and for dioxins only).[10]

As discussed in detail in Section A.4.2, exposure via these pathways is assessed for adults, various age categories for children, and nursing infants (for dioxins only).

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[10] Breast milk ingestion is an important exposure pathway for lipophilic compounds like dioxins and has been shown not to contribute meaningfully for exposures to mercury, cadmium, and POM. See Section A.4.2.3 of this attachment and Section 3.4 of Addendum 2 to this attachment for full discussions of infant exposures via breast milk ingestion.

Other non-inhalation exposure routes of possible concern for PB-HAPs discussed in HHRAP include the use of surface waters as a drinking water source and dermal exposure. These exposure routes, however, are not evaluated in the current assessment. The drinking water exposure pathway is not likely for the modeling scenario developed for this analysis because the likelihood that humans would use a lake as a drinking water source was assumed to be low.[11] Dermal absorption of chemicals that are originally airborne has been shown to a relatively minor pathway of exposure compared to other exposure pathways (EPA 2006, Cal/EPA 2000). Preliminary calculations of estimated dermal exposure and risk of PB-HAPs, presented in Addendum 3 to this attachment, showed that the dermal exposure route is not a significant risk pathway relative to ingestion exposures.

A.2.4 Approach to Development of the Tier 1 Scenario

The TRIM-based Tier 1 scenario described in this document is used to provide a means to qualitatively estimate the potential for non-inhalation risks above the levels of concern for PB-HAPs emissions from facilities in the context of residual risk assessments conducted as part of RTR. The Tier 1 scenario used to derive the threshold emission rates is not intended to be representative of any particular situation. Rather, it was developed for the purpose of RTR to portray a hypothetical exposure scenario that will generate emissions screening levels that are health protective for any potential exposure situation that might plausibly be encountered in the United States. A range of conditions was assessed when conceptualizing and developing the screening scenario. The final configuration was chosen so that for a given individual, any potential long-term exposure levels for a given geographic region would be reasonably unlikely to exceed those of the Tier 1 configuration. These criteria were met by constructing a hypothetical scenario that would be health-protective in key aspects, including spatial orientation, meteorology, types of exposures, and ingestion rates. The overall result is a scenario that is unlikely to occur at any one location but has a high likelihood of representing the upper end of all potential exposures. This latter aspect accomplishes the goal of striking a balance between health protectiveness and the level of accuracy called for in the ideal screening approach previously discussed.

The development and application of the Tier 1 scenario for residual risk evaluations considered EPA's technical and policy guidelines presented in the *Residual Risk Report to Congress* (EPA 1999); Volumes I and II of the *Air Toxics Risk Assessment Reference Library* (EPA 2004a, 2005a); and other EPA publications. The scenario described in this appendix is the culmination of analyses completed since 2005; it provides the basis for an efficient and scientifically defensible method for screening multipathway human health risk and provides a solid baseline from which to perform Tier 2 analyses, as described in Attachment B. Nevertheless, this scenario should not be considered "final" but rather a product that can continue to evolve based on feedback from the scientific community and Agency reviewers, lessons learned as the scenario is further applied for RTR, variations in EPA's needs and requirements, and other factors.

A.2.4.1 Modeling Framework

The approach for multipathway risk screening and evaluation for RTR can be divided into four steps:

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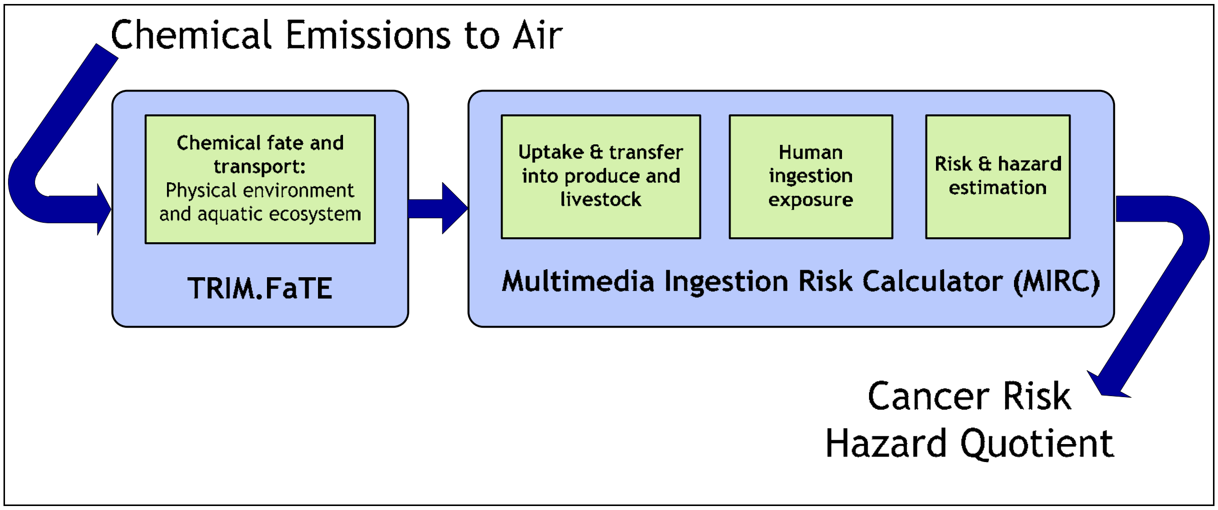
[11] An exception to this generality would be reservoirs used for drinking water supplies. This situation might be worthy of additional analysis, if warranted by the characteristics of a given assessment (e.g., to estimate PB-HAP concentrations in treated drinking water derived from reservoirs).

1. Fate and transport modeling of PB-HAPs emitted to air by the source that partition into soil, water, and other environmental media (including fish[12]);
2. Modeling of transfer and uptake of PB-HAPs into farm food chain media (e.g., produce, livestock, dairy products) from soil and air;
3. Estimating exposures from ingestion of selected media and estimating average daily ingestion doses for a hypothetical human receptor; and
4. Calculating lifetime cancer risk estimates or chronic non-cancer HQs, as appropriate, for each PB-HAP and comparing these to selected evaluation criteria.

The relationship among these four processes is shown in Exhibit_Att A-4.

Exhibit_Att A-4. Overview of Ingestion Exposure and Risk Screening Evaluation Method



As shown in Exhibit_Att A-4, two models are used to evaluate the four steps outlined above. EPA's TRIM methodology was conceived as a comprehensive modeling framework for evaluating risks from air toxics, and the TRIM system was designed to address each of the four steps involved in screening ingestion risk.[13] Currently, however, only one component corresponding to the first step included in Exhibit_Att A-4—the fate and transport module—is available for application in an ingestion risk assessment. EPA has completed some development activities for TRIM.Expo-Ingestion and TRIM.Risk-Human Health, two additional modules that cover the other three steps. Modeling software, however, is not currently available for these modules. For the RTR screening scenario, the Multimedia Ingestion Risk Calculator (MIRC), a Microsoft® Excel™-based computing framework, was constructed to complete the calculations required for estimating PB-HAP concentrations in farm food chain media, average daily ingestion doses, and cancer risks and chronic non-cancer HQs. This framework is

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[12] As discussed below, concentrations in fish calculated by the TRIM.FaTE model were used to estimate ingestion exposures for humans consuming fish. Modeling of fish concentrations is therefore discussed herein as part of the fate and transport modeling. Uptake of PB-HAPs into all other biotic media assumed to be ingested is modeled in the second step of the modeling framework.

[13] Information about the current status of TRIM modules and comprehensive documentation of modules developed thus far can be accessed on EPA's Technology Transfer Network (TTN) on the Fate, Exposure, and Risk Analysis website (http://www.epa.gov/ttn/fera/).

conceptually identical to the ingestion exposure and risk analyses that TRIM is intended to cover.

A.2.4.2 Model Configuration and Parameterization

The Tier 1 scenario is intended to reduce the possibility that EPA would underestimate potential multipathway human health risks. Although the health protective approach likely overestimates risk, EPA determined that this approach is appropriate for the purposes of an initial multipathway screening assessment. As was done with the preliminary multipathway screening for RTR conducted in 2006 (EPA 2006), exposures were modeled for a hypothetical farm homestead and fishable lake located adjacent to an emissions source. The hypothetical individual for which exposures were calculated was assumed to derive all potentially contaminated foodstuffs from adjacent locations, and many of the exposure/activity assumptions (e.g., amount of food consumed per day) were selected from the upper ends of representative exposure parameter distributions.

The physical/chemical environment represented in the screening scenario was parameterized with two types of values. One type is typical values, such as national averages. The second type is health-protective values, or values that would tend to overestimate concentrations in media driving ingestion exposures for humans, based on knowledge of exposure patterns. In general, the spatial and temporal aspects of the scenario and the components of the scenario that influence air concentrations and deposition rates (which in turn affect all other exposures) were defined to be health protective. Chemical-specific and non-chemical-specific properties of the environmental media were parameterized with either typical or health protective values; properties having greater uncertainty were assigned a greater level of health protective bias. The spatial layout of the Tier 1 scenario and the meteorological data (or a combination of these two factors) are generally more influential than physical/chemical parameters in dictating the screening model outcomes, taking into account the potential range of variation in possible values. For example, where and how the layout is spatially oriented relative to the dominant wind direction can dramatically affect the concentrations in air, thereby driving estimated concentrations of PB-HAPs in soil, water, and biota. In contrast, relatively large changes in soil characteristics within the range of possible values (e.g., organic carbon content, water content) typically result in relatively small changes in media concentrations.

The mix of health protective and central-tendency assumptions and parameterization is expected to result in a scenario configuration that, on average, is likely to overpredict environmental concentrations of PB-HAPs in media of interest for this evaluation. Given the intended application of this scenario as a screening tool, this health protective bias was deliberate, because of the desire to ensure that risks above levels of potential concern are not overlooked (i.e., to minimize false negatives). Although the inclusion of central-tendency values where warranted is intended to minimize the number of false positives, some false positives are to be expected from a screening scenario. False positives are addressed in subsequent tiers of the screening evaluation for a particular source.

A.2.5 Fate and Transport Modeling (TRIM.FaTE)

The fate and transport modeling step depicted in the first box in Exhibit_Att A-4 is implemented for RTR using the Fate, Transport, and Ecological Exposure module of the TRIM modeling system (TRIM.FaTE).[14] In developing the Tier 1 scenario, Version 3.6.2 of TRIM.FaTE was used to model the fate and transport of emitted PB-HAPs and to estimate concentrations in

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[14] TRIM.FaTE is a spatially explicit, compartmental mass balance model that describes movement and transformation of pollutants over time, through a user-defined, bounded system that includes both biotic and abiotic compartments. Outputs include pollutant concentrations in multiple environmental media and biota.

relevant media. Additional information about TRIM.FaTE, including support documentation, software, and the TRIM.FaTE public reference library, is available at http://www.epa.gov/ttn/fera/.

The algorithms used to model mercury species and polyaromatic hydrocarbons (PAHs) are described in Volume II of the *TRIM.FaTE Technical Support Document* (EPA 2002a). A comprehensive evaluation of the performance of TRIM.FaTE for modeling mercury was documented in Volumes I and II of the T*RIM.FaTE Evaluation Report* (EPA 2002b, 2005b). Algorithms specific to the fate and transport of 14 chlorinated dibenzo-dioxin and -furan congeners were added following the addition of those for mercury and PAHs. Documentation of the application of TRIM.FaTE for dioxin emissions is contained in the third volume of the *TRIM.FaTE Evaluation Report* (EPA 2004). More recently, the TRIM.FaTE public reference library was updated to include information on modeling for cadmium. In general, many of the algorithms and properties included in the public reference library that are used to model mercury (except for the mercury transformation algorithms) are also applicable to cadmium. Comprehensive technical documentation of TRIM.FaTE algorithms specific to cadmium has not yet been compiled; however, all chemical-specific properties used by TRIM.FaTE to model cadmium (as well as PAHs, mercury, and dioxins) are documented in Addendum 1 to this attachment. Based on a thorough 2011 evaluation of TRIM.FaTE performance in modeling mercury's fate, transport, and transformation in the aquatic food web, a zooplankton compartment was added to TRIM.FaTE's aquatic compartment to increase the resolution and accuracy of the aquatic food web modeling. Parameterization of the TRIM.FaTE scenario used for RTR screening is described in more detail in Section A.3.

A.2.6 Exposure Modeling and Risk Characterization (MIRC)

The algorithms included in MIRC that calculate chemical concentrations in farm food chain media and ingestion exposures for hypothetical individuals were obtained from EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities,* or HHRAP (EPA 2005a).[15] These algorithms, and the required exposure factors and other parameter values, were compiled into a database. An overview of the computational processes this tool carries out and the types of input data it requires is presented in Exhibit_Att A-5. This exhibit demonstrates the general relationships between the relevant TRIM.FaTE outputs (i.e., chemical concentrations in environmental media and fish) and the ingestion exposure and risk calculations carried out using MIRC. Additional discussion of exposure and risk calculations for the Tier 1 scenario is presented in Section A.4 and Addendum 2 to this attachment, and all inputs required by these calculations are documented in Addendum 2.

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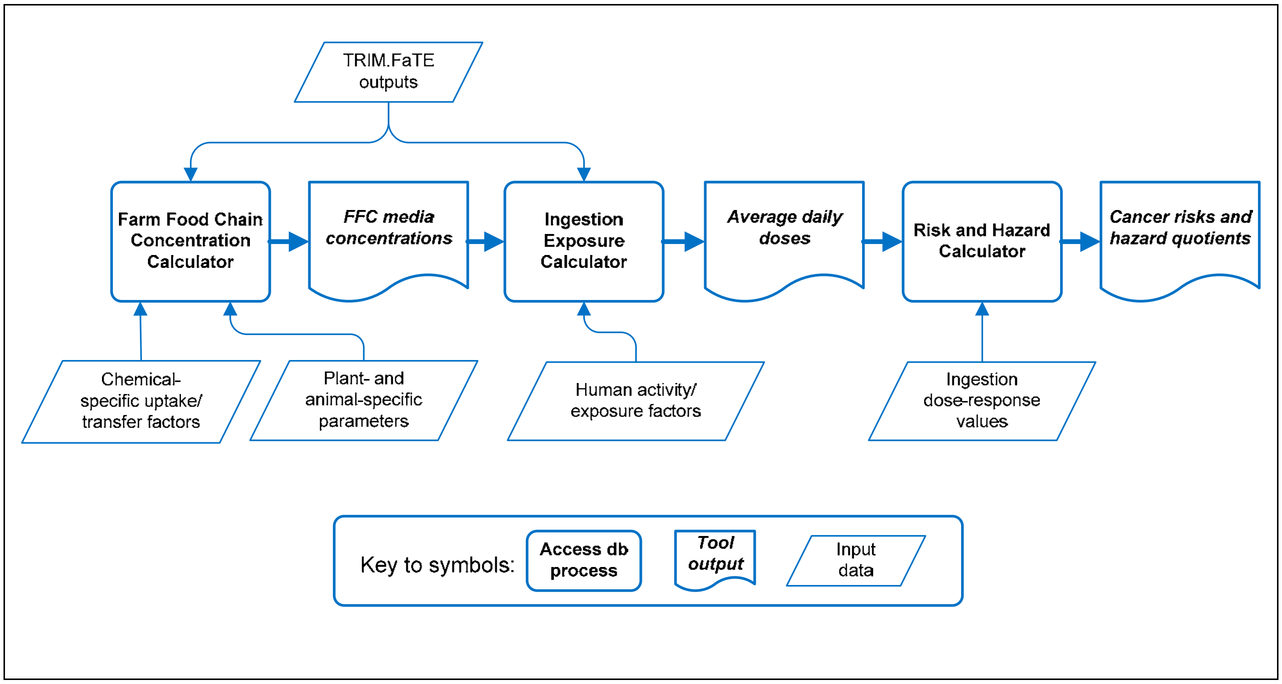
[15] The farm food chain calculations and ingestion exposure equations to be included in the TRIM.Expo software are expected to be very similar to those included in HHRAP.

Exhibit_Att A-5. Overview of Process Carried Out in the Multimedia Ingestion Risk Calculator



A.2.7 Implementation of Risk-based Emission Scaling Factors for POM and Dioxin Emissions

Two of the four PB-HAPs for which screening emission thresholds have been developed for RTR—POM and dioxins—are chemical groups comprising numerous individual entities. The members of these categories reported in NEI include both specific chemicals and groups containing multiple chemicals. For example, for POM, emissions reported in NEI include various species, such as benz[a]anthracene, 2-methylnaphthalene, and chrysene, as well as non-specific entries, such as “PAH, total.” The constituents included in the POM and dioxin PB-HAP categories are grouped together not only because they are types of the “same” HAP, but also because members of these groups are assumed to have similar characteristics with respect to toxicity and behavior in the environment.

To facilitate a practical application of the multipathway screening methods for RTR, reported emissions of POM and dioxins are normalized or scaled to a single reference chemical for each group. The reference chemicals used in RTR for POM and dioxins are benzo[a]pyrene and 2,3,7,8-TCDD, respectively. These compounds were selected because they are relatively well-studied among the members of the two groups and are also among the most toxic species within each group.

Derivation of appropriate scaling factors begins with an evaluation of the basic relationship used to characterize health risk:

$$Risk \propto (Exposure\ Concentration) \times (Toxicity)$$

For a given air pollutant, the incremental exposure concentration is directly proportional to the emissions of that substance. That is, as the emissions increase, so too does the exposure to that substance. Furthermore, toxicity is assumed to increase linearly with concentration. Consequently, emissions of one substance (e.g., chrysene) can be scaled proportional to a reference compound (e.g., benzo(a)pyrene or BaP) by applying weighting factors corresponding to the relative differences in exposure behavior and toxicity. Using the POM group as an example and BaP as the reference compound, this scaling can be expressed through an equation as follows:

$$Emiss_{PAHi:BaP} = Emiss_{PAHi} \times EEF_{PAHi:BaP} \times TEF_{PAHi:BaP}$$

where:

$\mathrm{Emiss}_{PAHi:BaP}$ = Risk-weighted emissions of PAH_i (weighted according to cancer risk relative to BaP for oral exposures)

$Emiss_{PAHi}$ = Emission rate of PAH_i

$EEF_{PAHi:BaP}$ = Exposure equivalency (weighting) factor accounting for difference in relative oral exposure between PAH_i and BaP

$TEF_{PAHi:BaP}$ = Toxicity equivalency (weighting) factor accounting for difference in relative toxicity via oral route between PAH_i and BaP

In combination, the product of the EEF and TEF for a given substance is considered to be a “risk equivalency factor” for the purposes of RTR evaluations that enables scaling of emissions of a given substance for a given exposure scenario.

The TEF for each PAH and dioxin species can be calculated on the basis of relative toxicities. Toxicities were not evaluated separately for RTR but are based on analyses conducted by EPA elsewhere. For PAHs, oral toxicity values for individual species have been derived following the same approach used to develop inhalation toxicity values. For dioxins, TEFs are based on the relative toxicities developed by EPA recently and are ultimately based on the values developed by the World Health Organization (van den Berg et al. 2006). Refer to Attachment B for more information on these values.

The EEFs can be calculated directly for each individual chemical that can be modeled in TRIM.FaTE and MIRC. TRIM.FaTE is configured for 14 POM congeners and 17 dioxin/furan congeners. For these substances, EEFs were calculated directly using the modeling approach and parameterization scheme for the Tier 1 scenario described in this document. Several other POM and dioxin emissions, however, are reported in the NEI. For these, exposure surrogates must be assigned after evaluating the correlation between chemical properties of the POM or dioxin congener and exposure quantified as lifetime average daily dose. The specific calculations for EEFs and exposure surrogates for each chemical group are discussed in the sections that follow.

A.2.7.1 Calculation of Scaling Factors for POM Congeners

The calculated EEFs, TEFs, and total REFs for the 14 POM congeners that are configured in TRIM.FaTE, plus 15 others not configured in TRIM.FaTE, are shown in Exhibit_Att A-6. To determine appropriate exposure surrogates for chemicals not parameterized in TRIM.FaTE, EPA evaluated the relationships between chemical-specific properties (e.g., K_{ow} and Henry’s law constant, k_h) and intermediate modeled values (e.g., deposition, soil concentration) and exposure in terms of lifetime average daily dose (LADDs) where the average daily doses (ADDs) for the youngest two age groups were adjusted by the age-dependent adjustment factors (ADAFs) to account for the mutagenic mode of action of PAHs. The correlation between K_{ow} and exposure is stronger than for any other chemical-specific property. Exposure surrogates were thus identified for each congener by calculating Total Lifetime Average Daily Dose (Age Adjusted) for each based on the congener's K_{ow} and the power regression of the modeled PAHs. Exhibit_Att A-7 shows that as K_{ow} increases, so too does exposure.

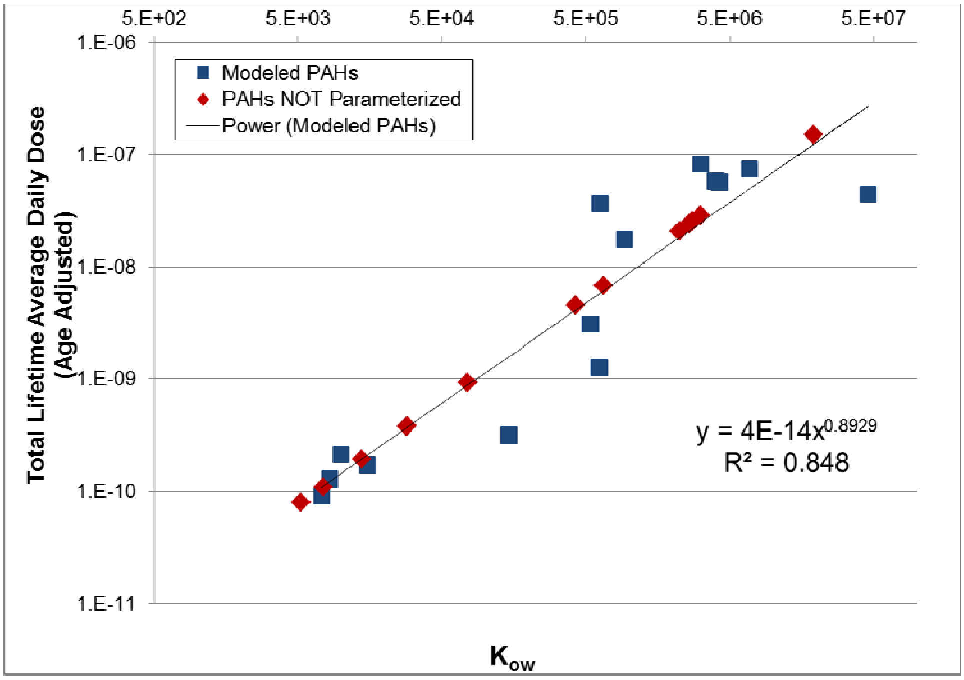
Exhibit_Att A-6. Exposure, Toxicity, and Risk Equivalency Factors Relative to BaP for POM Congeners Currently Evaluated in Tiers 1 and 2 Analyses

Chemical	Fully Parameterized in TRIM.FaTE?	Exposure Equivalency Factor (EEF)	Toxicity Equivalency Factor (TEF)[a]	Risk Equivalency Factor (REF)
Dibenzo(a,i)pyrene	n	27.5	16.4	452
7,12-Dimethylbenz(a)anthracene	Y	5.4	34.2	186
3-Methylcholanthrene	n	4.3	3.0	12.9
Dibenz(a,h)anthracene	Y	8.0	0.6	4.5
Benzo(k)fluoranthene	Y	18.0	0.2	3.0
Benzo(a)pyrene	Y	1.0	1.00	1.00
Benzo(b)flouranthene	Y	11.4	0.2	1.9
Indeno(1,2,3-cd)pyrene	Y	4.5	0.2	0.7
PAH, total	n	5.1	0.07	0.3
Polycyclic Organic Matter	n	5.1	0.07	0.3
Benzo(g,h,i)perylene	Y	4.3	0.07	0.3
Benzo(e)pyrene	n	4.5	0.07	0.3
Retene	n	3.7	0.07	0.3
Dibenzo(a,j)acridine	n	0.78	0.2	0.1
Perylene	n	1.2	0.07	0.08
Benzo(a)anthracene	Y	0.09	0.16	0.01
Chrysene	Y	0.25	0.02	0.004
2-Acetylaminofluorene	n	0.005	1.4	0.01
Fluoranthene	Y	0.04	0.07	0.003
Acenaphthylene	Y	0.04	0.07	0.003
2-Chloronaphthalene	n	0.03	0.07	0.002
Fluorene	Y	0.03	0.07	0.002
Acenaphthene	Y	0.02	0.07	0.002
1-Methylnaphthalene	n	0.02	0.07	0.001
2-Methylnaphthalene	Y	0.02	0.07	0.001
Carbazole	n	0.01	0.003	0.00003
Anthracene	n	0.06	0.000	0.00
Phenanthrene	n	0.06	0.00	0.00
Pyrene	n	0.15	0.00	0.00

[a] TEFs are calculated as the ratio of the cancer slope factor (CSF) for each specific POM congener to the CSF for benzo(a)pyrene. Dose response values, including CSFs, that are used in the screening assessment are discussed in Section 4 of Addendum 2 to this attachment.

For POMs reported as unspeciated groups (i.e., "PAH, total" and "Polycyclic Organic Matter") EPA assigned surrogates with K_{ow} values near the upper end of the range of all of the K_{ow} values, corresponding to an exposure near the upper end of the range (log $K_{ow} = 6.5$). This assignment is assumed to be health protective and likely will not under predict exposure.

Exhibit_Att A-7. Relationship between Exposure and K_{ow} for POM Congeners



A.2.7.2 Calculation of Scaling Factors for Dioxin Congeners

The calculated EEFs, TEFs, and REFs for the 17 dioxin congeners that are configured in TRIM.FaTE are presented in Exhibit_Att A-8. Although there are many dioxins reported in the NEI other than the 17 configured for TRIM.FaTE, to date, none of them have been included in emissions datasets that have been screened. Therefore, no surrogate EEF's have been developed for dioxins. In future screening assessments, if surrogate EEFs are needed, an approach similar to that used for POM will be used to develop surrogate EEFs for dioxins.

Many facilities report dioxins as "Dioxins, Total, without Individual Isomers Reported," "Dioxins," or as "2,3,7,8-TCDD TEQ," and in these cases, we do not adjust or scale the emissions. That is, we assume that they behave like and possess the toxic characteristics of TCDD. This approach could be improved by obtaining information on the speciation of dioxin emissions for each facility or an average speciation profile that could be assumed to apply to all facilities in a source category.

Exhibit_Att A-8. Exposure and Toxicity Equivalency Factors Relative to TCDD for Modeled Dioxin Congeners

Chemical	Exposure Equivalency Factor (EEF)	Toxicity Equivalency Factor (TEF)[a]	Risk Equivalency Factor (REF)
PentaCDD, 1,2,3,7,8-	3.8	1	3.8
TetraCDD, 2,3,7,8-	1	1	1
Dioxins, Total, w/o Indiv. Isomers Rptd.	1	1	1
Dioxins	1	1	1
2,3,7,8-TCDD TEQ	1	1	1

Chemical	Exposure Equivalency Factor (EEF)	Toxicity Equivalency Factor (TEF)[a]	Risk Equivalency Factor (REF)
HexaCDD, 1,2,3,4,7,8-	1.6	0.1	0.2
PentaCDF, 2,3,4,7,8-	0.4	0.3	0.1
HexaCDD, 1,2,3,6,7,8-	1.0	0.1	0.1
HexaCDF, 1,2,3,7,8,9-	0.5	0.1	0.05
HexaCDF, 1,2,3,6,7,8-	0.5	0.1	0.05
HexaCDD, 1,2,3,7,8,9 -	1.0	0.04	0.04
HexaCDF, 1,2,3,4,7,8-	0.3	0.1	0.03
HexaCDF, 2,3,4,6,7,8-	0.2	0.1	0.02
PentaCDF, 1,2,3,7,8-	0.4	0.03	0.01
TetraCDF, 2,3,7,8-	0.1	0.1	0.01
HeptaCDD, 1,2,3,4,6,7,8-	1.0	0.01	0.01
HeptaCDF, 1,2,3,4,6,7,8-	0.2	0.01	0.002
HeptaCDF, 1,2,3,4,7,8,9-	0.2	0.01	0.002
OctaCDD, 1,2,3,4,6,7,8,9-	1.1	0.0003	0.0003
OctaCDF, 1,2,3,4,6,7,8,9-	0.2	0.0003	0.0001

[a] Values from Van den Berg et al. (2006), except for 1,2,3,7,8,9-hexaCDD, which is calculated based on the ratio of the IRIS-based CSF for 1,2,3,7,8,9-hexaCDD to the IRIS-based CSF for 2,3,7,8-TCDD. Dose response values, including CSFs, that are used in the screening assessment are discussed in Section 4 of Addendum 2 to this attachment.

A.3 Description of Environmental Modeling Scenario

As described in Section A.2.4.2, the physical configuration of the RTR Screening Scenario was designed to encompass the upper end of potential long-term PB-HAP exposures, and the environmental and chemical-specific properties were parameterized with either health protective or central-tendency values. Information regarding the scenario configuration and important aspects of the parameterization process, justifications for selecting particular property values, and model uncertainties is presented in the sections that follow. Comprehensive documentation of TRIM.FaTE property values for this scenario is provided in Addendum 1 to this attachment.

A.3.1 Chemical Properties

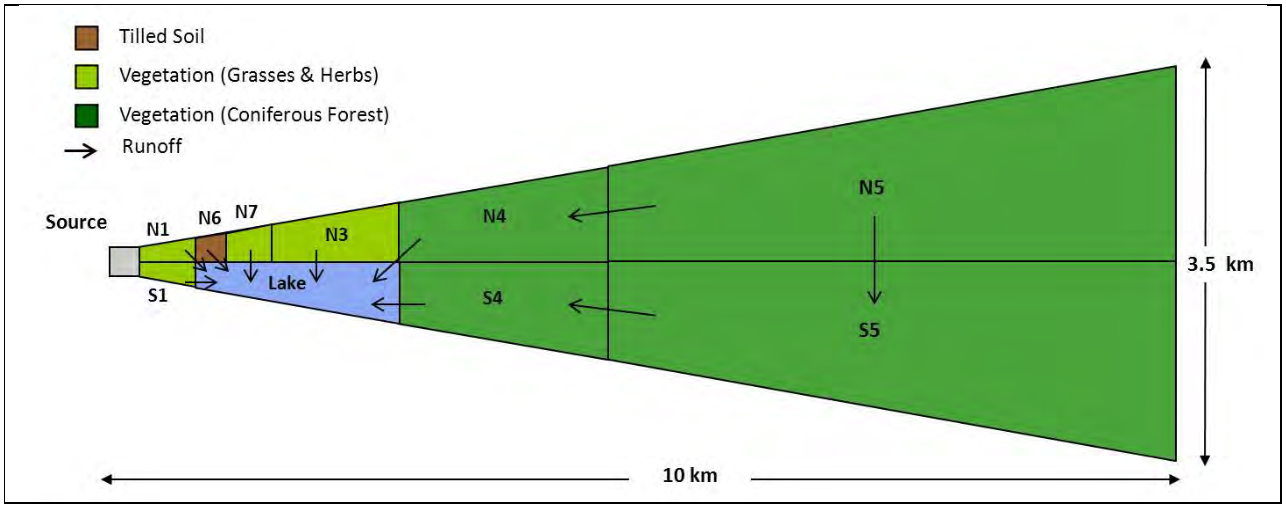
The general chemical/physical properties that TRIM.FaTE requires, such as Henry's law constant, molecular weight, and melting point, were obtained from peer-reviewed and standard reference sources. Numerous other chemical-specific properties are related more specifically to a particular abiotic or biotic compartment type; these properties are discussed generally in the sections that follow and are documented in Addendum 1 to this attachment.

A.3.2 Spatial Layout

For the purpose of estimating media concentrations, the TRIM.FaTE scenario is intended to represent a farm homestead and a fishable lake (and its surrounding watershed) located near the emissions source of interest. A diagram of the surface parcel layout is presented in Exhibit_Att A-9. The source parcel is parameterized as a square with sides of 250 m, which is assumed to be a fair estimation for the size of a relatively small-to-medium facility at the fence line. With a predominant wind direction toward the east, the modeled layout is generally symmetric about an east-west line and is wedge-shaped to reflect Gaussian dispersion of the emission plume.

A lateral, downwind distance of 10 km was established for the watershed included in the scenario. Based on the results of dispersion modeling, the location of the maximum air concentration and deposition rate is expected to occur relatively close to the facility (probably within a few hundred meters, with the exact location varying with stack height and other parameters) and well within a 10-km radius. Additionally, deposition rates for the PB-HAPs for which this screening scenario is applicable is expected to decrease by about two orders of magnitude relative to the predicted maximum rate within a 10-km radius. Extending the modeling layout beyond a 10-km downwind distance would increase the amount of deposition "captured" by the modeled watershed, but the incremental chemical mass expected to accumulate in the watershed diminishes rapidly with distance. In addition, the impact of this additional deposited mass on ingestion exposures is expected to be negligible.[16] Given these conditions, a downwind length of 10 km was determined to be appropriate for the screening scenario.

Exhibit_Att A-9. TRIM.FaTE Surface Parcel Layout



The north-south width of the wedge-shaped watershed was set based on the observed behavior of chemicals emitted to the ambient air. If meteorological stability is known or can be assumed, the lateral spread of the plume (σ_y, measured from the centerline) at a certain distance from the source can be estimated using the Pasquill-Gifford curves. Turner (1970) derived the equations for these curves, which can be found in the Industrial Source Complex 3 Dispersion Model Manual (among other sources).[17] For a relatively neutral atmosphere (stability class D), σ at 10km is about 550 m using this estimation. In a Gaussian distribution, about 99.6 percent of the plume spread area is contained within 3σ of the median line. Therefore, the plume σ was set at 3 times 550 m, or approximately 1.75 km from the centerline at a distance of 10 km. The plume

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[16] Mass deposited at the outer edge of the watershed is expected to result in only a very small increase in estimated exposure via fish consumption by increasing the chemical mass transported to the lake through erosion and runoff. The distance from these more distant locations to the lake would attenuate transport of chemical mass by erosion and runoff, dampening the effect of including additional deposition beyond 10 km. (Other exposure pathways largely would be unaffected; the soil concentrations used to calculate exposures for the farm food scenario are derived from soil parcels located close to the source and unaffected by deposition to the far reaches of the watershed.)

[17] http://www.epa.gov/scram001/userg/regmod/isc3v2.pdf

width for these conditions is expected to be about twice this distance, or 3.5 km. These dimensions were used to define the dimensions of the overall air and surface parcel layouts for the screening scenario.

The surface (land and surface water) modeling area was initially divided into five pairs of parcels the areas of which increase with distance from the source, which approximately corresponds to the spatial gradient that is expected in the downwind direction from the source. The second north parcel from the source was divided further into two parts; one of them tilled soil (Parcel N6) to represent agricultural conditions and the other (Parcel N7) untilled to represent pasture.

The depth of the surface soil compartments was set to 1 cm, except for Parcel N6, for which the depth was set to 20 cm to simulate the effect of tillage. Characteristics of the soil layers (e.g., organic carbon content, air and water content, and subsoil depth) generally were set to represent typical or national averages as summarized by McKone et al. (2001).

The overall shape and boundaries of the air parcel layout mirror those of the surface parcel layout. A single air parcel (N2) overlies surface Parcels N6 and N7, and the air over the lake is divided into air Parcels S2 and S3 (mirroring the analogous parcels on the north side of the lake).

A.3.3 Watershed and Water Body Parameterization

Properties associated with the watershed soil and lake determine how pollutants in the system are transported through and accumulate in various media compartments. These properties describe the physical characteristics of the environmental media included in the modeled region, as well as the assumed connections and relationships between media types and modeled spatial components that in turn affect chemical transport via water runoff, ground infiltration, deposition of suspended sediments in the water column, and other processes. This section presents the justification for setting the key properties of the soil, water, and sediment compartments. Also discussed are some of the chemical properties related to watershed and waterbody processes (chemical-specific compartment properties in TRIM.FaTE) and the configuration of terrestrial plants included in the scenario.

A.3.3.1 Water Balance

Water-related properties of the lake and related watershed characteristics (e.g., runoff rates from each surface soil compartment) were set so that a simplified water balance is achieved. Although TRIM.FaTE maintains a chemical mass balance, the model does not calculate or maintain media mass balances (e.g., for water) except where specified in certain formulas. For the Tier 1 scenario, the parameters were set to satisfy two equations relating water volume. The first equation maintains a balance of water entering and leaving the terrestrial portion of the scenario:

[total precipitation] = [evapotranspiration] + [total runoff]

In this equation, total runoff is equal to the sum of overland runoff to the lake and seepage to the lake via groundwater.

The second equation describes the volumetric balance of transfers of water to and from the lake:

[total runoff] + [direct precipitation to the lake] = [evaporation from the lake surface] +
[outflow from the lake]

Note that TRIM.FaTE actually uses only some of these properties (e.g., precipitation rate and surface runoff, but not evapotranspiration). The water characteristics assumed for the Tier 1 scenario are meant to represent a relatively wet and moderately warm location in the United States (USGS 1987). Following are the assumptions for this scenario:

- 35 percent of the total precipitation leaves the scenario through evapotranspiration.
- 25 percent of total precipitation infiltrates into the groundwater and eventually flows into the lake.
- 40 percent of total precipitation contributes to overland runoff.

For these calculations, the source parcel was considered to be outside the watershed and therefore was not included in the water balance. The evaporation rate from the lake was assumed to be 700 mm/yr based on data reported by Morton (1986) for various lakes. The runoff rate was defined to be spatially constant and temporally constant (i.e., it is not linked to precipitation events) throughout the modeled domain. Based on these assumptions, the outflow of water from the lake is about 18 million m^3/yr, which translates to a volumetric turnover rate of about 12.2 lake volumes per year.

Other quantitative water body and watershed characteristics TRIM.FaTE uses are listed in Addendum 1 to this attachment.

A.3.3.2 Sediment Balance

A simplified balance of sediment transfers between the watershed and the lake was also maintained for the screening scenario via the parameterization of sediment-related properties. As with water, the model does not internally balance sediment mass; these calculations were performed externally for the purposes of setting parameter values. The sediment balance maintained is described by the following equation, where terms represent mass of sediment:

[total surface soil transfers to the lake via erosion] =
[removal of sediment from the water column via outflow] + [sediment burial]

where the second term (removal of sediment from the water column via outflow) is accounted for in TRIM.FaTE by lake flushing rate and the third term (sediment burial) is the transfer of sediment from the unconsolidated benthic sediment compartment to the consolidated sediment layer.

To maintain the sediment balance, erosion rates were calculated for each surface soil compartment using the universal soil loss equation (USLE, Wischmeier and Smith 1978), assuming a relatively high rate of erosion. The total suspended sediment concentration is assumed to remain constant in TRIM.FaTE, and the flushing rate of the lake (calculated via the water balance approach described above) was then used to estimate the removal of sediment from the modeling domain via lake water outflow. The difference between these sediment fluxes was taken to be the sediment burial rate. The sediment burial rate is the rate at which sediment particles in the unconsolidated benthic sediment layer are transported to the consolidated sediment, where the particles can no longer freely interact with the water column.

In TRIM.FaTE, the consolidated sediment layer is represented with a sediment sink; as with all sinks in TRIM.FaTE, chemical mass sorbed to buried sediment that is transported to the sink cannot be returned to the modeling domain. The burial rate is a formula property calculated by the model according to the difference between user-specified values for sediment deposition velocity (from the water column to the benthic sediment) and sediment resuspension velocity (back into the water column from the benthic sediments). These formula properties assume a constant volume of particles in the sediment layer (because the densities for benthic and suspended sediment particles were defined to the same value, the mass of particles in the sediment is also constant).

For the Tier 1 scenario described here, the average sediment delivery rate (i.e., transfer of sediment mass from watershed surface soil to the lake due to erosion) for the entire watershed was estimated to be about 0.0036 kg/m^2-day, based on calculations using the USLE. The HHRAP documentation notes that using the USLE to calculate sediment load to a lake from the surrounding watershed sometimes leads to overestimates (EPA 2005a). For the Tier 1 scenario, however, this approach was considered to be appropriate in that health protective assumptions are a goal of the screening scenario.[18] Surface soil compartments adjacent to the lake are linked directly to the lake for the purposes of estimating erosion and runoff transfers (see layout in Exhibit_Att A-9). Erosion and runoff from the source parcel are linked directly to a sink and do not enter the Tier 1 scenario lake. The transport of sediment to the lake via overland is thus assumed to be efficient. Note that erosion from parcels not directly adjacent to the lake is assumed to be somewhat attenuated, effected by using a lower sediment delivery ratio in the USLE.

Using the calculated surface soil erosion rates for the scenario, the total average daily sediment load to the lake from the watershed is about 16,600 kg/day. About 15 percent of this load is removed from the lake via outflow of suspended sediments (based on a calculated flush rate of 12.2 volume turnovers per year) with the remainder of the sediment input to the lake transferred to the sediment burial sink.

A.3.4 Meteorology

Meteorological properties used in TRIM.FaTE algorithms include air temperature, mixing height, wind speed and direction, and precipitation rate. These properties, which can vary significantly among geographic locations, and seasonally and hourly for a single location, greatly influence the chemical concentrations predicted in media of interest. Because the screening scenario is intended to be generally applicable for any U.S. location, and to minimize the frequency of false negatives, a health protective configuration was used. The meteorology of the screening scenario was defined to ensure that (when used in combination with the selected spatial layout) the maximum exposures that might be encountered for the scenarios of interest would be encompassed (i.e., consumption of home-grown farm foodstuffs and self-caught fish, with all farm foods and fish obtained from locations impacted by chemicals emitted from the local source). Ensuring that the meteorological parameters were not overly protective of health, such as *always* having the wind blow toward the location of interest, however, was also important to avoid too many false positives.

The meteorological data for the screening scenario are intended to be representative of a location with a low wind speed, a wind direction that strongly favors the watershed, and a relatively high amount of total precipitation falling on the watershed. The values used were based on actual data trends for U.S. locations as specified in Exhibit_Att A-10 but an artificial data set was compiled for this analysis (for example, temporally variable meteorological parameters were made to vary only on a daily basis). This simplified approach allowed for greater control (relative to selecting a data set for an actual location) so that desired trends or outcomes could be specified. Also, using a meteorological data set with values varying on a

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[18] Based on sensitivity analysis, a higher erosion rate will both increase surface water concentrations and decrease surface soil concentrations; the relative impact on resulting concentrations, however, will be proportionally greater in the waterbody.

daily basis rather than a shorter period (such as hourly, which is the typical temporal interval for meteorological measurements) reduced required model run time. Meteorological inputs are summarized in Exhibit_Att A-10.

The sensitivity of modeled PB-HAPs to changes in these meteorological variables was tested. Lower wind speeds and mixing heights affected concentrations the most. This sensitivity is not unexpected because lower wind speeds should increase pollutant deposition onto the soil and lower mixing heights should reduce the volume through which pollutants disperse. The wind speed used for the screening scenario was 2.8 m/s, the 5th percentile of the annual averages among 239 stations; by comparison, the mean annual average wind speed is approximately 4 m/s in the contiguous United States). The mixing height (mean heights from 4 states) used was 710 m (the 5th percentile of annual averages among all 40 states in the SCRAM database).

Exhibit_Att A-10. Summary of Key Meteorological Inputs

Meteorological Property	Selected Value	Justification
Air temperature	Constant at 298 Kelvin	Recommended default value listed in HHRAP (EPA 2005a). Value is similar to the mean daily June temperature in much of the U.S. Southern Plains and Southeast.[a]
Mixing height	Constant at 710 m	Value is 5th percentile of annual average mixing heights for 75 U.S. locations, using data obtained from EPA's SCRAM Web site.[b] Value is the approximate U.S. median for periods without precipitation, based on data compiled by Holzworth (1972). Value is conservative compared to the 1- to 2-km typical mid-latitude daytime value (Stull 1988).
Wind direction	Blows from source parcel into scenario domain (west to east) 3 days per week; during other times does not blow into domain	A wind direction that favors the location of interest (for example, a watershed downwind of a source of concern) will tend to result in more emitted mass accumulating in the location of interest. For much of the U.S. mid-Atlantic and western regions, the wind tends to favor the eastward direction.[a] Among the NCDC 1981–2010 normalized wind vector data, the average wind direction had a strong eastward component at over one-third of the stations.[c] For the hypothetical RTR scenario, a more extreme example of this pattern is represented by conditions in Yakima, Washington, where the wind blows eastward approximately 40 percent of the time based on a review of wind direction data compiled by the National Weather Service (NCDC 1995). This pattern was approximated in the RTR scenario with a configuration in which the modeled domain is downwind of the source 3 out of 7 days.
Horizontal wind speed	Constant at 2.8 m/sec	Set to 5th percentile of annual average speed for 239 stations across the contiguous United States (about 50 years of data per station). Value is similar to the annual average wind speeds of many areas of the U.S. east coast and west coast.[a]
Precipitation frequency	Precipitation occurs 3 days per week; wind direction blows into domain 2 of these days	This value was selected so that two-thirds of the total precipitation occurs when the domain is downwind of the modeled source. This pattern approximates that for rainy U.S. locations, where precipitation occurs 35–40% of the time (Holzworth 1972). These locations include parts of the U.S. Northeast and Northwest.[a]

Meteorological Property	Selected Value	Justification
Total Precipitation	1.5 m/yr	Assumed to represent rainy conditions for the United States. This annual precipitation amount is experienced in parts of the U.S. Deep South and parts of the U.S. northwest coast.[a] Conditional precipitation rate (rainfall rate when precipitation is occurring) is 9.59 mm/d, which is similar to conditions in many areas along the U.S. east coast and in the Midwest and Plains.[a]

[a] National Climatic Data Center CliMaps (NCDC-CliMaps) (2007). http://cdo.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl.
[b] Support Center for Regulatory Atmospheric Modeling; http://www.epa.gov/ttn/scram/.
[c] National Climatic Data Center 1981-2010 Climate Normals; http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

A.3.5 Aquatic Food Web

The aquatic food web is an important part of the screening scenario because the chemical concentrations modeled in fish are used to calculate human ingestion exposure and risks associated with eating contaminated local fish. A biokinetic approach to modeling bioaccumulation in fish is used in the RTR screening scenario. The primary producers (first trophic level) in the TRIM.FaTE aquatic ecosystems are algae and macrophytes in the water column and detritus in the sediments (the latter simulated as sediment particles). Zooplankton feed on algae in the water column, while benthic invertebrates, represented as a single compartment, consume detritus that settles to the sediment compartment. In the water column, small young-of-the-year fish and minnows feed on zooplankton and phytopolankton. The small fish are in turn consumed by larger or “pan” fish (e.g., bluegills, white perch), which are in turn consumed by the top consumers (e.g., gar, pickerel). The invertebrates in the sediments of the benthic environment support small bottom-feeding fish (young-of-the-year fish for many species), which in turn are consumed by larger bottom-feeding fish (e.g., catfish). For TRIM.FaTE to provide reasonable predictions of the distribution of a chemical across biotic and abiotic compartments in aquatic systems, the biomass of the aquatic biotic compartments must represent all biota in the system and the distribution of biomass among the trophic levels and groups must be as realistic as possible.

To support the development of a relatively generic freshwater aquatic ecosystem in which to model bioaccumulation in fish, a literature search, review, and analysis was conducted (ICF 2005). This research demonstrated that the diversity of species and food webs across U.S. aquatic ecosystems is substantial, reflecting the wide range of sizes, locations, and physical/chemical attributes of both flowing (rivers, streams) and low-flow water bodies (ponds, lakes, reservoirs). In general, lentic bodies of water (lakes and ponds) can accumulate higher levels of contaminants in both sediments and biota than lotic systems (rivers, streams). Also, that initial research (ICF 2005) suggests that a lake of at least 60 hectares (ha) or 150 acres could support higher trophic level predatory fish, with some fraction of their diet comprising smaller fish.

The RTR Tier 1 scenario includes a generic aquatic ecosystem with a 47-hectare (116-acre) lake. Although slightly smaller than the size suggested by the previous review (ICF 2005), a 47-ha lake is large enough to support higher trophic level fish given appropriate conditions (e.g., high productivity given a sufficient nutrient base and average temperature and growing season). Also, this size was compatible with the overall size of the defined watershed in the screening scenario. The fish types, biomass, diet fractions, and body weights recommended for fish compartments for the Tier 1 scenario are listed in Exhibit_Att A-11. Biomass is based on an assumption that the total fish biomass (wet-weight) for the aquatic ecosystem is 5.7 grams per square meter (g_w/m^2, ICF 2005). That assumption yields health protective (i.e., higher) estimates of chemical concentrations in fish than would the assumption of higher standing biomass and fish productivity.

In general, the food web implemented in the Tier 1 scenario is consistent with aquatic food webs that support trophic level 4 fish (to maximize bioaccumulation), and is intended to be generally health protective.

Exhibit_Att A-11. Aquatic Biota Parameters for the TRIM.FaTE Screening Scenario

TRIM.FaTE Compartment Type	Organisms Represented by Compartment	Biomass		Diet	Average Body Weight (kg)
		Areal density (g_w/m^2)	Fraction of Total Fish Biomass		
Algae	green algae, diatoms, blue-green algae	7.95	–	Autotrophic	–
Zooplankton	crustaceans, rotifers, protozoans	6.36	–	100% algae[a]	5.7 E−8
Macrophyte	hydrilla, milfoil	500	–	–	–
Water column planktivore	young-of-the-year, minnows	2.0	35.1%	100% zooplankton	0.025
Water column omnivore	bluegill, white perch	0.5	8.8%	100% water column planktivore	0.25
Water column carnivore	largemouth bass, walleye	0.2	3.5%	100% water column omnivore	2.0
Benthic invertebrate	aquatic insect larvae, crustaceans, mollusks[b]	20	–	detritus in sediments	0.000255
Benthic omnivore	small catfish, rock bass	2.0	35.1%	100% benthic invert.	0.25
Benthic carnivore	large catfish, sculpins	1.0	17.5%	50% benthic invert. 50% benthic omniv.	2.0
Total Fish Biomass[c]		**5.7**			

[a] Algae is modeled as a phase of surface water in TRIM.FaTE.

[b] Benthic invertebrates include aquatic insects (e.g., nymphs of mayflies, caddisflies, dragonflies, and other species that emerge from the water when they become adults), crustaceans (e.g., amphipods, crayfish), and mollusks (e.g., snails, mussels).

[c] Total fish biomass does not include algae, macrophytes, zooplankton, or benthic invertebrates.

A.3.6 Using TRIM.FaTE Media Concentrations

The Tier 1 scenario outputs include average PB-HAP concentrations and deposition rates for each year and for each parcel of the model scenario. In each surface parcel, deposition rates to the soil are provided as are soil concentrations for the surface, root, and vadose zones and grass or leaf concentrations as appropriate for the plants. For each air parcel, air concentrations are provided. For the lake, surface water concentrations and concentrations in the various levels of the aquatic food chain are provided. For the ingestion exposure calculations, some concentrations are used to calculate direct exposure (e.g., soil ingestion), and some are used to perform the farm food chain concentration calculations in the various media that humans can ingest (see Exhibit_Att A-4).

The locations that determine exposures were selected to be health protective. Decisions regarding which TRIM.FaTE outputs to use in calculating exposures for the Tier 1 scenario assume exposure at locations very close to the modeled source. These locations are predicted to have amongst the highest media concentrations consistent with the specified spatial layout, thereby resulting in higher exposures to the emitted chemicals. These assumptions are summarized in Exhibit_Att A-12.

Exhibit_Att A-12. Spatial Considerations – TRIM.FaTE Results Selected for Calculating Farm Food Chain Media Concentrations and Receptor Exposures

TRIM.FaTE Output Used in Exposure Calculations	Representative Compartment
Concentration in air, for uptake by plants via vapor transfer	Air compartment in air Parcel N2 (air over tilled soil)
Deposition rates, for uptake by farm produce	Deposition to surface soil compartment in surface Parcel N6 (tilled soil)
Concentration in surface soil, for incidental ingestion by humans and farm animals	Surface soil compartment in surface Parcel N1 (untilled soil, closest to facility)
Concentration in soil, for uptake by farm produce and animal feed	Surface soil compartment in surface Parcel N6 (tilled soil)
Concentration in fish consumed by angler	Water column carnivore compartment in lake (50% of fish consumed) and benthic carnivore in lake (50% of fish consumed)

TRIM.FaTE can output instantaneous chemical concentrations for a user-specified time step and also can be configured to calculate temporal averages (e.g., annual averages). For the Tier 1 scenario, the model is set up to output results on a daily basis, largely because daily is the smallest time step over which input data change (i.e., wind direction and precipitation rate). Daily concentration results were averaged to obtain annual average concentrations. The default assumption is annual average concentrations for media during the fiftieth year of emissions.

For the chemicals modeled in this scenario, long-term concentrations in environmental media will be relatively constant at 50 years. Aside from mercury, chemicals modeled for RTR approach steady state before 50 years. And, although mercury concentrations do not achieve steady state after 50 years in the modeled screening scenario configuration, the rate of change in mercury concentrations shows a decreasing trend.

A.4 Description of Exposure and Risk Modeling Scenario

This section describes the approach for modeling chemical concentrations in farm food chain (FFC) media (Section A.4.1); estimating human exposures associated with ingestion of FFC media, incidental ingestion of soil, ingestion of fish, and infant consumption of breast milk (Section A.4.2); and calculating human health screening risk metrics associated with these exposure pathways (Section A.4.3). All of these calculations are conducted using MIRC. For this multipathway screening evaluation, partitioning of PB-HAPs into FFC media is modeled with MIRC, not as a part of the TRIM.FaTE modeling. Consequently, processes and inputs related to estimating chemical levels in FFC media are summarized in this section and discussed in detail in Addendum 2 to this attachment.

A.4.1 Calculating Concentrations in Farm Food Chain Media

As was shown in Exhibit_Att A-5, MIRC was compiled to calculate concentrations of PB-HAPs in foodstuffs that are part of the farm food chain. The FFC media included in this screening scenario include:

- exposed and protected fruit,
- exposed and protected vegetables,

- root vegetables,
- beef,
- dairy products,
- pork, and
- poultry and eggs.

The algorithms used in MIRC were obtained from EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP; EPA 2005a). These algorithms model the transfer of concentrations of PB-HAPs in FFC media using biotransfer factors. Environmental media concentrations (i.e., the chemical source terms in these algorithms) are obtained from TRIM.FaTE. As noted in Section 2.2.2, the TRIM.FaTE outputs included as inputs to MIRC are the following:

- PB-HAP concentrations in air;
- air-to-surface deposition rates for PB-HAPs in both particle and vapor phases;
- PB-HAP concentrations in fish tissue for water column carnivores and benthic carnivores; and
- PB-HAP concentrations in surface soil and root zone soil.

In general, plant- and animal-specific parameter values, including chemical-specific transfer factors for FFC media, were obtained from the Hazardous Waste Companion Database included in HHRAP (EPA 2005a). Addendum 2 to this attachment provides parameter values used in MIRC for the Tier 1 assessment.

A.4.2 Ingestion Exposure

MIRC was used to estimate ingestion rates as ADDs, normalized to body weight for a range of exposure pathways. Exposure pathways included are incidental ingestion of soil, consumption of fish, produce, farm animals and related products, and ingestion of breast milk by infants. The ingestion exposure pathways included in the screening evaluation and the environmental media through which these exposures occur are summarized in Exhibit_Att A-13.

A.4.2.1 Exposure Scenarios and Corresponding Inputs

Specific exposure scenarios are developed by defining the ingestion activity patterns (i.e., estimating how much of each medium is consumed and the fraction of the consumed medium that is grown in or obtained from contaminated areas) and the characteristics of the hypothetical human exposed (e.g., age and body weight). MIRC computes exposure doses and risks for each ingestion pathway separately, enabling the pathway(s) of interest for each PB-HAP to be determined. Data related to exposure factors and receptor characteristics were obtained primarily from EPA's *Exposure Factors Handbook* (EPA 2011).

Exhibit_Att A-13. Summary of Ingestion Exposure Pathways and Routes of Uptake

Ingestion Exposure Pathway	**Medium Ingested**	**Intermediate Exposure Pathway – Farm Animals[a]**	**Environmental Uptake Route**	
			Medium	**Process[b]**
Incidental ingestion of soil	Untilled surface soil	N/A	Surface soil	Deposition; transfer via erosion and runoff [c]
Consumption of fish	Fish from local water body	N/A	Fish tissue	Direct uptake from water and consumption of food compartments modeled in TRIM.FaTE[c]
Consumption of breast milk[d]	Breast milk	N/A	Breast milk	Contaminant ingested by mother partitions to breast milk
Consumption of produce	Aboveground produce, exposed fruits and vegetables	N/A	Air Air Soil	Deposition to leaves/plants Vapor transfer Root uptake
	Aboveground produce, protected fruits and vegetables	N/A	Soil	Root uptake
	Belowground produce	N/A	Soil	Root uptake
Consumption of farm animals and related food products	Beef	Ingestion of forage	Air Air Soil	Direct deposition to plant Vapor transfer to plant Root uptake
		Ingestion of silage		
		Ingestion of grain	Soil	Root uptake
		Ingestion of soil	Soil	Ingestion from surface
	Dairy (milk)	Ingestion of forage	Air Air Soil	Direct deposition to plant Vapor transfer to plant Root uptake
		Ingestion of silage		
		Ingestion of grain	Soil	Root uptake
		Ingestion of soil	Soil	Ingestion from surface
	Pork	Ingestion of silage	Air Air Soil	Direct deposition to plant Vapor transfer to plant Root uptake
		Ingestion of grain	Soil	Root uptake
		Ingestion of soil	Soil	Ingestion from surface
	Poultry	Ingestion of grain	Soil	Root uptake
		Ingestion of soil	Soil	Ingestion from surface
	Eggs	Ingestion of grain	Soil	Root uptake
		Ingestion of soil	Soil	Ingestion from surface

[a] Calculation of intermediate exposure concentrations were required only for the farm animal/animal product ingestion pathways.
[b] Process by which HAP enters medium ingested by humans.
[c] Modeled in TRIM.FaTE.
[d] The consumption of breast milk exposure scenario is discussed in Section A.4.2.3.

For the Tier 1 scenario described here, exposure characteristics that would result in a highly health protective estimate of total exposure were selected. The ingestion rate for each medium was set at high-end values (equal to the 90th percentile values for all food types except for fish, which was set at 99th percentile values). All media were assumed to be obtained from locations impacted by the modeled source. Although this approach could result in an overestimate of total chemical exposure for a hypothetical exposure scenario (for example, note that the total food ingestion rate that results is extremely high for a hypothetical consumer with ingestion rates in the upper percentile for every food type), it was selected to avoid underestimating exposure for any single farm food type. The exposure characteristics selected for the Tier 1 scenario are summarized in Exhibit_Att A-14.

Exhibit_Att A-14. Overview of Exposure Factors Used for RTR Multipathway Screening[a,b]

Exposure Factor	Selection for Screening Assessment
Age group evaluated	Infants under 1 year (breast milk only) Children 1–2 years of age Children 3–5 years of age Children 6–11 years of age Children 12–19 years of age Adult (20–70 years)
Body weight (BW; varies by age)	Weighted mean of national distribution or recommended value
Ingestion rate (IR) for farm produce and animal products other than fish (varies by age and medium)	90th percentile of distribution of consumers who produce own food
Ingestion rate for fish	For adults, 99th percentile *as-prepared* ingestion rate representative of subsistence fisher woman. For children, based on 99th percentile, *as-prepared*, consumer-only, national ingestion rates – adjusted.
Exposure frequency (EF)	365 days/year
Exposure duration	Lifetime, for estimating cancer risk; varies by chemical for chronic non-cancer evaluation
Fraction contaminated (FC) (varies by media consumed)[c]	1
Cooking loss[d]	Assumed to be “typical”; varies depending on food product (see Addendum 2 to this attachment). Cooking losses were not considered for fish consumption because intake rates represent “as prepared” values.
Food preparation/cooking adjustment factor for fish[e]	Mercury = 1.5 Cadmium = 1.5 Dioxin = 0.7 PAH = 1.0

[a] Data for exposure characteristics are presented in Addendum 2 to this attachment. Exposure parameter values were based on data obtained primarily from the *Exposure Factors Handbook* (EPA 2011). See Addendum 2 to this attachment for details.
[b] Exposure factor inputs are used in calculating ADD estimates for each exposure pathway. ADD equations for each pathway evaluated in this screening assessment are provided in Addendum 2.
[c] Fraction contaminated represents the fraction of food product that is derived from the environment included in the screening scenario (e.g., produce grown on soil impacted by PB-HAPs). This parameter is defined separately for each FFC medium; however, for the Tier 1 scenario, all ingested media are assumed to be impacted.
[d] Cooking loss inputs were included to simulate the amount of a food product that is not ingested due to loss during preparation or cooking, or after cooking.
[e] Because “as consumed,” fish consumption rates are used with whole-fish concentrations, adjustments might be appropriate to adjust the fish tissue concentrations to reflect concentrations after food preparation. See Addendum 2, Section 6.4.4 for additional discussion.

A.4.2.2 Calculating Average Daily Doses

MIRC calculates chemical-specific ADDs normalized to body weight (mg PB-HAP per kg of body weight per day). Equations used to calculate ADDs were adapted from the algorithms provided in the technical documentation of EPA’s *Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) Modeling System* (EPA 2003), which derived much of its input data from the *Exposure Factors Handbook* (EPA 2011). The ingestion exposure modeling approach embodied by 3MRA is conceptually similar to that presented in HHRAP. A discussion of exposure dose estimation and the equations to calculate ADDs for each ingestion pathway are provided in Addendum 2 to this attachment.

A.4.2.3 Infant Ingestion of Breast Milk

A nursing mother exposed to contaminants by any ingestion pathway described above can pass the contaminants to her infant through breast milk (ATSDR 1998). The nursing infant's exposure can be estimated from the levels of chemical concentrations in the breast milk, which in turn can be estimated based on the mother's chemical intake.

Reports of bioaccumulation of lipophilic compounds such as polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs), and dioxins are prevalent in the scientific literature. Due to their high lipophilicity, these compounds partition almost exclusively to the milk fat of breast milk rather than the aqueous phase (EPA 1998). PCBs, PCDFs, and PCDDs are the most documented groups of contaminants found in breast milk. Other compounds with lower octanol-water partition coefficients, such as phenol, benzene, halobenzenes, and PAHs, are found in both the milk fat and the aqueous phase of breast milk. Heavy metals such as arsenic, lead, cadmium, and mercury have been found in the aqueous phase of the breast milk. However, given their chemical and physical characteristics (and the impact such qualities have on partitioning within the body and pharmacokinetics), substances that do not partition as strongly to the lipophilic phase of breast milk tend to be of lower concern with regard to exposures to nursing infants. Because of the greater concern with regard to dioxins for this exposure pathway, it is the only PB-HAP included in the breast milk exposure pathway for RTR at this time. This approach is consistent with the risk assessment procedures included in EPA's Human Health Risk Assessment Protocol (EPA 2005a).

Exposure via the breast milk consumption pathway is estimated in MIRC for dioxins only. This pathway is included in computing total exposure for developing the screening threshold for dioxins. In the absence of congener-specific data, dioxin congeners were assumed to manifest the same tendency to accumulate in breast milk as 2,3,7,8-TCDD.

A.4.3 Calculating Risk

MIRC was used to calculate excess lifetime cancer risk and non-cancer hazard (expressed as the hazard quotient or HQ) using the calculated ADDs and ingestion dose-response values. Chemical dose-response data include cancer slope factors (CSFs) for ingestion and non-cancer oral RfDs. The CSFs and RfDs for the PB-HAPs included in the Tier 1 scenario are presented in Exhibit_Att A-15 and are discussed in more detail in Addendum 2 to this attachment. Equations used to estimate cancer risk and non-cancer hazard also are provided in Addendum 2 to this attachment.

Exhibit_Att A-15. Dose-response Values for PB-HAPs Addressed by the Screening Scenario

PB-HAP	CSF ([mg/kg-day]$^{-1}$)	Source	RfD (mg/kg-day)	Source
Inorganics				
Cadmium compounds (as Cd)	not available		1E−3	IRIS
Elemental mercury	not available		not available	
Divalent mercury	not available		3E−4	IRIS
Methyl mercury	not available		1E−4	IRIS
Organics				
Benzo[a]pyrene[a]	7.3	IRIS	not available	
2,3,7,8-TCDD	1.5E+5	EPA ORD	7E−10	IRIS

Source: EPA (2007).

CSF = cancer slope factor; RfD = reference dose; IRIS = EPA's Integrated Risk Information System; Cal/EPA = California Environmental Protection Agency; EPA ORD = EPA's Office of Research and Development

[a] For consistency with the overall approach for dose-response assessment of PAHs, the CSF listed in IRIS for benzo[a]pyrene ([7.3 mg/kg-day]$^{-1}$) was adjusted due to its mutagenic mode of action as discussed below (see also Addendum 2 to this attachment).

Estimated individual cancer risks for the PAHs included in the screening scenario were adjusted upward to account for the mutagenic cancer potency of these compounds during childhood, as specified by EPA in supplemental guidance for cancer risk assessment (EPA 2005c). Specifically, cancer potency for PAHs is assumed to be tenfold greater for the first 2 years of life and threefold greater for the next 14 years. These factors were incorporated into a time-weighted total increase in potency over a lifetime of 70 years. The cancer potency adjustment for chemicals with a mutagenic mode of action is discussed in Addendum 2 to this attachment.

A.4.4 Summary of Tier 1 Assumptions

As emphasized previously, the screening scenario created for evaluating PB-HAP emissions from RTR facilities is intended to be health protective to prevent underestimating risk. The scenario also is intended to avoid grossly overestimating risk to the point where no emissions screen. The overall degree to which the scenario is health protective is the sum of the multiple assumptions that affect the outputs of the fate and transport, exposure, and risk modeling. Exhibit_Att A-16 summarizes important characteristics that influence exposure and risk estimates for this scenario and indicates the general degree of health protectiveness associated with the values for each assumption. Although this summary does not provide a quantitative estimate of the output uncertainty or the degree to which exposures and risks estimated using the scenario would be overestimated, it does demonstrate qualitatively that the scenario generally overestimates exposure and thus favors a health-protective risk output.

Exhibit_Att A-16. Summary of RTR Tier 1 Screening Scenario Assumptions

Characteristic	Value	Neutral or Health Protective?	Comments on Assumptions
General Spatial Attributes			
Farm location	375 m from source; generally downwind	Health Protective	Location dictates soil and air concentrations and deposition rates used to calculate chemical levels in farm produce.
Lake location	375 m from source; generally downwind	Health Protective	Location dictates where impacted fish population is located.

Characteristic	Value	Neutral or Health Protective?	Comments on Assumptions
Surface soil properties	Typical values or national averages	Neutral	Based on existing EPA documentation and other references.
Size of farm parcel	About 4 ha	Health Protective	Relatively small parcel size results in higher chemical concentration.
Size of lake	47 ha; about 3 m average depth	Health Protective	Lake is large enough to support an aquatic ecosystem with higher trophic-level fish, but is relatively small and shallow (thus increasing surface area-to-volume ratio).
Meteorological Inputs			
Total precipitation	1.5 m/yr	Health Protective	Intended to represent rainy U.S. location; set to highest state-wide average for the contiguous United States.
Precipitation frequency (with respect to impacted farm/lake)	2/3 of total precipitation fall on farm/lake and watershed	Health Protective	Most of total precipitation occurs when the farm/lake are downwind of the source.
Wind direction	Farm/lake are downwind 40% of the time	Health Protective	Farm/lake located in the predominantly downwind direction. Temporal dominance of wind direction based on data from Yakima, Washington, where wind is predominantly from the west.
Wind speed	2.8 m/sec	Health Protective	Low wind speed (5th percentile of long-term averages for contiguous United States); increases net deposition to lake/watershed.
Air temperature	298 K	Neutral	Typical for summer temperatures in central and southern United States.
Mixing height	710 m	Health Protective	Relatively low long-term average mixing height (5th percentile of long-term averages for contiguous United States); increases estimated air concentration.
Watershed and Water Body Characteristics			
Evaporation of lake surface water	700 mm/yr	Neutral	Based on sensitivity analyses, value is not expected to under- or overestimate concentration in surface water.
Surface runoff into lake	Equal to 40% of total precipitation	Health Protective	Based on typical water flow in wetter U.S. locations; higher runoff results in greater transfer of chemical to lake.
Surface water turnover rate in lake	About 12 turnovers per year	Neutral	Consistent with calculated water balance; reasonable in light of published values for small lakes. Might overestimate flushing rate if water inputs are also overestimated. Note that after evapotranspiration, remaining water volume added via precipitation is assumed to flow into or through lake.

Characteristic	Value	Neutral or Health Protective?	Comments on Assumptions
Soil erosion from surface soil into lake	Varies by parcel; ranges from 0.002 to 0.01 kg/m^2-day	Neutral	Erosion rates calculated using the universal soil loss equation (USLE); inputs to USLE were selected to be generally conservative with regard to concentration in the pond (i.e., higher erosion rates were favored). Might underestimate erosion for locations susceptible to high erosion rates. Note that higher erosion increases concentration in lake (and fish) but decreases levels in surface soil (and farm products).
Aquatic food web structure and components	Multilevel; includes large, upper trophic-level fish	Health Protective	Inclusion of upper trophic-level fish and absence of large-bodied herbivore/detritivore fish favor higher concentrations of bioaccumulative chemicals and result in higher concentrations in consumed fish. Linear food-chain maximizes concentration of bioaccumulative chemicals in higher trophic-level fish.
Parameters for Estimating Concentrations in Farm Food Chain Media			
Fraction of plants and soil ingested by farm animals that is contaminated	1.0 (all food and soil from contaminated areas)	Health Protective	Assumes livestock feed sources (including grains and silage) are derived from most highly impacted locations.
Soil- and air-to-plant transfer factors for produce and related parameters	Typical (see Addendum 2 to this attachment for details)	Neutral	Obtained from peer-reviewed and standard EPA reference sources.
Biotransfer factors for efficiency of uptake by animal of chemical in food/soil	Typical (see Addendum 2 to this attachment for details)	Neutral	Obtained from peer-reviewed and standard EPA reference sources.
Bioavailability of chemicals in soil (for soil ingested by animals)	1.0 (relative to bioavailability of chemical in plant matter)	Health Protective	Probably overestimates bioavailability in soil; many chemicals are less bioavailable in soil than in plants.

Exhibit_Att A-16. Summary of RTR Screening Scenario Assumptions

Characteristic	Value	Neutral or Health Protective?	Comments on Assumptions
Ingestion Exposure Assumptions			
Ingestion rates for all farm produce/livestock types	Person obtains all food sources from local farm; ingestion rate is 90th percentile of rates for home-produced food items	Health Protective	All food derived from impacted farm; total food ingestion rate would exceed expected body weight-normalized ingestion rates (prevents underestimating any individual food type).
Fish ingestion rate	Adult: 373 g/day Child age groups: 1 to 2: 108 g/day 3 to 5: 159 g/day 6 to 11: 268 g/day 12 to 19: 331 g/day	Health Protective	The adult rate is the 99th percentile value for adult females from Burger (2002) and is considered representative of subsistence anglers. Rates for children are based on the 99th percentile, consumer-only fish ingestion rates from EPA 2002. Rates were adjusted to be representative of the age groups used in the screening scenario. See Addendum 2 to this attachment for a detailed discussion.
Exposure frequency	Consumption of contaminated food items occurs 365 days/yr	Health Protective	All meals from local farm products.
Body weight	Mean of national distribution	Neutral	Note that this does not affect the body-weight-normalized rates for produce and animal products.
Other Chemical-Specific Characteristics			
General chemical properties used in fate and transport modeling (Henry's law, K_{ow}, etc.)	Varies	Neutral	Obtained from peer-reviewed sources; intended to be representative of typical behavior and characteristics.
"General" physical properties (plant matter density, aquatic life biomass, algal growth rate, etc.)	Varies	Neutral	Obtained from peer-reviewed sources; intended to be representative of typical behavior and characteristics.
Dose-response values	Varies	Neutral to Health Protective	Values used are those determined to be appropriate for risk assessment by OAQPS; values are developed to be health protective.

A.5 Evaluation of Screening Scenario

A.5.1 Introduction

The screening scenario developed for assessing multipathway human health risk for EPA's Risk and Technology Review has been subjected to a series of evaluations. The major PB-HAP categories of concern for this analysis are cadmium compounds (Section A.5.2), mercury compounds (Section A.5.3), dioxins (Section A.5.4), and POM (Section A.5.5). The scenario evaluations were focused primarily on assessing the behavior of these HAP categories in the environment, the accumulation of these chemicals in ingestible food products, and the predominant pathways of human exposure.

A.5.2 Cadmium Compounds

Some of the largest anthropogenic sources of cadmium to air are facilities that process, mine, or smelt cadmium-zinc ores or cadmium-zinc-lead ores, coal- and oil-fired boilers, other urban and industrial facilities, phosphate fertilizer manufacturing facilities, road dust, and municipal sewage sludge incinerators (ATSDR 2008).

A.5.2.1 Behavior in the Environment

Once emitted into the environment, airborne cadmium particles can be transported over long distances before being deposited. Cadmium has been observed to partition primarily to soil when released to the environment (ATSDR 2008). The mobility of cadmium in soil depends strongly on soil pH, clay content, and availability of organic matter—factors that determine whether the cadmium is dissolved or sorbed in surface soil. In general, cadmium adsorbs to soil particles in the surface layers of the soil profile, but to a lesser degree than many other heavy metals (HSDB 2005). Cadmium also binds strongly to organic matter, rendering the metal relatively immobile in some soils. Nonetheless, some plants still can take up cadmium efficiently, thus providing an entry point for cadmium into the food chain (ATSDR 2008).

Cadmium also enters surface waters, which can occur via atmospheric deposition, runoff and erosion, or wastewater streams. Most cadmium compounds entering the water column are quickly removed through adsorption to organic matter in sediment or to other suspended compounds. Cadmium that remains in the water column is expected to exist primarily in the dissolved state where it is available for uptake by aquatic organisms.

Freshwater fish accumulate cadmium primarily through direct uptake of the dissolved form through the gills and secondarily through the diet, which plays a variable role in total cadmium uptake (Reinfelder et al. 1998; Chen et al. 2000; Saiki et al. 1995). Although some biomagnification of cadmium has been reported for aquatic food chains in saltwater systems, biomagnification in freshwater systems appears to be present only at lower trophic levels (Chen et al. 2000) and in narrowly defined niches (e.g., plankton/macroinvertebrate food chains; Croteau et al. 2005). Biomagnification factors (BMFs) of less than 1 generally have been reported for fish at higher trophic levels, indicating that cadmium concentrations generally biodiminish from lower to higher trophic levels (Chen et al. 2000; Mason et al. 2000).

For the RTR screening scenario, the partitioning behavior modeled in TRIM.FaTE was consistent with the behavior of cadmium expected in the natural environment.

A.5.2.2 Concentrations in Ingestible Products

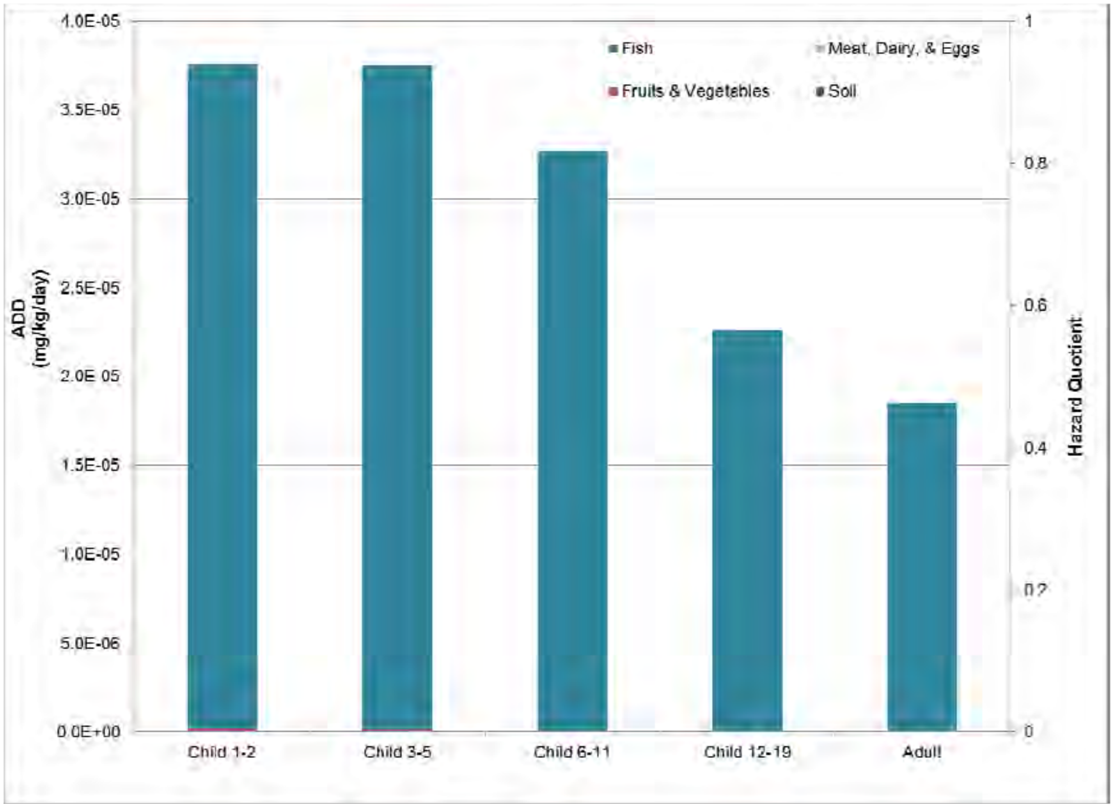
Most non-inhalation exposure to cadmium outside of occupational settings is through dietary intake. Available data indicate that cadmium accumulates in plants, aquatic organisms, and terrestrial animals, offering multiple ingestion exposure pathways (ATSDR 2008). Actual cadmium levels in ingestible products, however, varies based on type of food, agricultural and cultivation practices, atmospheric deposition rates, characteristics of environmental media, and presence of other anthropogenic pollutants. Meat and fish generally contain lower amounts of cadmium overall, but cadmium can be highly concentrated in certain organ meats, such as kidney and liver (ATSDR 2008). In a study of cadmium concentrations in 14 food groups (including prepared foods), meat, cheese, and fruits generally contained low levels of cadmium (ATSDR 2008).

For the RTR screening scenario, the cadmium concentrations output by MIRC were consistent with reported values in all ingestible media products. The products with higher reported cadmium levels in the literature, including soil, plants, and fish, also contained the higher modeled concentrations.

A.5.2.3 Average Daily Dose (ADD)

To determine the media most relevant to exposure and risk, the ingestion exposure factors must be considered in addition to the estimated media concentrations (i.e., a higher concentration for a particular medium does not necessarily mean higher risk). In Exhibit_Att A-17, the contributions of ingestion exposure pathways to the average daily dose (ADD) (and thus the HQ) for the different age categories are presented. As shown in the exhibit, fish ingestion is the dominant exposure pathway across all age categories, accounting for nearly 100 percent of the ADD for all groups. The combined contribution from all other exposure pathways accounts for less than 0.7 percent of the total ADD for all age groups. Most of the additional exposure was from ingestion of fruits and vegetables. The highest ADD corresponds to children aged 1–2 years; thus, the exposure corresponding to this group was used to determine the emission threshold for cadmium. In other words, the threshold emissions rate for cadmium is set at the level where the HQ for this age category is equal to 1.0.

Exhibit_Att A-17. Estimated Contributions of Modeled Food Types to Cadmium Ingestion Exposures and Hazard Quotients



A.5.3 Mercury Compounds

Some of the largest anthropogenic sources of mercury to air are facilities that process, mine, or smelt mercury ores; industrial/commercial boilers; fossil fuel combustion activities (primarily coal); cement production facilities; other urban and industrial facilities; and medical and municipal waste incinerators (ATSDR 1999). These facilities can emit a mixture of elemental and divalent mercury, mostly in the gaseous phase, with some divalent forms in particle-bound phases (EPA 1997).

A.5.3.1 Behavior in the Environment

Once emitted into the environment, mercury undergoes changes in form and species as it moves through environmental media. Elemental mercury is the most prevalent species of mercury in the atmosphere. Due to the long residence time of elemental mercury in the atmosphere, this compound is relatively well distributed, even on a global scale.

Divalent mercury is removed from the atmosphere at a faster rate than elemental mercury, and it can be transferred to the surface near the emission source via wet or dry deposition where it appears to adsorb tightly to soil particles (EPA 1997) or dissolved organic carbon. Divalent mercury in soil also can be methylated by microbes or reduced to elemental mercury and revolatilized back into the atmosphere. Most divalent mercury from atmospheric deposition will remain in the soil profile, however, in the form of inorganic compounds bound to soil organic matter. Although this complexing behavior with organic matter significantly limits mercury transport, the ability of mercury to form these complexes greatly depends on soil conditions such as pH, temperature, and soil humic content. For example, mercury strongly adsorbs to humic materials and sesquioxides in soil at pH > 4 and in soils with high iron and aluminum content (ATSDR 1999). Small amounts of mercury in soil can be transported to surface water via runoff or leaching.

Mercury could also enter the water column through atmospheric fallout. Once in the water body, divalent mercury can be methylated through microbial activity. In addition, divalent and methyl mercury can be further reduced to elemental mercury, which can volatilize and reenter the atmosphere. Solid forms of inorganic mercury compounds could adsorb to particulates in the water column or partition to the sediment bed (EPA 1997).

The solubility of mercury in water depends on the species and form of mercury present as well as properties of the water such as water pH and chloride ion concentration (ATSDR 1999). Low pH favors the methylation of mercury in the water column, typically performed by sulfur-reducing bacteria in anaerobic conditions. Methyl mercury is typically of greatest concern because it readily bioaccumulates and efficiently biomagnifies in aquatic organisms. A considerable amount (25–60 percent) of both divalent mercury compounds and methyl mercury is strongly bound to particulates in the water column (EPA 1997). The remaining mercury is dissolved. Most of the elemental mercury produced as a result of reduction of divalent mercury volatilizes back into the atmosphere.

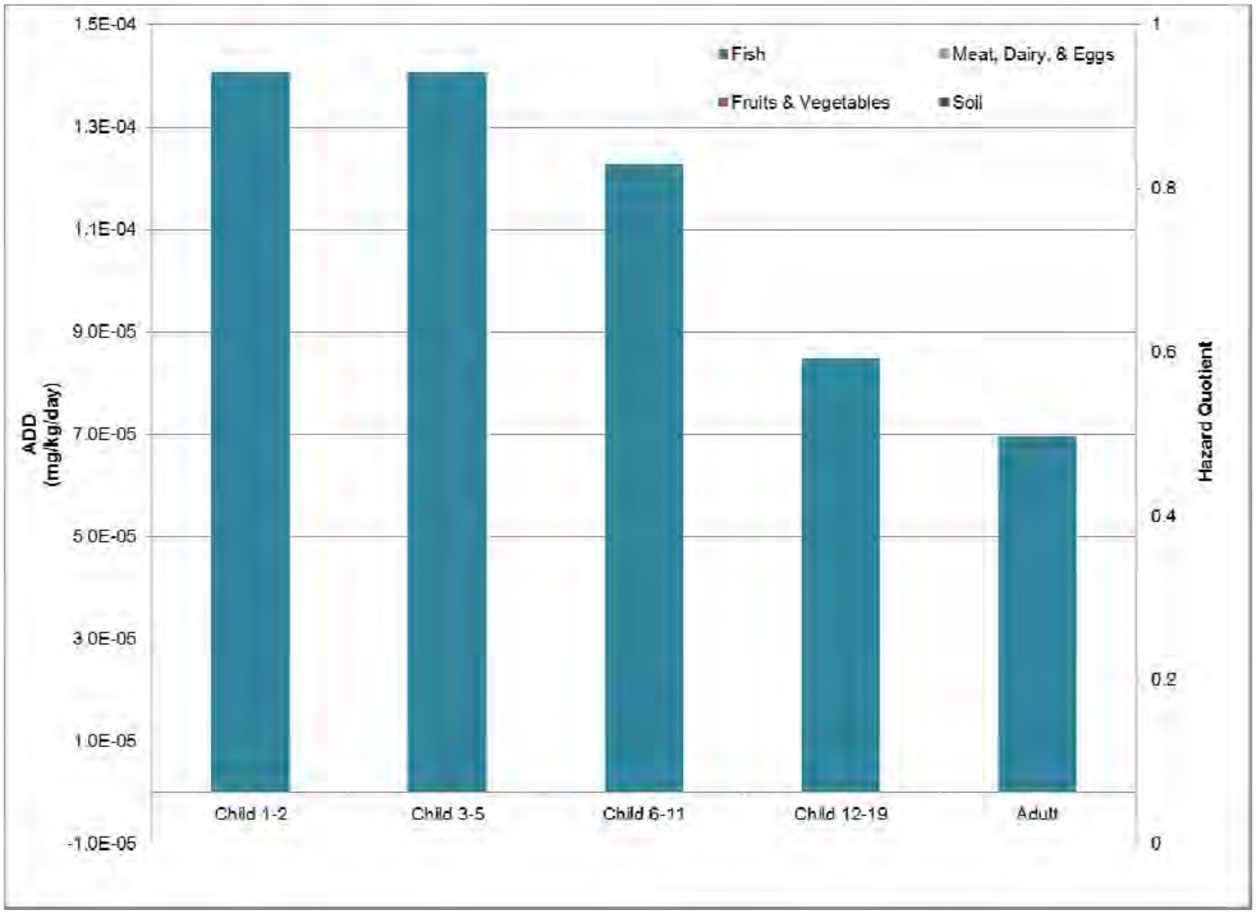
For the screening scenario, the partitioning behavior modeled in TRIM.FaTE generally was consistent with trends noted in the literature. Divalent mercury was the most prevalent species in modeled surface soil, surface water, and sediment compartments, while methyl mercury was the dominant species in fish.

A.5.3.2 Concentrations in Ingestible Products

Available data indicate that mercury bioaccumulates in plants, aquatic organisms, and terrestrial animals, providing multiple ingestion exposure pathways (EPA 1997; ATSDR 1999). Low levels of mercury are found in plants, with leafy vegetables containing higher concentrations than potatoes, grains, legumes, and other vegetables and fruits (ATSDR 1999; EPA 1997). Cattle demethylate mercury in the rumen and, therefore, store very little of the mercury they ingest by foraging or consuming silage or grain. Thus, mercury content in meat and cow's milk is low (ATSDR 1999). Concentrations of methyl mercury in fish are generally highest in larger, older specimens at the higher trophic levels (EPA 1997).

Although data on mercury in foods other than fish are not abundant in the literature, total mercury concentrations output by MIRC were generally consistent with the reported values that were available. The exposure pathways that most influenced the mercury HQs in the model are presented in Exhibit_Att A-18. As shown, the dominant exposure pathway for all age groups is ingestion of fish. Relative to divalent mercury, methyl mercury concentrations in fish were very high (approximately 95 percent of total mercury).

Exhibit_Att A-18. Estimated Contributions of Modeled Food Types to Methyl Mercury Ingestion Exposures



A.5.3.3 Average Daily Dose

In Exhibit_Att A-18, the contributions of ingestion exposure pathways to the ADD (and thus the HQ) for methyl mercury across the different age categories are presented. As shown, fish is the dominant exposure pathway across all age categories, accounting for nearly 100 percent of the ADD for each group. The combined contribution of all other exposure pathways accounts for less than 1 percent of the total ADD for all age groups. The high degree of exposure to methyl mercury through fish ingestion is attributed to the ease with which this compound bioaccumulates and biomagnifies in fish and to the health protective ingestion assumptions used in the screening scenario. The highest ADD corresponds to children aged 1–2 years;

thus, the exposure corresponding to this group was used to determine the emission threshold for mercury.

A.5.4 Dioxins

Incineration and combustion processes are believed to be the primary emission sources for chlorinated dioxins (ATSDR 1998). The five stationary source categories that generate the vast majority of 2,3,7,8-TCDD emissions in the United States are municipal waste incineration, medical waste incineration, hazardous waste kilns from Portland cement manufacturing, secondary aluminum smelting, and biological incineration.

A.5.4.1 Behavior in the Environment

Dioxins emitted to the atmosphere can be transported long distances in vapor form or bound to particulates, depositing in soils and water bodies in otherwise pristine locations far from the source. Although airborne dioxins are susceptible to wet and dry deposition, most dioxins emitted to the atmosphere through incineration/combustion processes are not deposited close to the source (ATSDR 1998).

In soil, dioxins strongly adsorb to organic matter and show very little vertical movement, particularly in soils with a high organic carbon content (ATSDR 1998). Most dioxins deposited in soil are expected to remain buried in the soil profile, with erosion of contaminated soil particles the only significant mechanism for transport to water bodies.

The dry deposition of dioxins from the atmosphere to water bodies is another important transport process. Because of the hydrophobic nature of dioxins, most dioxins entering the water column are expected to adsorb to suspended organic particles or partition to bed sediment, which appears to be the primary environmental sink for this chemical group (EPA 2004c). Although dioxins bound to aquatic sediment primarily become buried in the sediment compartment, some resuspension and remobilization of congeners can occur if sediments are disturbed by benthic organisms (ATSDR 1998).

Bioaccumulation factors (BAFs) in fish are high as a result of the lipophilic nature of chlorinated dioxins. Although the processes by which freshwater fish accumulate dioxins are not well understood, both fish and invertebrates bioaccumulate congeners that have partitioned to sediment or have become suspended in water (EPA 2004c). Because most dioxins in the aquatic environment are adsorbed to suspended particles, however, direct uptake from the water is unlikely to be the primary route of exposure for most aquatic organisms at higher trophic levels (ATSDR 1998). At lower trophic levels, the primary route of exposure appears to be through uptake of water in contaminated sediment pores, and the primary route of exposure in the higher trophic levels appears to be through food chain transfer. Following ingestion, some fish can slowly metabolize certain congeners, such as 2,3,7,8-TCDD, and release the polar metabolites in bile. This process ultimately might limit bioaccumulation at higher trophic levels (ATSDR 1998).

For the RTR screening scenario, the partitioning behavior modeled in TRIM.FaTE was consistent with the behavior of 2,3,7,8-TCDD expected in the natural environment. Also of note is that dioxins readily partition into breast milk due to the lipophilic nature of these compounds.

A.5.4.2 Concentrations in Ingestible Products

The primary source of non-inhalation exposure to dioxins outside of occupational settings is through dietary intake, which accounts for more than 90 percent of daily dioxin exposure (ATSDR 1998). Available data indicate that dioxins concentrate in plants, aquatic organisms, and animals, offering multiple ingestion exposure pathways. Actual congener levels in ingestible products, however, can vary based on type of food, agricultural and cultivation practices, atmospheric deposition rates, characteristics of environmental media, and presence of other anthropogenic pollutants. Dioxins appear to enter the terrestrial food chain primarily through vapor-phase deposition onto surfaces of plants, which are then consumed by larger animals. Another major source of exposure to dioxins is through ingestion of contaminated soil by animals.

Observed trends indicate that meat, dairy, and fish consumption are the dominant exposure pathways, comprising 90 percent of dioxin dietary intake (ATSDR 1998). Consistent with the literature, the modeled concentration of 2,3,7,8-TCDD in the fish compartment for the screening scenario was at least one order of magnitude greater than concentrations in the other compartments. Among the compartments with the lowest concentrations were fruits and vegetables, which do not readily accumulate 2,3,7,8-TCDD.

Ingestion of breast milk during infancy and fish ingestion contribute to over 97 percent of lifetime dioxin exposure for 2,3,7,8-TCDD in the screening scenario. Daily intakes of 2,3,7,8-TCDD from cow's milk, produce, and fish have been reported in the literature to comprise 27 percent, 11 percent, and 10 percent, respectively, of the total daily intake in the general population. Some studies note that specific subpopulations, such as subsistence farmers and anglers, however, might have very different exposure profiles in which fish, meat, and dairy drive congener exposure (ATSDR 1998). Given the subsistence diet modeled in the RTR screening scenario, the high exposure from consumption of fish is appropriate within the context of this analysis.

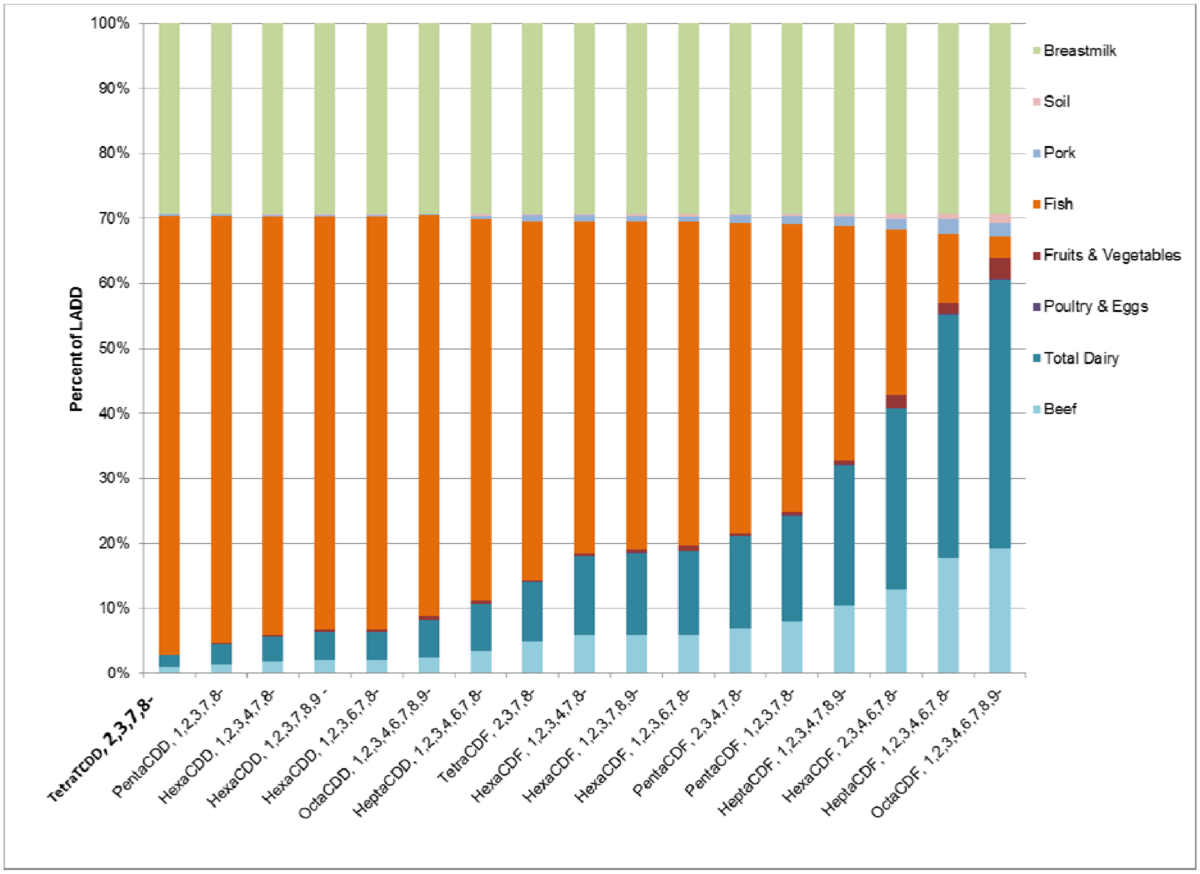
A.5.4.3 Lifetime Average Daily Dose (LADD)

The contributions of ingestion exposure pathways to the lifetime average daily dose (LADD) (and thus lifetime cancer risk) for the modeled dioxin congeners are presented in Exhibit_Att A-19. Based on the modeling methodology and assumptions used, exposures via the breast milk pathway consistently account for approximately 30 percent of the lifetime exposure for all congeners, while exposure via fish, soil, and the various farm food chain pathways is highly variable across congeners. This variability can be explained in part by differences in the physiochemical properties that drive the environmental transport processes of these congeners (e.g., K_{ow}, molecular weight). The differences are also likely attributed to differences in the congener-specific half-life in abiotic media and the degree to which the congener is metabolized in biotic media.

A.5.5 Polycyclic Aromatic Hydrocarbons

PAHs can enter the atmosphere as a result of a variety of combustion processes, both natural and anthropogenic. Stationary emission sources account for approximately 80 percent of total annual PAH emissions. Although the primary source of stationary source PAH emissions is thought to be residential wood burning, other processes such as power generation; incineration; coal tar, coke, and asphalt production; and petroleum catalytic cracking are also major contributors (ATSDR 1995).

Exhibit_Att A-19. Estimated Contributions of Modeled Food Types to Dioxin Ingestion Exposures



A.5.5.1 Behavior in the Environment

PAHs emitted to the atmosphere can travel long distances in vapor form or attached to particles, or they can deposit relatively close to an emission source via wet or dry deposition onto water, soil, and vegetation. In the atmosphere, PAHs are found primarily in the particle-bound phase, and atmospheric residence time and transport distances are highly influenced by climatic conditions and the size of the particles to which they are bound (ATSDR 1995).

As a result of sustained input from anthropogenic sources, PAHs are ubiquitous in soil. High molecular weight PAHs, such as benzo(a)pyrene, strongly adsorb to organic carbon in soil, indicating that adsorption to soil particles will limit the mobility of these compounds following deposition to soil (ATSDR 1995).

Most PAHs enter the water column directly through atmospheric deposition (ATSDR 1995). Following deposition onto surface waters, approximately two-thirds of PAHs adsorb strongly to sediment and suspended particles, while only small amounts revolatilize back to the atmosphere (ATSDR 1995). Aquatic organisms can accumulate PAHs via uptake from water, sediment, or food. Although fish and other organisms readily take up PAHs from contaminated food (e.g., aquatic insects, other benthic invertegrates, smaller fish), biomagnification generally does not occur because many organisms can rapidly metabolize PAHs (ATSDR 1995). As a result, concentrations of PAHs have generally been observed to decrease with increasing trophic levels (ATSDR 1995). Due to this ability to metabolize PAHs, BAFs in fish are not expected to be especially high. Sediment-dwelling organisms can experience increased exposure to PAHs through association (e.g., direct uptake, consumption) with contaminated sediment (ATSDR 1995).

For the screening scenario, the partitioning behavior of benzo(a)pyrene is generally consistent with trends reported in the literature.

A.5.5.2 Concentrations in Ingestible Products

The primary source of non-inhalation exposure to benzo(a)pyrene outside of occupational settings is through dietary intake. Exposure can depend on the origin of the food (higher values are often recorded at contaminated sites) and the method of food preparation (higher values have been reported for food that is smoked or grilled). PAHs have been observed to bioaccumulate in aquatic organisms and terrestrial animals through uptake of contaminated water, soil, and food. These compounds are readily metabolized by higher trophic level organisms, including humans, however, so biomagnification is not considered to be significant (ATSDR 1995). Plants accumulate PAHs primarily through atmospheric deposition, but chemical concentrations tend to be below detection levels. PAHs in meat have been observed at concentrations below detection levels up to higher concentrations when the meat is smoked. Similar concentrations have been reported for fish, with smoked fish concentrations sometimes quadruple those found in terrestrial animals. Because PAH concentrations are highest in products that are smoked or grilled, most of the available data for benzo(a)pyrene in food is for products that have been prepared using these processes. As a result, reported values might be significantly higher than those output by MIRC.

For the RTR screening scenario, concentrations output by MIRC were generally lower than the reported ranges for benzo(a)pyrene in ingestible products. This trend is likely the result of background exposure in reported measurements and available data that are skewed toward concentrations in highly contaminated products. Considering these mitigating factors, the RTR screening scenario output concentrations are within the range of plausible values for PAHs in ingestible products.

A.5.5.3 Lifetime Average Daily Dose

The contributions of ingestion exposure pathways to the LADD (and thus lifetime cancer risk) for various PAHs are presented in Exhibit_Att A-20. As shown, the variability in the driving exposure pathways across PAHs is significant, with fish, beef, dairy, fruits, and vegetables comprising between 90 and 99 percent of exposure for different PAHs.

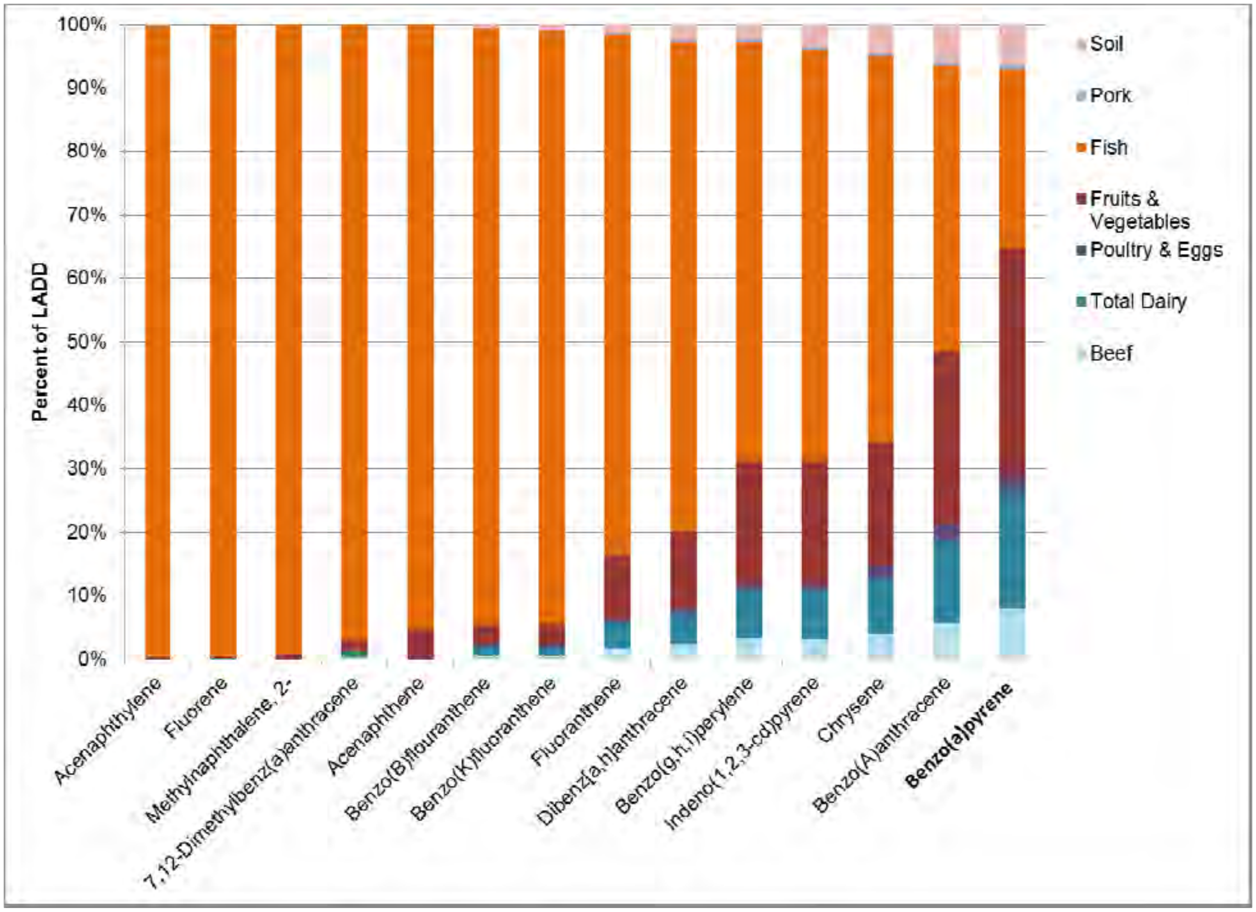
This variability can be accounted for in part by differences in the physiochemical properties that drive the environmental fate and transport processes of these PAHs (e.g., K_{ow}, molecular weight, chemical structure), differences in the PAH-specific half-life in abiotic media, and the degree to which the PAHs are metabolized in biotic media. The variability in exposure pathways is consistent with information provided in the literature.

A.5.6 Summary

This analysis provides a summary of the fate and transport processes and the major routes of exposure for the PB-HAP categories of interest to EPA's RTR Program, as modeled in TRIM.FaTE. In general, the modeled behavior of the compounds is consistent with data found in the literature.

This analysis reveals that fish ingestion is a major route of exposure for cadmium, mercury, dioxins, and PAHs. For organics (i.e., dioxins and PAHs), the farm-food-chain also is a major route of exposure, with beef and dairy contributing significantly to the LADD.

Exhibit_Att A-20. Estimated Contributions of Modeled Food Types to PAH Ingestion Exposures



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Addendum 1. TRIM.FaTE Inputs

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Exhibits, Addendum 1

This attachment provides tables of the modeling inputs for the TRIM.FaTE screening scenario. Exhibit_Add A1-1 presents runtime settings for TRIM.FaTE. Exhibit_Add A1-2 and Exhibit_Add A1-3 present meteorological and air parameters, respectively, entered into the model. Exhibit_Add A1-4, Exhibit_Add A1-5, and Exhibit_Add A1-6 present the parameters for soil and groundwater, runoff assumptions, and the USLE (universal soil loss equation) erosion parameters, respectively, for the screening scenario. Exhibit_Add A1-7 and Exhibit_Add A1-8 present terrestrial parameters. Exhibit_Add A1-9 through Exhibit 1-11 present lake parameters, and Exhibit_Add A1-12 through Exhibit 1-27 present parameters specific to the chemicals modeled in the scenario.

Exhibit_Add A1-1. TRIM.FaTE Simulation Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Start of simulation	date/time	1/1/1990, midnight	Consistent with met data.
End of simulation	date/time	1/1/2040, midnight	Consistent with met data set; selected to provide a 50-year modeling period.
Simulation time step	hr	1	Selected value.
Output time stepa	hr	4	Selected value.

[a] Output time step is set in TRIM.FaTE using the scenario properties "simulationStepsPerOutputStep" and "simulationTimeStep."

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Exhibit_Add A1-2. Meteorological Inputs for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Meteorological Inputs			
Air temperature	degrees K	298	USEPA 2005.
Horizontal wind speed	m/sec	2.8	5th percentile annual average value for contiguous United States, calculated from 30 yrs of annual normal temperature values.
Vertical wind speed	m/sec	0.0	Assumption; vertical wind speed not used by any of the algorithms in the version of the TRIM.FaTE library used for screening.
Wind direction	degrees clockwise from N (blowing from)	3-days-on 4-days-off	On is defined as time during which wind is blowing into the model domain. A conservative estimate of time during which wind should blow into the modeling domain was determined by evaluating HUSWO; it was concluded that a conservative estimate would be approximately 42% of the time.
Rainfall rate	m^3[rain]/m^2 [surface area]-day	varies daily	1.5 m/yr is the maximum statewide 30-year (1971-2000) average for the contiguous United States, excluding Rhode Island because of extreme weather conditions on Mt. Washington. Data obtained from the National Climatic Data Center at http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmpcp.txt. The precipitation frequency was 3-days-on:4-days-off based on data from Holzworth, 1972.
Mixing height (used to set air VE property named "top")	m	710	5th percentile annual average mixing heights (calculated from daily morning and afternoon values), for all stations on SCRM (40 state, 70 stations).
isDay_SteadyState_forAir	unitless	--	Value not used in current dynamic runs (would need to be reevaluated if steady-state runs are needed).
isDay_SteadyState_forOther	unitless	--	

Exhibit_Add A1-3. Air Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Atmospheric dust load	kg[dust]/m^3[air]	6.15E-08	Bidleman 1988
Density of air	g/cm^3	0.0012	USEPA 1997b
Dust density	kg[dust]/m^3[dust]	1,400	Bidleman 1988
Fraction organic matter on particulates	unitless	0.2	Harner and Bidleman 1998

Exhibit_Add A1-4. Soil and Groundwater Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Surface Soil Compartment Type			
Air content	volume[air]/volume[compartment]	0.28	McKone et al. 2001.
Average vertical velocity of water (percolation)	m/day	8.22E-04	Assumed to be 0.2 times average precipitation for site.
Boundary layer thickness above surface soil	m	0.005	Thibodeaux 1996; McKone et al. 2001 (Table 3).
Density of soil solids (dry weight)	kg[soil]/m^3[soil]	2600	Default in McKone et al. 2001 (Table 3).
Thickness - untilled[a]	m	0.01	McKone et al. 2001 (p. 30).
Thickness - tilled[a]	m	0.20	USEPA 2005.
Erosion fraction	unitless	varies[b]	See Exhibit 5.
Fraction of area available for erosion	m^2[area available]/m^2[total]	1	Assumption ; area assumed rural.
Fraction of area available for runoff	m^2[area available]/m^2[total]	1	Assumption ; area assumed rural.
Fraction of area available for vertical diffusion	m^2[area available]/m^2[total]	1	Assumption ; area assumed rural.
Fraction sand	unitless	0.25	Assumption.
Organic carbon fraction	unitless	0.008	U.S. average in McKone et al. 2001 (Table 16 and A-3).
pH	unitless	6.8	Assumption.
Runoff fraction	unitless	varies[b]	See Exhibit_Add A1-5.
Total erosion rate	kg [soil]/m^2/day	varies[b]	See Exhibit_Add A1-6.
Total runoff rate	m^3[water]/m^2/day	1.64E-03	Calculated using scenario-specific precipitation rate and assumptions associated with water balance.
Water content	volume[water]/volume[compartment]	0.15	McKone et al. 2001
Root Zone Soil Compartment Type			
Air content	volume[air]/volume[compartment]	0.25	McKone et al 2001 (Table 16).
Average vertical velocity of water (percolation)	m/day	8.22E-04	Assumed as 0.2 times average precipitation for New England in McKone et al. 2001.
Density of soil solids (dry weight)	kg[soil]/m^3[soil]	2,600	McKone et al. 2001 (Table 3).
Fraction sand	unitless	0.25	Assumption.

Exhibit_Add A1-4. Soil and Groundwater Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Root Zone Soil Compartment Type, continued			
Thickness - untilled[a]	m	0.79	McKone et al. 2001 (Table 16 - U.S. average).
Thickness - tilled[a]	m	0.6	Adjusted from McKone et al. 2001 (Table 16).
Organic carbon fraction	unitless	0.008	McKone et al. 2001 (Tables 16 and A-3, U.S. average).
pH	unitless	6.8	Assumption.
Water content	volume[water]/volume[compartment]	0.15	McKone et al. 2001
Vadose Zone Soil Compartment Type			
Air content	volume[air]/volume[compartment]	0.22	McKone et al. 2001 (Table 17).
Average vertical velocity of water (percolation)	m/day	8.22E-04	Assumed as 0.2 times average precipitation for New England in McKone et al. 2001.
Density of soil solids (dry weight)	kg[soil]/m^3[soil]	2,600	Default in McKone et al. 2001 (Table 3).
Fraction sand	unitless	0.35	Assumption.
Thickness[a]	m	1.4	McKone et al. 2001 (Table 17).
Organic carbon fraction	unitless	0.003	McKone et al. 2001 (Tables 16 and A-3, U.S. average).
pH	unitless	6.8	Assumption.
Water content	volume[water]/volume[compartment]	0.21	McKone et al. 2001 (Table 17 - national average).
Groundwater Compartment Type			
Thickness[a]	m	3	McKone et al. 2001 (Table 3).
Fraction sand	unitless	0.4	Assumption.
Organic carbon fraction	unitless	0.004	Assumption.
pH	unitless	6.8	Assumption.
Porosity	volume[total pore space]/volume[compartment]	0.2	Default in McKone et al. 2001 (Table 3).
Density of solid material in aquifer	kg[soil]/m^3[soil]	2,600	Default in McKone et al. 2001 (Table 3).

[a] Set using the volume element properties file.

[b] See separate tables (Exhibit_Add A1-5 and Exhibit_Add A1-6) for erosion/runoff fractions and total erosion rates.

Exhibit_Add A1-5. Runoff Assumptions for the TRIM.FaTE Screening Scenario

Originating Compartment	Destination Compartment	Runoff/Erosion Fraction
SurfSoil_Source	SurfSoil_N1	0.0
	SurfSoil_S1	0.0
	sink	1.0
SurfSoil_N1	SW_Pond	1.0
	SurfSoil_Source	0.0
	SurfSoil_N6	0.0
	SurfSoil_S1	0.0
	sink	0.0
SurfSoil_S1	SW_Pond	1.0
	SurfSoil_Source	0.0
	SurfSoil_N1	0.0
	sink	0.0
SurfSoil_N6	SW_Pond	1.0
	SurfSoil_N1	0.0
	SurfSoil_N7	0.0
	sink	0.0
SurfSoil_N7	SW_Pond	1.0
	SurfSoil_N6	0.0
	SurfSoil_N3	0.0
	sink	0.0
SurfSoil_N3	SW_Pond	1.0
	SurfSoil_N7	0.0
	SurfSoil_N4	0.0
	sink	0.0
SurfSoil_N4	SW_Pond	1.0
	SurfSoil_N3	0.0
	SurfSoil_N5	0.0
	SurfSoil_S4	0.0
	sink	0.0
SurfSoil_S4	SW_Pond	1.0
	SurfSoil_N4	0.0
	SurfSoil_S5	0.0
	sink	0.0
SurfSoil_N5[a]	SW_Pond	0.0
	SurfSoil_N4	0.5
	SurfSoil_S5	0.5
	sink	0.0
SurfSoil_S5[a]	SW_Pond	0.0
	SurfSoil_N5	0.0
	SurfSoil_S4	1.0
	sink	0.0

[a] Assumes that N5 is higher ground than S5, and half of the runoff flows into N4, and the other half into S5. Assumes all runoff from S5 flows into S4.

Exhibit_Add A1-6. USLE Erosion Parameters for the TRIM.FaTE Screening Scenario

Soil Parcel	**Area**	**Rainfall/Erosivity Index**	**Soil Erodibility Index**	**Length-Slope Factor**	**Land Use**	**Cover Mgmt Factor**	**Supporting Practices Factor**	**Unit Soil Loss**		**Sediment Delivery Ratio**[a]	**Calculated (Adjusted) Erosion Rate**
Code	m^2	R (100 ft-ton/ac)	K (ton/ac/(100 ft-ton/acre))	LS (USCS)	type	C (USCS)	P	A (ton/ac/yr)	A ($kg/m^2/d$)	SDR[a]	$kg/m^2/d$
N1	5.8E+04	300	0.39	1.5	grass	0.1	1	17.55	0.010779	0.533	0.005740
N6	4.1E+04	300	0.39	1.5	crops	0.2	1	35.1	0.021557	0.557	0.012014
N7	7.3E+04	300	0.39	1.5	grass	0.1	1	17.55	0.010779	0.518	0.005580
N3	3.5E+05	300	0.39	1.5	grass	0.1	1	17.55	0.010779	0.385	0.004151
N4	2.0E+06	300	0.39	1.5	forest	0.1	1	17.55	0.010779	0.309	0.003331
N5	6.7E+06	300	0.39	1.5	forest	0.1	1	17.55	0.010779	0.196	0.002116
S1	5.8E+04	300	0.39	1.5	grass	0.1	1	17.55	0.010779	0.533	0.005740
S4	2.0E+06	300	0.39	1.5	forest	0.1	1	17.55	0.010779	0.309	0.003331
S5	6.7E+06	300	0.39	1.5	forest	0.1	1	17.55	0.010779	0.196	0.002116

[a] Calculated using $SDR = a * (AL)^{-b}$; where *a* is the empirical intercept coefficient (based on the size of the watershed), AL is the total watershed area receiving deposition (m^2), and *b* is the empirical slope coefficient (always 0.125).

Exhibit_Add A1-7. Terrestrial Plant Placement for the TRIM.FaTE Screening Scenario

Surface Soil Volume Element	Surface Soil Depth (m)	Coniferous Forest	Grasses/ Herbs	None
Source	0.01			x
N1	0.01		x	
N6	0.20 (tilled)			x
N7	0.01		x	
N3	0.01		x	
N4	0.01	x		
N5	0.01	x		
S1	0.01		x	
S4	0.01	x		
S5	0.01	x		

Exhibit_Add A1-8. Terrestrial Plant Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Coniferous[a]		Grass/Herb[a]	
		Value Used	Reference	Value Used	Reference
Leaf Compartment Type					
Allow exchange	1=yes, 0=no	1	-	Seasonal[b]	-
Average leaf area index	m^2[leaf]/ m^2[area]	5.0	Harvard Forest, dom. red oak and red maple, CDIAC website	5.0	Mid-range of 4-6 for old fields, R.J. Luxmoore, ORNL.
Calculate wet deposition interception fraction (Boolean)	1=yes, 0=no	0	Assumption.	0	Assumption.
Correction exponent, octanol to lipid	unitless	0.76	From roots, Trapp 1995.	0.76	From roots, Trapp 1995.
Degree stomatal opening	unitless	1	Assumed value of 1 for daytime (stomatal diffusion is turned off at night using a different property, IsDay).	1	Assumed value of 1 for daytime (stomatal diffusion is turned off at night using a different property, IsDay).
Density of wet leaf	kg/m^3	820	Paterson et al. 1991.	820	Paterson et al. 1991.
Leaf wetting factor	m	3.00E-04	1E-04 to 6E-04 for different crops and elements, Muller and Prohl 1993.	3.00E-04	1E-04 to 6E-04 for different crops and elements, Muller and Prohl 1993.
Length of leaf	m	0.01	Assumption.	0.05	Assumption.
Lipid content	kg/kg wet weight	0.00224	European beech, Riederer 1995.	0.00224	European beech, Riederer 1995.
Litter fall rate	1/day	0.0021	value assumes 1st-order relationship and that 99% of leaves fall over 6 years	Seasonal[c]	-
Stomatal area normalized effective diffusion path length	1/m	200	Wilmer and Fricker 1996.	200	Wilmer and Fricker 1996.
Vegetation attenuation factor	m^2/kg	2.9	Grass/hay, Baes et al. 1984.	2.9	Grass/hay, Baes et al. 1984.
Water content	unitless	0.8	Paterson et al. 1991.	0.8	Paterson et al. 1991.
Wet deposition interception fraction	unitless	0.2	Calculated based on 5 years of local met data, 1987-1991.	0.2	Calculated based on 5 years of local met data, 1987-1991.
Wet mass of leaf per soil area	kg[fresh leaf]/m^2[area]	2.0	Calculated from leaf area index, leaf thickness (Simonich and Hites, 1994), density of wet foliage.	0.6	Calculated from leaf area index and Leith 1975.
Particle on Leaf Compartment Type					
Allow exchange	1=yes, 0=no	1	-	Seasonal[b]	-

Exhibit_Add A1-8. Terrestrial Plant Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Coniferous[a]		Grass/Herb[a]	
		Value Used	Reference	Value Used	Reference
Particle on Leaf Compartment Type, continued					
Volume particle per area leaf	m^3[leaf particles]/m^2[leaf]	1.00E-09	Based on particle density and size distribution for atmospheric particles measured on an adhesive surface, Coe and Lindberg 1987.	1.00E-09	Based on particle density and size distribution for atmospheric particles measured on an adhesive surface, Coe and Lindberg 1987.
Root Compartment Type – Nonwoody Only					
Allow exchange	1=yes, 0=no			Seasonal[b]	-
Correction exponent, octanol to lipid	unitless			0.76	Trapp 1995.
Lipid content of root	kg/kg wet weight			0.011	Calculated.
Water content of root	kg/kg wet weight			0.8	Assumption.
Wet density of root	kg/m^3			820	Soybean, Paterson et al. 1991.
Wet mass per soil area	kg/m^2			1.4	Temperate grassland, Jackson et al. 1996.
Stem Compartment Type – Nonwoody Only					
Allow exchange	1=yes, 0=no			Seasonal[b]	-
Correction exponent, octanol to lipid	unitless			0.76	Trapp 1995.
Density of phloem fluid	kg/m^3			1,000	Assumption.
Density of xylem fluid	kg/cm^3			900	Assumption.
Flow rate of transpired water per leaf area	m^3[water]/m^2[leaf]			0.0048	Crank et al. 1981.
Fraction of transpiration flow rate that is phloem rate	unitless			0.05	Paterson et al. 1991.
Lipid content of stem	kg/kg wet weight			0.00224	Leaves of European beech, Riederer 1995.
Water content of stem	unitless			0.8	Paterson et al. 1991
Wet density of stem	kg/m^3			830	Assumption.
Wet mass per soil area	kg/m^2			0.24	Calculated from leaf and root biomass density.

[a] See Exhibit_Add A1-7 for assignment of plant types to surface soil compartments.

[b] Begins March 9 (set to 1), ends November 7 (set to 0). Nationwide 80th percentile.

[c] Begins November 7, ends December 6; rate = 0.15/day during this time (value assumes 99 percent of leaves fall in 30 days).

Exhibit_Add A1-9. Surface Water Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Algae carbon content (fraction)	unitless	0.465	APHA 1995.
Algae density in water column	g[algae]/L[water]	0.0025	Millard et al. 1996 as cited in ICF 2005.
Algae growth rate	1/day	0.7	Hudson et al. 1994 as cited in Mason et al. 1995b.
Algae radius	um	2.5	Mason et al. 1995b.
Algae water content (fraction)	unitless	0.9	APHA 1995.
Average algae cell density (per volume cell, not water)	g[algae]/m^3[algae]	1,000,000	Mason et al. 1995b, Mason et al. 1996.
Boundary layer thickness above sediment	m	0.02	Cal EPA 1993.
Chloride concentration	mg/L	8.0	Kaushal et al. 2005.
Chlorophyll concentration	mg/L	0.0029	ICF 2005.
Depth[a]	m	3.18	WI DNR 2007 - calculation based on relationship between drainage basin and lake area size.
Dimensionless viscous sublayer thickness	unitless	4	Ambrose et al. 1995.
Drag coefficient for water body	unitless	0.0011	Ambrose et al. 1995.
Flush rate	1/year	12.17	Calculated based on pond dimensions and flow calculations.
Fraction Sand	unitless	0.25	Assumption.
Organic carbon fraction in suspended sediments	unitless	0.02	Assumption.
pH	unitless	7.3	Assumption.
Suspended sediment deposition velocity	m/day	2	USEPA 1997b.
Total suspended sediment concentration	kg[sediment]/m^3[water column]	0.05	USEPA 2005.
Water temperature	degrees K	298	USEPA 2005.

[a] Set using the volume element properties named "top" and "bottom."

Exhibit_Add A1-10. Sediment Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value Used	Reference
Depth[a]	m	0.05	McKone et al. 2001 (Table 3).
Fraction sand	unitless	0.25	Assumption.
Organic carbon fraction	unitless	0.02	McKone et al. 2001 (Table 3).
Porosity of the sediment zone	volume[total pore space]/volume[sediment compartment]	0.6	USEPA 2005.
Solid material density in sediment	kg[sediment]/m^3[sediment]	2,600	McKone et al. 2001 (Table 3).
pH	unitless	7.3	Assumption.
Sediment resuspension velocity	m/day	6.69E-05	Calculated from water balance model.

[a] Set using the volume element properties named "top" and "bottom."

Exhibit_Add A1-11. Aquatic Animals Food Chain, Density, and Mass for the TRIM.FaTE Screening Scenario

Aquatic Biota (Consuming Organism)	Fraction Diet								Biomass (kg/m^2)	Body Weight (kg)	Reference
	Algae	Zooplankton	Benthic Invertebrate	Water Column Herbivore	Benthic Omnivore	Water Column Omnivore	Benthic Carnivore	Water Column Carnivore			
Benthic Invertebrate	0%	0%	0%	0%	0%	0%	0%	0%	0.020	2.55E-04	Assumption.
Water Column Herbivore	0%	100%	0%	0%	0%	0%	0%	0%	0.002	0.025	Assumption.
Benthic Omnivore	0%	0%	100%	0%	0%	0%	0%	0%	0.002	2.50E-01	Assumption.
Water Column Omnivore	0%	0%	0%	100%	0%	0%	0%	0%	0.001	0.25	Assumption.
Benthic Carnivore	0%	0%	50%	0%	50%	0%	0%	0%	0.001	2.0	Assumption.
Water Column Carnivore	0%	0%	0%	0%	0%	100%	0%	0%	0.0002	2.0	Assumption.
Zooplankton	100%	0%	0%	0%	0%	0%	0%	0%	0.0064	5.70E-08	Assumption.

Exhibit_Add A1-12. Cadmium Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name[a]	Units	Value	Reference
CAS number[b]	unitless	7440-43-9	-
Diffusion coefficient in pure air	m^2[air]/day	0.71	USEPA 1999 (Table A-2-35).
Diffusion coefficient in pure water	m^2[water]/day	8.16E-05	USEPA 1999 (Table A-2-35).
Henry's Law constant	Pa-m^3/mol	1.00E-37	USEPA 1999 (Table A-2-35; assumed to be zero).
Melting point	degrees K	594	ATSDR 1999.
Molecular weight	g/mol	112.41	ATSDR 1999.
Octanol-air partition coefficient (K_{oa})	m^3[air]/m^3[octanol]	-	-
Octanol-carbon partition coefficient (K_{oc})		-	-
Octanol-water partition coefficient (K_{ow})	L[water]/kg[octanol]	-	-

[a] All parameters in this table are TRIM.FaTE chemical properties.

[b] This CAS numbers applies to elemental Cd; however, the cations of cadmium are being modeled.

Exhibit_Add A1-13. Mercury Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)[b]	**Hg(2)**[b]	**MHg**[b]	
CAS number	unitless	7439-97-6	14302-87-5	22967-92-6	-
Diffusion coefficient in pure air	m^2[air]/day	0.478	0.478	0.456	USEPA 1997b.
Diffusion coefficient in pure water	m^2[water]/day	5.54E-05	5.54E-05	5.28E-05	USEPA 1997b.
Henry's Law constant	Pa-m^3/mol	719	7.19E-05	0.0477	USEPA 1997b.
Melting point	degrees K	234	5.50E+02	443	CARB 1994.
Molecular weight	g/mol	201	201	216	USEPA 1997b.
Octanol-water partition coefficient (K_{ow})	L[water]/kg[octanol]	4.15	3.33	1.7	Mason et al. 1996.
Vapor washout ratio	m^3[air]/m^3[rain]	1,200	1.6E+06	0	USEPA 1997b, based on Petersen et al. 1995.

[a] All parameters in this table are TRIM.FaTE chemical properties.

[b] On this and all following tables, Hg(0) = elemental mercury, Hg(2) = divalent mercury, and MHg = methyl mercury.

Exhibit_Add A1-14. PAH Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value							
		2Methyl	712DMB	Acenaphthene	Acenaphthylene	BaA	BaP	BbF	BghiP
CAS number	unitless	91-57-6	57-97-6	83-32-9	208-96-8	56-55-3	50-32-8	205-99-2	191-24-2
Diffusion coefficient in pure air	m^2/day	0.451	0.691	0.009	0.388	0.441	0.372	0.009	0.190
Diffusion coefficient in pure water	m^2/day	6.70E-05	6.91E-05	8.64E-05	6.03E-05	7.78E-05	7.78E-05	8.64E-05	4.54E-05
Henry's Law constant	Pa-m^3/mol	50.56	0.20	18.50	12.70	1.22	0.07	0.05	0.03
Melting point	degrees K	307.75	396.65	366.15	365.65	433	452	441	550.15
Molecular weight	g/mol	142.20	256.35	154.21	152.20	228.29	252.32	252.32	276.34
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	7.24E+03	6.31E+05	8.32E+03	1.00E+04	6.17E+05	9.33E+05	6.03E+05	4.27E+06

Parameter Name	Units	Value					
		BkF	Chr	DahA	Fluoranthene	Fluorene	IcdP
CAS number	unitless	207-08-9	218-01-9	53-70-3	206-44-0	86-73-7	193-39-5
Diffusion coefficient in pure air	m^2/day	0.009	0.009	0.009	0.009	0.009	0.009
Diffusion coefficient in pure water	m^2/day	8.64E-05	8.64E-05	8.64E-05	8.64E-05	8.64E-05	8.64E-05
Henry's Law constant	Pa-m^3/mol	0.04	0.53	0.01	1.96	9.81	0.03
Melting point	degrees K	490	531	539	383.15	383.15	437
Molecular weight	g/mol	252.32	228.29	278.33	202.26	166.20	276.34
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	8.71E+05	5.37E+05	3.16E+06	1.45E+05	1.51E+04	5.25E+06

Exhibit_Add A1-14. PAH Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	Units	Reference
CAS number	unitless	-
Diffusion coefficient in pure air	m^2/day	USEPA 2005. Exceptions include USEPA 1997a (7,12-Dimethylbenz(a)anthracene), and USEPA 2007 (2-Methylnaphthalene, Acenaphthylene, and Benzo(g,h,i)perylene)
Diffusion coefficient in pure water	m^2/day	USEPA 2005. Exceptions include USEPA 1997a (7,12-Dimethylbenz(a)anthracene), and USEPA 2007 (2-Methylnaphthalene, Acenaphthylene, and Benzo(g,h,i)perylene)
Henry's Law constant	Pa-m^3/mol	USEPA 2005. Exceptions include USEPA 2003 (2-Methylnaphthalene) HSDB 2001a (7,12-Dimethylbenz(a)anthracene), HSDB 2001b (Acenaphthylene), and HSDB 2001c (Benzo(g,h,i)perylene)
Melting point	degrees K	Budavari 1996. Exceptions include USEPA 2003 (2-Methylnaphthalene), HSDB 2001a (7,12-Dimethylbenz(a)anthracene), HSDB 2001b (Acenaphthylene), HSDB 2001c (Benzo(g,h,i)perylene), and USEPA 2005 (Acenaphthene, Fluoranthene, and Fluorene)
Molecular weight	g/mol	Budavari 1996. Exceptions include USEPA 2003 (2-Methylnaphthalene), HSDB 2001a (7,12-Dimethylbenz(a)anthracene), HSDB 2001b (Acenaphthylene), HSDB 2001c (Benzo(g,h,i)perylene), and USEPA 2005 (Acenaphthene, Fluoranthene, and Fluorene)
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	Hansch et al. 1995. Exceptions include Passivirta et al. 1999 (Acenaphthylene, Benzo(k)fluoranthene, and Indeno(1,2,3-cd)pyrene), and Sangster 1993 (Benzo(b)fluoranthene)

Exhibit_Add A1-15. Dioxin Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	**Units**	**Value**						
		1,2,3,4,6,7,8,9-OCDD	**1,2,3,4,6,7,8,9-OCDF**	**1,2,3,4,6,7,8-HpCDD**	**1,2,3,4,6,7,8-HpCDF**	**1,2,3,4,7,8,9-HpCDF**	**1,2,3,4,7,8-HxCDD**	**1,2,3,4,7,8-HxCDF**
CAS number	unitless	3268-87-9	39001-02-0	35822-46-9	67562-39-4	55673-89-7	39227-28-6	70648-26-9
Diffusion coefficient in pure air	m^2/day	0.751	0.168	0.782	0.176	0.176	0.816	0.183
Diffusion coefficient in pure water	m^2/day	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05
Henry's Law constant	Pa-m^3/mol	0.684	0.19	1.22	1.43	1.42	1.08	1.45
Melting point	degrees K	603.0	259.0	538.0	236.5	222.0	546.0	499.0
Molecular weight	g/mol	460	443.76	425.2	409.31	409.31	391	374.87
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	1.58E+08	1.00E+08	1.00E+08	2.51E+07	7.94E+06	6.31E+07	1.00E+07

Parameter Name	**Units**	**Value**						
		1,2,3,6,7,8-HxCDD	**1,2,3,6,7,8-HxCDF**	**1,2,3,7,8,9-HxCDD**	**1,2,3,7,8,9-HxCDF**	**1,2,3,7,8-PeCDD**	**1,2,3,7,8-PeCDF**	**2,3,4,6,7,8-HxCDF**
CAS number	unitless	57653-85-7	57117-44-9	19408-74-3	72918-21-9	40321-76-4	57117-41-6	60851-34-5
Diffusion coefficient in pure air	m^2/day	0.816	0.183	0.816	0.183	0.854	0.192	0.183
Diffusion coefficient in pure water	m^2/day	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05	6.91E-05
Henry's Law constant	Pa-m^3/mol	1.11	0.741	1.11	1.11	0.263	0.507	1.11
Melting point	degrees K	558.0	506.0	517.0	509.0	513.0	499.0	512.5
Molecular weight	g/mol	390.84	374.87	390.84	374.87	356.4	340.42	374.87
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	1.62E+08	8.24E+07	1.62E+08	3.80E+07	1.86E+07	6.17E+06	8.31E+07

Exhibit_Add A1-15. Dioxin Chemical-Specific Parameters for the TRIM.FaTE Screening Scenario

Parameter Name	**Units**	**Value**			**Reference**
		2,3,4,7,8-PeCDF	**2,3,7,8-TCDD**	**2,3,7,8-TCDF**	
CAS number	unitless	57117-31-4	1746-01-6	51207-31-9	-
Diffusion coefficient in pure air	m^2/day	0.192	0.899	0.203	US EPA 2005
Diffusion coefficient in pure water	m^2/day	6.91E-05	4.84E-05	5.19E-05	US EPA 2005
Henry's Law constant	Pa-m^3/mol	0.505	3.33	1.46	US EPA 2005
Melting point	degrees K	469.3	578.0	500.0	Mackay et al. 2000. Exceptions include USEPA 2000a (1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDF, and 1,2,3,7,8-PeCDD), ATSDR 1998 (1,2,3,6,7,8-HxCDF, 1,2,3,7,8-PeCDF, and 2,3,4,6,7,8-HxCDF), and NLM 2002 (1,2,3,7,8,9-HxCDD)
Molecular weight	g/mol	340.42	322	306	Mackay et al. 2000. Exceptions include ATSDR 1998 (1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDF, 1,2,3,7,8-PeCDD, 1,2,3,7,8-PeCDF, and 2,3,4,6,7,8-HxCDF) and NLM 2002 (1,2,3,6,7,8-HxCDD and 1,2,3,7,8,9-HxCDD)
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	3.16E+06	6.31E+06	1.26E+06	Mackay et al. 1992 as cited in USEPA 2000b. Exceptions include Mackay et al. 2000 (1,2,3,4,7,8,9-HpCDF), USEPA 2000a (1,2,3,6,7,8-HxCDD, 1,2,3,6,7,8-HxCDF, 1,2,3,7,8,9-HxCDD, 1,2,3,7,8,9-HxCDF, and 2,3,4,6,7,8-HxCDF), and Sijm et al. 1989 as cited in USEPA 2000b (1,2,3,7,8-PeCDD)

Exhibit_Add A1-16. Cadmium Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value	Reference
Air Compartment Type			
Particle dry deposition velocity	m/day	260	Calculated from Muhlbaier and Tissue 1980.
Washout ratio	m^3[air]/m^3[rain]	200,000	MacKay et al. 1986.
Surface Soil Compartment Type			
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	Assumption.
Root Zone Soil Compartment Type			
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	Assumption.
Vadose Zone Soil Compartment Type			
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	Assumption.
Surface Water Compartment Type			
Ratio of concentration in water to concentration in algae to concentration dissolved in water	L[water]/g[algae wet wt]	1.87	McGeer et al. 2003.

Exhibit_Add A1-17. Mercury Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Air Compartment Type					
Particle dry deposition velocity	m/day	500	500	500	CalTOX value cited in McKone et al. 2001.
Demethylation rate	1/day	N/A	N/A	0	Assumption.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	0.00385	0	0	Low end of half-life range (6 months to 2 years) in USEPA 1997b.
Reduction rate	1/day	0	0	0	Assumption.
Washout ratio	m^3[air]/m^3[rain]	200,000	200,000	200,000	Assumption.
Surface Soil Compartment Type					
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	0	0	Assumption.
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	USEPA 1997b.
Vapor dry deposition velocity	m/day	50	2500	0	Hg(0) - from Lindberg et al. 1992; Hg(2) - estimate by USEPA using the Industrial Source Complex (ISC) Model - [See Vol. III, App. A of the Mercury Study Report (USEPA 1997b)].
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari and Verta 1995 is 3E-2 to 6E-2 /day; value is average maximum potential demethylation rate constant under anaerobic conditions.
Methylation rate	1/day	0	0.001	0	Range reported in Porvari and Verta 1995 is 2E-4 to 1E-3 /day; value is average maximum potential methylation rate constant under anaerobic conditions.
Oxidation rate	1/day	0	0	0	Value assumed in USEPA 1997b.
Reduction rate	1/day	0	1.25E-05	0	Value used for untilled surface soil (2cm), 10% moisture content, in USEPA 1997b; general range is (0.0013/day)*moisture content to (0.0001/day)*moisture content for forested region (Lindberg 1996; Carpi and Lindberg 1997).

Exhibit_Add A1-17. Mercury Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Root Zone Soil Compartment Type					
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	0	0	Assumption.
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	USEPA 1997b.
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari and Verta 1995 is 3E-2 to 6E-2 /day; value is average maximum potential demethylation rate constant under anaerobic conditions.
Methylation rate	1/day	0	0.001	0	Range reported in Porvari and Verta 1995 is 2E-4 to 1E-3 /day; value is average maximum potential methylation rate constant under anaerobic conditions.
Oxidation rate	1/day	0	0	0	Value assumed in USEPA 1997b.
Reduction rate	1/day	0	3.25E-06	0	Value used for tilled surface soil (20cm), 10% moisture content, in USEPA 1997b (Lindberg 1996; Carpi and Lindberg 1997).
Vadose Zone Soil Compartment Type					
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	0	0	Assumption.
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	USEPA 1997b.
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari and Verta 1995 is 3E-2 to 6E-2 /day; value is average maximum potential demethylation rate constant under anaerobic conditions.
Methylation rate	1/day	0	0.001	0	Range reported in Porvari and Verta 1995 is 2E-4 to 1E-3 /day; value is average maximum potential methylation rate constant under anaerobic conditions.
Oxidation rate	1/day	0	0	0	Value assumed in USEPA 1997b.
Reduction rate	1/day	0	3.25E-06	0	Value used for tilled surface soil (20cm), 10% moisture content, in USEPA 1997b (Lindberg 1996; Carpi and Lindberg 1997).

Exhibit_Add A1-17. Mercury Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Groundwater Compartment Type					
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	USEPA 1997b.
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari and Verta 1995 is 3E-2 to 6E-2 /day; value is average maximum potential demethylation rate constant under anaerobic conditions.
Methylation rate	1/day	0	0.001	0	Range reported in Porvari and Verta 1995 is 2E-4 to 1E-3 /day; value is average maximum potential methylation rate constant under anaerobic conditions.
Oxidation rate	1/day	1.00E-08	0	0	Small default nonzero value (0 assumed in USEPA 1997b).
Reduction rate	1/day	0	3.25E-06	0	Value used for tilled surface soil (20cm), 10% moisture content, in USEPA 1997b (Lindberg 1996; Carpi and Lindberg 1997).
Surface Water Compartment Type					
Algal surface area-specific uptake rate constant	nmol/[µm2-day-nmol]	0	2.04E-10	3.60E-10	Assumes radius = 2.5mm, Mason et al. 1995b, Mason et al. 1996; Hg(0) assumed same as Hg(2).
D_{ow} ("overall K_{ow}")	L[water]/kg[octanol]	0	-a	-b	Mason et al. 1996.
Solids-water partition coefficient	L[water]/kg[solids wet wt]	1,000	100,000	100,000	USEPA 1997b.
Vapor dry deposition velocity	m/day	N/A	2500		USEPA 1997b (Vol. III, App. A).
Demethylation rate	1/day	N/A	N/A	0.013	Average range of 1E-3 to 2.5E-2/day from Gilmour and Henry 1991.
Methylation rate	1/day	0	0.001	0	Value used in EPA 1997; range is 1E-4 to 3E-4/day (Gilmour and Henry 1991).
Oxidation rate	1/day	0	0	0	Assumption.
Reduction rate	1/day	0	0.0075	0	Value used in USEPA 1997b; reported values range from less than 5E-3/day for depths greater than 17m, up to 3.5/day (Xiao et al. 1995; Vandal et al. 1995; Mason et al. 1995a; Amyot et al. 1997).

Exhibit_Add A1-17. Mercury Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Sediment Compartment Type					
Solids-water partition coefficient	L[water]/kg[solids wet wt]	3,000	50,000	3,000	USEPA 1997b.
Demethylation rate	1/day	N/A	N/A	0.0501	Average range of 2E-4 to 1E-1/day from Gilmour and Henry 1991.
Methylation rate	1/day	0	1.00E-04	0	Value used in EPA 1997b; range is 1E-5 to 1E-3/day, Gilmour and Henry 1991.
Oxidation rate	1/day	0	0	0	Assumption.
Reduction rate	1/day	0	1.00E-06	0	Inferred value based on presence of Hg(0) in sediment porewater (USEPA 1997b; Vandal et al. 1995).

[a] TRIM.FaTE Formula Property, which varies from 0.025 to 1.625 depending on pH and chloride concentration.

[b] TRIM.FaTE Formula Property, which varies from 0.075 to 1.7 depending on pH and chloride concentration.

Exhibit_Add A1-18. PAH Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value								
		2Methyl	712DMB	Acenaph-thene	Acenaph-thylene	BaA	BaP	BbF	BghiP	BkF
Air Compartment Type										
Particle dry deposition velocity	m/day	500	500	500	500	500	500	500	500	500
Half-life	day	0.154	0.092	0.3	0.208	0.125	0.046	0.596	0.215	0.458
Washout ratio		200000	200000	200000	200000	200000	200000	200000	200000	200000
Surface Soil Compartment Type										
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0	0	0	0
Half-life	day	18	24	56	66.5	680	530	610	415	2140
Root Zone Soil Compartment Type										
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0	0	0	0
Half-life	day	18	24	56	66.5	680	530	610	415	2140
Vadose Zone Soil Compartment Type										
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0	0	0	0
Half-life	day	36	48	112	133	1360	1060	1220	830	4280
Groundwater Compartment Type										
Half-life	day	36	48	112	133	1360	1060	1220	830	4280
Surface Water Compartment Type										
Ratio Of Conc In Algae To Conc Dissolved In Water	(g[chem]/kg[algae]) / (g[chem]/L[water])	2.6	333.4	3	3.7	325	510	317	1539	473
Half-life	day	78	216	25	184	0.375	0.138	90	1670	62.4
Sediment Compartment Type										
Half-life	day	2290	2290	2290	2290	2290	2290	2290	2290	2290

Exhibit_Add A1-18. PAH Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Air Compartment Type							
Particle dry deposition velocity	m/day	500	500	500	500	500	McKone et al. 2001.
Half-life	day	0.334	0.178	0.46	0.46	0.262	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), USEPA 1998 (7,12-Dimethylbenz(a)anthracene, Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001d (Acenaphthene), HSDB 2001b (Acenaphthylene), and Spero et al. 2000 (Fluorene).
Washout ratio		200000	200000	200000	200000	200000	Mackay et al. 1986.
Surface Soil Compartment Type							
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	Assumption.
Half-life	day	1000	940	275	33	730	MacKay et al. 2000 / average of range. Exceptions include ATSDR 2005 (2-Methylnaphthalene), USEPA 1998 (7,12-Dimethylbenz(a)anthracene, Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001d (Acenaphthene), HSDB 2001b (Acenaphthylene), and HSDB 2001e (Fluorene).
Root Zone Soil Compartment Type							
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	Assumption.
Half-life	day	1000	940	275	33	730	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), USEPA 1998 (7,12-Dimethylbenz(a)anthracene, Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001d (Acenaphthene), HSDB 2001b (Acenaphthylene), and HSDB 2001e (Fluorene).
Vadose Zone Soil Compartment Type							
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	Assumption.

Exhibit_Add A1-18. PAH Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoran-thene	Fluor-ene	IcdP	
Vadose Zone Soil Compartment Type, continued							
Half-life	day	2000	1880	550	66	1460	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), USEPA 1998 (7,12-Dimethylbenz(a)anthracene, Benzo(g,h,i)perylene, and Fluoranthene) / twice average of range, HSDB 2001d (Acenaphthene) / multiplied by 2, HSDB 2001b (Acenaphthylene) / multiplied by 2, and HSDB 2001e (Fluorene) / multiplied by 2.
Groundwater Compartment Type							
Half-life	day	2000	1880	550	66	1460	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), USEPA 1998 (7,12-Dimethylbenz(a)anthracene, Benzo(g,h,i)perylene, and Fluoranthene) / twice average of range, HSDB 2001d (Acenaphthene) / multiplied by 2, HSDB 2001b (Acenaphthylene) / multiplied by 2, and HSDB 2001e (Fluorene) / multiplied by 2.
Surface Water Compartment Type							
RatioOfConcInAlgaeToConcDissolvedInWater	(g[chem]/kg[algae])/ (g[chem]/L[water])	280	1388	67.4	5.8	1653	K_{ow} from Del Vento and Dachs 2002.
Half-life	day	1.626	97.8	160	8.5	750	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include HSDB 2005 (2-Methylnaphthalene), HSDB 2001a (7-12 Dimethylbenz(a)anthracene), HSDB 2001d (Acenaphthene), HSDB 2001b (Acenaphthylene), and HSDB 2001c (Benzo(g,h,i)perylene), Montgomery 2000 (Fluoranthene), and Boyle 1985 (Fluorene).
Sediment Compartment Type							
Half-life	day	2290	2290	2290	2290	2290	Mackay et al. 1992 / PAH values are the mean half-life of the log class that Mackay et al. assigned for sediment, except for BbF and IcdP, which were not in Table 2.3 of Mackay et. al.

Exhibit_Add A1-19. Dioxin Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					
		1,2,3,4,6,7,8,9-OCDD	1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8-HxCDD
Air Compartment Type							
Deposition Velocity	m/day	500	500	500	500	500	500
Half-life	day	162	321	64	137	122	42
Washout Ratio	m^3[air]/m^3[rain]	91000	22000	64000	32000	32000	9000
Surface Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Halflife	day	3650	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Vadose Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	1008	1008	1008	1008	1008	1008
Groundwater Compartment Type							
Half-life	day	1008	1008	1008	1008	1008	1008
Surface Water Compartment Type							
Ratio Of Conc In Algae To Conc Dissolved In Water	(g[chem]/g[algae])/(g[chem]/L[water])	5.31	4.54	4.54	2.83	1.9	3.88
Half-life	day	0.67	0.58	47	0.58	0.58	6.3
Sediment Compartment Type							
Half-life	day	1095	1095	1095	1095	1095	1095

Exhibit_Add A1-19. Dioxin Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	**Units**	**Value**					
		1,2,3,4,7,8-HxCDF	**1,2,3,6,7,8-HxCDD**	**1,2,3,6,7,8-HxCDF**	**1,2,3,7,8,9-HxCDD**	**1,2,3,7,8,9-HxCDF**	**1,2,3,7,8-PeCDD**
Air Compartment Type							
Deposition velocity	m/day	500	500	500	500	500	500
Half-life	day	78	28	55	28	51	18
Washout ratio	m^3[air]/m^3[rain]	10000	9000	10000	9000	10000	18000
Surface Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Vadose Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	1008	1008	1008	1008	1008	1008
Groundwater Compartment Type							
Half-life	day	1008	1008	1008	1008	1008	1008
Surface Water Compartment Type							
Ratio Of Conc In Algae To Conc Dissolved In Water	(g[chem]/g[algae])/ (g[chem]/L[water])	2.06	5.36	4.25	5.36	3.26	1.55
Half-life	day	0.58	6.3	0.58	6.3	0.58	2.7
Sediment Compartment Type							
Half-life	day	1095	1095	1095	1095	1095	1095

Exhibit_Add A1-19. Dioxin Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value				
		1,2,3,7,8-PeCDF	2,3,4,6,7,8-HxCDF	2,3,4,7,8-PeCDF	2,3,7,8-TCDD	2,3,7,8-TCDF
Air Compartment Type						
Deposition velocity	m/day	500	500	500	500	500
Half-life	day	31	59	33	12	19
Washout ratio	m^3[air]/m^3[rain]	13000	10000	14000	18000	19000
Surface Soil Compartment Type						
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type						
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650
Vadose Zone Soil Compartment Type						
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0
Half-life	day	1008	1008	1008	1008	1008
Groundwater Compartment Type						
Half-life	day	1008	1008	1008	1008	1008
Surface Water Compartment Type						
Ratio Of Conc In Algae To Conc Dissolved In Water	(g[chem]/g[algae])/ (g[chem]/L[water])	1.75	4.26	1.39	1.76	0.71
Half-life	day	0.19	0.58	0.19	2.7	0.18
Sediment Compartment Type						
Half-life	day	1095	1095	1095	1095	1095

Exhibit_Add A1-19. Dioxin Chemical-Specific Parameters for Abiotic Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Reference
Air Compartment Type	
Deposition velocity	McKone et al. 2001.
Half-life	Atkinson 1996 as cited in USEPA 2000b; vapor phase reaction with hydroxyl radical.
Washout ratio	Vulykh et al. 2001.
Surface Soil Compartment Type	
Input characteristic depth	Not used (model set to calculate value).
Use input characteristic depth (Boolean)	Assumption.
Half-life	Mackay et al. 2000; the degradation rate was cited by multiple authors, value is for 2,3,7,8-TCDD.
Root Zone Soil Compartment Type	
Input characteristic depth	Not used (model set to calculate value).
Use input characteristic depth	Assumption.
Half-life	Mackay et al. 2000; the degradation rate was cited by multiple authors, value is for 2,3,7,8-TCDD.
Vadose Zone Soil Compartment Type	
Input characteristic depth	Not used (model set to calculate value).
Use input characteristic depth (Boolean)	Assumption.
Half-life	Average value of the range presented in Mackay et al. 2000; based on estimated unacclimated aerobic biodegradation half-life, value is for 2,3,7,8-TCDD.
Groundwater Compartment Type	
Half-life	Average value of the range presented in Mackay et al. 2000; based on estimated unacclimated aerobic biodegradation half-life, value is for 2,3,7,8-TCDD.
Surface Water Compartment Type	
Ratio Of Conc In Algae To Conc Dissolved In Water	Estimated from K_{ow} value using model from DelVento and Dachs 2002
Half-life	Kim and O’Keefe 1998, as cited in USEPA 2000b.
Sediment Compartment Type	
Half-life	Estimation based on Adriaens and Grbic-Galic 1992,1993 and Adriaens et al. 1995 as cited in USEPA 2000b.

Exhibit_Add A1-20. Cadmium Chemical-Specific Parameters for Plant Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value	Reference
Leaf Compartment Type			
Transfer factor to leaf particle	1/day	0.002	Assumption.
Particle on Leaf Compartment Type			
Transfer factor to leaf	1/day	0.200	Assumption.
Root Compartment Type - Grasses and Herbs[a]			
Root to Root Soil Partition-Alpha of Steady State	unitless	0.95	Henning et al. 2001.
Root to Root Soil Partition-Partitioning Coefficient	m^3[bulk root soil]/m^3[root]	0.23	Nriagu 1980; based on average value calculated from various agricultural plant species.
Root to Root Soil Partition-Time to Reach Alpha	day	28	Henning et al. 2001.
Stem Compartment Type - Grasses and Herbs[a]			
Transpiration stream concentration factor (TSCF)	m^3[soil pore water]/m^3[xylem fluid]	0.45	Tsiros et al. 1999.

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Exhibit_Add A1-21. Mercury Chemical-Specific Parameters for Plant Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Leaf Compartment Type					
Transfer factor to leaf particle	1/day	0.002	0.002	0.002	Assumed based on 1% of transfer factor from leaf particle to leaf.
Demethylation rate	1/day	N/A	N/A	0.03	Calculated from Bache et al. 1973.
Methylation rate	1/day	0	0	0	Assumed from Gay 1975, Bache et al. 1973.
Oxidation rate	1/day	1.0E+06	0	0	Assumed to be nearly instantaneous
Reduction rate	1/day	0	0	0	Assumption.
Particle on Leaf Compartment Type					
Transfer factor to leaf	1/day	0.2	0.2	0.2	Assumption.
Demethylation rate	1/day	N/A	N/A	0	Assumption.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	0	0	0	Assumption.
Reduction rate	1/day	0	0	0	Assumption.
Root Compartment Type - Grasses and Herbs[a]					
Alpha for root-root zone bulk soil	unitless	0.95	0.95	0.95	Selected value.
Root/root-zone-soil-water partition coefficient	m^3[bulk root soil]/ m^3[root]	0	0.18	1.2	Hg^{2-} geometric mean Leonard et al. 1998, John 1972, Hogg et al. 1978; MHg-assumed, based on Hogg et al. 1978.
t-alpha for root-root zone bulk soil	day	21	21	21	Assumption.
Demethylation rate	1/day	N/A	N/A	0	Assumption.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	0	0	0	Assumption.
Reduction rate	1/day	0	0	0	Assumption.
Stem Compartment Type - Grasses and Herbs[a]					
Transpiration stream concentration factor (TSCF)	m^3[soil pore water]/m^3[xylem fluid]	0	0.5	0.2	Calculation from Norway spruce, Scots pine, Bishop et al. 1998.
Demethylation rate	1/day	N/A	N/A	0.03	Calculated from Bache et al. 1973.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	0	0	0	Assumption.
Reduction rate	1/day	0	0	0	Assumption.

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Exhibit_Add A1-22. PAH Chemical-Specific Parameters for Plant Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	**Units**	**Value**								
		2Methyl	**712DMB**	**Acenaph-thene**	**Acenaph-thylene**	**BaA**	**BaP**	**BbF**	**BghiP**	**BkF**
Leaf Compartment Type										
Transfer factor to leaf particle	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Half-life	day	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Particle on Leaf Compartment Type										
Transfer factor to leaf	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Half-life	day	2.31	2.31	2.31	2.31	1.84	2.31	3.56	2.31	17.80
Root Compartment Type - Grasses and Herbs[a]										
Half-life	day	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60
Root soil-water interaction - alpha	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Stem Compartment Type - Grasses and Herbs[a]										
Half-life	day	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Exhibit_Add A1-23. PAH Chemical-Specific Parameters for Plant Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoran-thene	Fluorene	IcdP	
Leaf Compartment Type							
Transfer factor to leaf particle	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	Assumption.
Half-life	day	3.50	3.50	3.50	3.50	3.50	Edwards 1988 (calculated from metabolic rate constant).
Particle on Leaf Compartment Type							
Transfer factor to leaf	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	Assumption.
Half-life	day	4.12	17.80	2.31	2.31	17.80	Calculated as 2 times the measured photolysis half-life from Mackay et al. 1992. Exceptions include values that have been set equal to Benzo(a)pyrene (2-Methylnaphthalene; 7,12-Dimethylbenz(a)anthracene; Acenaphthene; Acenaphthylene; Benzo(ghi)perylene; Fluoranthene; and Fluorene).
Root Compartment Type - Grasses and Herbs[a]							
Half-life	day	34.60	34.60	34.60	34.60	34.60	Edwards 1988 (calculated from metabolic rate constant).
Root soil water interaction - alpha	unitless	0.95	0.95	0.95	0.95	0.95	Assumption.
Stem Compartment Type - Grasses and Herbs[a]							
Half-life	day	3.50	3.50	3.50	3.50	3.50	Edwards 1988 (calculated from metabolic rate constant).

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Exhibit_Add A1-23. Dioxin Chemical-Specific Parameters for Plant Compartments in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value	Reference
		All Dioxins	
Leaf Compartment Type			
Transfer factor to leaf particle	1/day	0.003	Calculated as 1 percent of transfer factor to leaf; highly uncertain.
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba et al. 1995; soybean root cell culture metabolism test data for DDE.
Particle on Leaf Compartment Type			
Transfer factor to leaf	1/day	0.3	Assumption based on USEPA 2000b (an estimate for mercury) and Trapp 1995; highly uncertain.
Half-life	day	4.4	McCrady and Maggard 1993; photodegradation sorbed to grass foliage in sunlight; assumed 10% sunlight per day.
Root Compartment Type - Grasses and Herbs[a]			
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba et al. 1995; soybean root cell culture metabolism test data for DDE.
Root soil-water interaction - alpha	unitless	0.95	Assumption.
Stem Compartment Type - Grasses and Herbs[a]			
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba et al. 1995; soybean root cell culture metabolism test data for DDE.

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Exhibit_Add A1-24. Cadmium Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value	Reference
Zooplankton Compartment Type			
Absorption rate constant	L[water]/kg[fish wet wt]-day	1500	Goulet 2007.
Assimilation efficiency from algae	unitless	0.5	Goulet 2007.
Elimination rate constant	1/day	0.03	Goulet 2007.
Benthic Invertebrate Compartment Type			
Sediment partitioning - alpha of equilibrium	unitless	0.95	Assumption.
Sediment partitioning - partition coefficient	kg[bulk sed/kg[invertebrate wet wt]	0.27	Assumption.
Sediment partitioning - time to reach alpha of equilibrium	day	21	Hare et al. 2001.
Benthic Omnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Assumption based on Yan and Wang 2002.
Absorption rate constant	unitless	1.23	Calculated based on body weight from regression in Hendriks and Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Assumption.
Benthic Carnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Assumption based on Yan and Wang 2002.
Absorption rate constant	unitless	0.66	Calculated based on body weight from regression in Hendriks and Heikens 2001.
Elimination rate constant	unitless	1.68E-03	Assumption.
Water-column Herbivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Assumed value based on Yan and Wang 2002.
Assimilation efficiency from plants	unitless	0.1	Assumed value based on Yan and Wang 2002.
Absorption rate constant	unitless	2.46	Calculated based on body weight from regression in Hendriks and Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Assumption.

Exhibit_Add A1-24. Cadmium Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value	Reference
Water-column Omnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Assumption based on Yan and Wang 2002.
Assimilation efficiency from plants	unitless	0.1	Assumption based on Yan and Wang 2002.
Absorption rate constant	unitless	1.23	Calculated based on body weight from regression in Hendriks and Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Assumption.
Water-column Carnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Assumption based on Yan and Wang 2002.
Absorption rate constant	unitless	0.66	Calculated based on body weight from regression in Hendriks and Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Assumption

Exhibit_Add A1-25. Mercury Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Zooplankton Compartment Type					
Assimilation Efficiency From Algae	unitless	0.2	0.015	0.5	Environment Canada 2002.
Half-life	day	1.0E+09	1.0E+09	1.0E+09	Assumption.
How Much Faster Hg Elimination Is Than For MHg	unitless	3	3	1	Assumption.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	0	1.0E+06	0	Assumption.
Reduction rate	1/day	0	0	0	Assumption.
Benthic Invertebrate Compartment Type					
Alpha of equilibrium for sediment partitioning	unitless	0.95	0.95	0.95	Selected value (i.e., proportion of equilibrium achieved by time “t”).
Benthic invertebrate-bulk sediment partition coefficient	kg[bulk sediment]/kg[invertebrate wet wt]	0.0824	0.0824	5.04	Hg(0) - assumed based on Hg(2) value; Hg(2) and MHg - Saouter et al. 1991.
t-alpha for equilibrium for sediment partitioning	day	14	14	14	Experiment duration from Saouter et al. 1991.
All Fish Compartments Types[a]					
Elimination adjustment factor	unitless	3	3	1	Trudel and Rasmussen 1997.
Assimilation efficiency from food	unitless	0.06	0.06	0.5	Williams et al. 2010.
Demethylation rate	1/day	N/A	N/A	0	Assumption.
Methylation rate	1/day	0	0	0	Assumption.
Oxidation rate	1/day	1.0E+06	0	0	Assumption.
Reduction rate	1/day	0	0	0	Assumption.
Water-column Herbivore Compartment Type					
Assimilation efficiency from plankton	unitless	0.06	0.06	0.5	Williams et al. 2010.

[a] Screening scenario includes: Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

Exhibit_Add A1-26. PAH Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value								
		2Methyl	712DMB	Acenaph-thene	Acenaph-thylene	BaA	BaP	BbF	BghiP	BkF
Zooplankton Compartment Type										
Absorption rate constant	L[water]/kg[fish wet wt]-day	790	42650.94	42231	42302.18	42650.81	42652.78	42650.68	42655.77	42652.5
Assimilation efficiency from algae	unitless	0.5	0.25	0.5	0.5	0.46	0.25	0.25	0.25	0.25
Elimination rate constant	1/day	169.68	2.03	148.07	123.44	2.073	1.3864	2.12	0.33	1.48
Half-life	day	0.007788	17	0.00239	0.00239	1.284	16.5	17	17	17
Benthic Invertebrate Compartment Type										
Clearance constant	unitless	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6
V_d (ratio of concentration in benthic invertebrates to concentration in water)	ml/g	7235	7235	7235	7235	7235	7235	7235	7235	7235
Half-life	day	0.722	17	0.722	0.722	1.284	16.5	17	17	17
All Fish Compartment Types[a]										
Gamma fish	unitless	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Assimilation efficiency from food	unitless	0.5	0.15	0.5	0.32	0.15	0.15	0.15	0.15	0.15
Half-life	day	0.2	2	0.2	0.2	0.408	1.925	2	2	2

[a] Screening scenario includes: Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

Exhibit_Add A1-26. PAH Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoran-thene	Fluorene	IcdP	
Zooplankton Compartment Type							
Absorption rate constant	L[water]/kg[fish wet wt]-day	42649.95	42655.48	142000	15000	42655.93	K_{ow} from Arnot et al. 2004. Exception is Berrojalbiz et al. 2009 (2-Methylnaphthalene, Fluoranthene, and Fluorene).
Assimilation efficiency from algae	unitless	0.46	0.25	0.49	0.5	0.25	K_{ow} from Arnot et al. 2004. Exception is maximum value from Wang and Wang 2006 (7,12-Dimethylbenz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene).
Elimination rate constant	1/day	2.3746	0.4331	8.678	81.87	0.269	K_{ow} from Arnot et al. 2004.
Half-life	day	0.495	17	0.00239	0.0002476	17	McElroy 1990. Exceptions include Berrojalbiz et al. 2009 (2-Methylnaphthalene, Fluoranthene, and Fluorene) and Moermond et al. 2007 (Benz(a)anthracene and Benzo(a)pyrene).
Benthic Invertebrate Compartment Type							
Clearance constant	unitless	100.6	100.6	100.6	100.6	100.6	Stehly et al. 1990.
V_d (ratio of concentration in benthic invertebrates to concentration in water)	ml/g	7235	7235	7235	7235	7235	Stehly et al. 1990.
Half-life	day	0.495	17	0.722	0.722	17	Moermond et al. 2007.

Exhibit_Add A1-26. PAH Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
All Fish Compartment Types[a]							
Gamma fish	unitless	0.2	0.2	0.2	0.2	0.2	Thomann 1989.
Assimilation efficiency from food	unitless	0.15	0.15	0.14	0.14	0.15	Lemair et al. 1992. Exceptions include Barber 2008 (2-Methylnaphthalene and Acenaphthene) and Niimi and Palazzo 1986 (Acenaphthylene, Fluoranthene, and Fluorene).
Half-life	day	0.533	2	0.165	0.2	2	Moermond et al. 2007.

[a] Screening scenario includes: Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

Exhibit_Add A1-27. Dioxin Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value								
		1,2,3,4,6,7,8,9-OCDD	1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF
Zooplankton Compartment										
Absorption rate constant	L[water]/kg[fish wet wt]-day	8640	8640	8640	8640	8640	8640	8640	8640	8640
Assimilation efficiency from algae	unitless	0.08	0.05	0.21	0.09	0.2	0.31	0.31	0.31	0.31
Elimination rate constant	1/day	0.0102	0.016	0.016	0.0616	0.1829	0.0252	0.1474	0.0099	0.0194
Half-life	day	7E+06	7E+06	7E+06	7E+06	7E+06	7E+06	7E+06	7E+06	7E+06
Benthic Invertebrate Compartment										
Clearance constant	unitless	0	0	0	0	0	0	0	0	0
Sediment partitioning partition coefficient	kg/kg	0.0013	0.0017	0.0055	0.0012	0.042	0.033	0.0081	0.013	0.02
Sediment partitioning alpha of equilibrium	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Sediment partitioning time to reach alpha of equilibrium	days	120	42	120	42	42	120	42	120	42
V_d (ratio of concentration in benthic invertebrates to concentration in water)	ml/g	0	0	0	0	0	0	0	0	0
Half-life	day	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2
All Fish Compartments[a]										
Assimilation efficiency from food	unitless	0.08	0.05	0.21	0.09	0.2	0.37	0.31	0.31	0.31
Chemical uptake rate via gill	L[water]/kg[fish wet wt]-day	11	6	56	25	50	102	200	300	200
Half-life	day	70	70	70	70	70	70	70	70	70

Exhibit_Add A1-27. Dioxin Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Value							
		1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-HxCDF	1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF	2,3,4,6,7,8-HxCDF	2,3,4,7,8-PeCDF	2,3,7,8-TCDD	2,3,7,8-TCDF
Zooplankton Compartment									
Absorption Rate Constant	L[water]/kg[fish wet wt]-day	8640	8640	8640	8640	8640	8640	8640	8640
Assimilation Efficiency from Algae	unitless	0.31	0.31	0.42	0.42	0.31	0.42	0.41	0.51
Elimination Rate Constant	1/day	0.0099	0.0413	0.0819	0.2316	0.0192	0.4331	0.2268	1.0375
Half-life	day	7E+06	7E+06	7E+06	7E+06	7E+08	7E+08	7E+06	7E+08
Benthic Invertebrate Compartment									
Clearance Constant	unitless	0	0	0	0	0	0	0	0
Sediment Partitioning Partition Coefficient	kg/kg	0.015	0.067	0.098	0.024	0.072	0.17	0.205	0.056
Sediment Partitioning Alpha of Equilibrium	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Sediment Partitioning Time to Reach Alpha of Equilibrium	days	120	42	120	42	42	42	120	42
V_d (ratio of concentration in benthic invertebrates to concentration in water)	ml/g	0	0	0	0	0	0	0	0
Half-life	day	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2
All Fish Compartments[a]									
Assimilation efficiency from food	unitless	0.31	0.31	0.42	0.42	0.31	0.42	0.41	0.51
Chemical uptake rate via gill	L[water]/kg[fish wet wt]-day	300	200	700	300	200	400	600	400
Half-life	day	70	70	70	70	70	70	70	70

Exhibit_Add A1-27. Dioxin Chemical-Specific Parameters for Aquatic Species in the TRIM.FaTE Screening Scenario

Parameter Name	Units	Reference
Zooplankton Compartment		
Absorption rate constant	L[water]/kg[fish wet wt]-day	Zhang et al. 2011; used copepod k_u value.
Assimilation efficiency from algae	unitless	Morrison et al. 1999. Exceptions include Niimi and Oliver 1986 (1,2,3,4,6,7,8,9-OCDD, 1,2,3,4,6,7,8,9-OCDF), Berntssen et al. 2007 (1,2,3,4,6,7,8-HpCDD, 1,2,3,4,6,7,8-HpCDF), and 1,2,3,4,7,8,9-HpCDF set conservatively as approximate linear interpolation between values for 1,2,3,4,7,8-HxCDD and 1,2,3,4,6,7,8-HpCDD / 1,2,3,4,6,7,8-HpCDF (i.e., 0.3 to 0.1–0.2).
Elimination rate constant	1/day	Arnot and Gobas 2004; used K_{ow} value.
Half-life	day	Morrison et al. 1999; used metabolic rates for invertebrates.
Benthic Invertebrate Compartment		
Clearance constant	unitless	Assumption.
Sediment partitioning partition coefficient	kg/kg	Rubinstein et al. 1990; used TCDD data for sandworm.
Sediment partitioning alpha of equilibrium	unitless	Rubinstein et al. 1990.
Sediment Partitioning Time to Reach Alpha of Equilibrium	days	Rubinstein et al. 1990.
V_d (ratio of concentration in benthic invertebrates to concentration in water)	ml/g	Assumption.
Half-life	day	Rubinstein et al. 1990; used TCDD data for sandworm.
All Fish Compartmentsa		
Assimilation Efficiency from Food	unitless	Morrison et al. 1999. Exceptions include Niimi and Oliver 1996 (1,2,3,4,6,7,8,9-OCDD, 1,2,3,4,6,7,8,9-OCDF), Van den Berg et al. 1994 (1,2,3,4,6,7,8-HpCDD), Berntssen et al. 2007 (1,2,3,4,6,7,8-HpCDF), and 1,2,3,4,7,8,9-HpCDF set conservatively as approximate linear interpolation between values for 1,2,3,4,7,8-HxCDD and 1,2,3,4,6,7,8-HpCDD / 1,2,3,4,6,7,8-HpCDF (i.e., 0.3 to 0.1–0.2).
Chemical Uptake Rate Via Gill	L[water]/kg[fish wet wt]-day	Muir et al. 1985. Exception is Opperhuizen et al. 1986 (1,2,3,7,8,9-HxCDF, 1,2,3,7,8-PeCDD, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 2,3,7,8-TCDD, 2,3,7,8-TCDF).
Half-life	day	Berntssen et al. 2007.

[a] Screening scenario includes: Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

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Addendum 2. Description of Multimedia Ingestion Risk Calculator (MIRC) Used for RTR Exposure and Risk Estimates

CONTENTS, ADDENDUM 2

Exhibits, Addendum 2

Equations, Addendum 2

1. Introduction

1.1. Purpose and Overview

This document provides a detailed description of the *Multimedia Ingestion Risk Calculator* (MIRC), a modeling tool and database designed to assist in estimating risks via multiple ingestion pathways, particularly for food products grown or raised at home or on a farm.[19] MIRC was designed to estimate risks to humans from ingestion of produce or animal products, fish, and water in the vicinity of a source of chemical emissions to air. The user can evaluate either generalized (e.g., health protective default) or more site-specific scenarios using the same tool. MIRC includes a database of exposure parameter values, offering the user the option of selecting mean, median, and upper percentile values for many parameters, data permitting. Generally health protective default values were assigned to each parameter in the tool and the default configuration is used for initial risk screening efforts by EPA's Office of Air Quality Planning and Standards' (OAQPS) for Risk and Technology Review (RTR) multimedia risk assessments. MIRC also allows the user to define the farm food chain (FFC) parameter values and receptor characteristics to better represent a site-specific scenario.

With user-input concentrations for one or more chemicals in air and soil and air-to-surface deposition rates, MIRC calculates the chemical's concentrations in home- or farm-grown produce and animal food products using FFC algorithms adapted from EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (hereafter referred to as HHRAP; EPA 2005a). MIRC uses these calculated concentrations, along with user-input chemical concentrations for fish and drinking water, to estimate chemical intake rates, as average daily doses (ADDs), for adults, children, and nursing infants. Users can obtain chemical input concentrations and deposition rates from measurements at an actual site or from a transport and fate model, such as TRIM.FaTE, as is done for RTR risk assessment.

For a specified set of chemical concentrations and MIRC parameter options, MIRC calculates ADDs separately for adults, four age groups of children, and infants to reflect differences in food ingestion rates and diet at different lifestages. MIRC estimates age-specific hazard quotients (HQs) as the ratio of age-specific ADDs to the reference dose (RfD) for a chemical. The most appropriate HQ for a chemical depends on its toxic mode of action and the duration of exposure required to produce an effect. MIRC also estimates average lifetime ADDs and compares those to cancer slope factors (CSFs) to estimate cancer risks. A breast milk ingestion pathway is available to estimate exposure and risks to nursing infants.

MIRC was developed to be a flexible, transparent application. The tool includes chemical transfer and ingestion exposure algorithms and a database of parameter values, many with several options, used by these equations. The MIRC database includes values for the relevant physiochemical properties and toxicity reference values for more than 500 chemicals, including approximately 60 inorganics taken primarily from a database developed for HHRAP (EPA 2005a). Although designed for OAQPS' RTR assessments for sources of hazardous air pollutants (HAPs), the tool is flexible in its design and can be used to assess risks in many other contexts where soil and air concentrations are predicted or measured.

1.2. Scope of MIRC

For persistent and bioaccumulative (PB) chemicals, risks from direct inhalation of the chemical can be much less than risks from ingestion of the chemical in water, fish, and food products

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[19] Fully functional versions of MIRC have been developed in both Access™-based and Excel™-based formats; however, MIRC currently is not publicly available.

grown in an area of chemical deposition. Vegetables and fruits in such areas can become contaminated directly by deposition of the airborne chemical to foliage, fruits, and vegetables or indirectly by root uptake of the chemical deposited to soils. Livestock can be exposed to the PB chemicals via ingestion of contaminated forage and incidental ingestion of contaminated soils.

For PB chemicals, evaluation of the inhalation pathway for air pollutants may reveal only a portion of the risk to individuals in such populations. Households that consume high quantities of self-caught fish or locally grown produce and animal products may be particularly susceptible to ingestion of chemicals transferred from air in the vicinity of an air emissions source. For PB chemicals in particular, therefore, EPA developed methods of estimating risk from indirect exposure pathways associated with the deposition of airborne chemicals to gardens and farms, as described in HHRAP (EPA 2005a).

1.3. Use in EPA's Air Toxics Program

For PB-HAPs, indirect exposure pathways, such as ingestion, might contribute more to total risk than the inhalation pathway. EPA therefore developed several computer software tools to assist in evaluating exposure and risk from non-inhalation pathways. EPA developed the Total Risk Integrated Methodology (TRIM) Environmental Fate, Transport, and Ecological Exposure (TRIM.FaTE) computer program to simulate the release, transport, and fate of HAPs from a specific source throughout the area in which local (non-source) chemical deposition is likely to be a concern. TRIM.FaTE models the transport of individual chemicals from the source through air by advection (wind) of particle- and vapor-phase chemical and deposition of the chemical from air to terrestrial and aquatic ecosystems by wet and dry deposition. Movement of the chemical through a watershed via erosion and runoff, uptake by plants, and other abiotic and biotic transfer processes also are simulated. For the chemical that reaches surface waters, TRIM.FaTE models uptake and bioaccumulation to trophic level (TL) 3 and 4 fish (i.e., pan fish and game fish, respectively).

MIRC was developed to process TRIM.FaTE results, in particular, air deposition rates and the concentrations of a chemical, after a specified duration of emissions, in several spatially explicit environmental compartments, including air, surface and root-zone soils, surface and ground waters, and fish. MIRC uses those results to calculate exposure to the chemical through ingestion of locally grown foods, including various types of fruits and vegetables, poultry, swine, and dairy (and beef) cattle. MIRC also calculates the associated risks for individuals who consume those foods. MIRC was designed to use specific TRIM.FaTE results to estimate FFC concentrations, ingestion exposures, and human health risks for OAQPS' RTR assessments. It uses the same approach that OAQPS intends to implement directly in its TRIM system via three modules beyond TRIM.FaTE: TRIM Farm Food Chain, TRIM.Expo$_{\text{Ingestion}}$, and TRIM.Risk.[20]

1.4. MIRC Highlights

Although designed to assist EPA OAQPS in its RTR assessments, MIRC is a stand-alone software application that can be used in other contexts. A user can supply either measured or estimated chemical concentrations for soil, air, water, and fish, and also can provide air deposition rates likely for the location(s) of interest based on local meteorology. The user can accept the default values for many exposure parameters and screen for small possibilities of risk, or the user can select other options or overwrite parameter values to tailor the estimates to a specific scenario or location.

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[20] General information about the TRIM system is available at http://www.epa.gov/ttn/fera/trim_gen.html.

MIRC complies with EPA's latest guidelines for exposure and risk assessment, including HHRAP; the Agency's 2005 *Guidelines for Carcinogen Risk Assessment* (Cancer Guidelines), *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (Supplemental Guidance), and *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (EPA 2005b,c,d); and its 2008 *Child-Specific Exposure Factors Handbook* (EPA 2008a). In particular, MIRC provides several important capabilities:

- When provided air and soil concentrations, the MIRC software package allows rapid calculation of screening-level exposures and risks associated with household consumption of locally grown/raised foods.
- MIRC can calculate exposures and risks associated with incidental ingestion of surface soils, fish consumption, and drinking water.
- The tool calculates ADDs (i.e., chemical intake rates) for six "built-in" age groups to allow use of age-group-specific body weights, ingestion rates, food preferences, and susceptibility to toxic effects.
- Its database of chemical information covers plant- and animal-specific transfer factors and other inputs that determine concentrations in farm food stuffs.
- Value options for receptor characteristics in the database include the mean and 50th, 90th, 95th, and 99th percentile values where data permit.
- For carcinogens with a mutagenic mode of action, MIRC estimates a lifetime ADD using the three lifestages and potency adjustment factors recommended in EPA's 2005 Cancer Guidelines and Supplemental Guidance.
- The data for exposure parameters in the tool have been updated to include the latest recommended values for children issued September 30, 2008, in the Agency's Child-Specific Exposure Factors Handbook (CSEFH) (EPA 2008a).

1.5. Organization of This Addendum

Sections 2 through 5 of this addendum describe the exposure and risk models implemented in MIRC. Section 2 provides an overview of the FFC exposure scenario and indicates options available to a user to tailor the scenario to specific applications. Section 3 describes the exposure algorithms used in MIRC, including how ADDs are calculated. Section 4 presents the toxicity reference values included in MIRC to calculate risks. Section 5 describes the risk characterization algorithms in MIRC. Section 6 of this document describes data input options for the model. Section 7 describes the default parameterization of MIRC for application to health protective risk screening assessments, and Section 8 provides the references.

Note that the default parameterization described in Section 7 was used to estimate Tier 1 screening threshold emission rates of PB-HAPs from RTR facilities. These emissions levels are assumed to pose negligible risk to subsistence communities in the vicinity of a facility emitting the PB-HAPs to air. Users of MIRC can modify the default values for many of the parameters to better represent a specific exposure scenario.

2. MIRC Overview

The *Multimedia Ingestion Risk Calculator* (MIRC) software package is designed to allow rapid calculation of screening-level exposures and risks associated with subsistence and recreational farmer/fisher populations in the vicinity of a source of chemical emissions to air. The tool allows a user to assess human exposures via ingestion pathways, including drinking water consumption, incidental soil ingestion, fish ingestion, and ingestion of ten types of farm food chain (FFC) products: exposed fruits, protected fruits, exposed vegetables, protected vegetables, root vegetables, beef, total dairy, pork, poultry, and eggs. The tool also includes a breast milk ingestion and risk module for nursing infants. For fruits and vegetables, the terms "exposed" and "protected" refer to whether the edible portion of the plant is exposed to the atmosphere.

The remainder of this overview consists of three sections. The first (Section 2.1 of this addendum) provides an overview of the MIRC software package. The second and third sections summarize the ingestion exposure pathways included in the tool and the "built-in" receptor age categories, respectively (Sections 2.2 and 2.3 of this addendum).

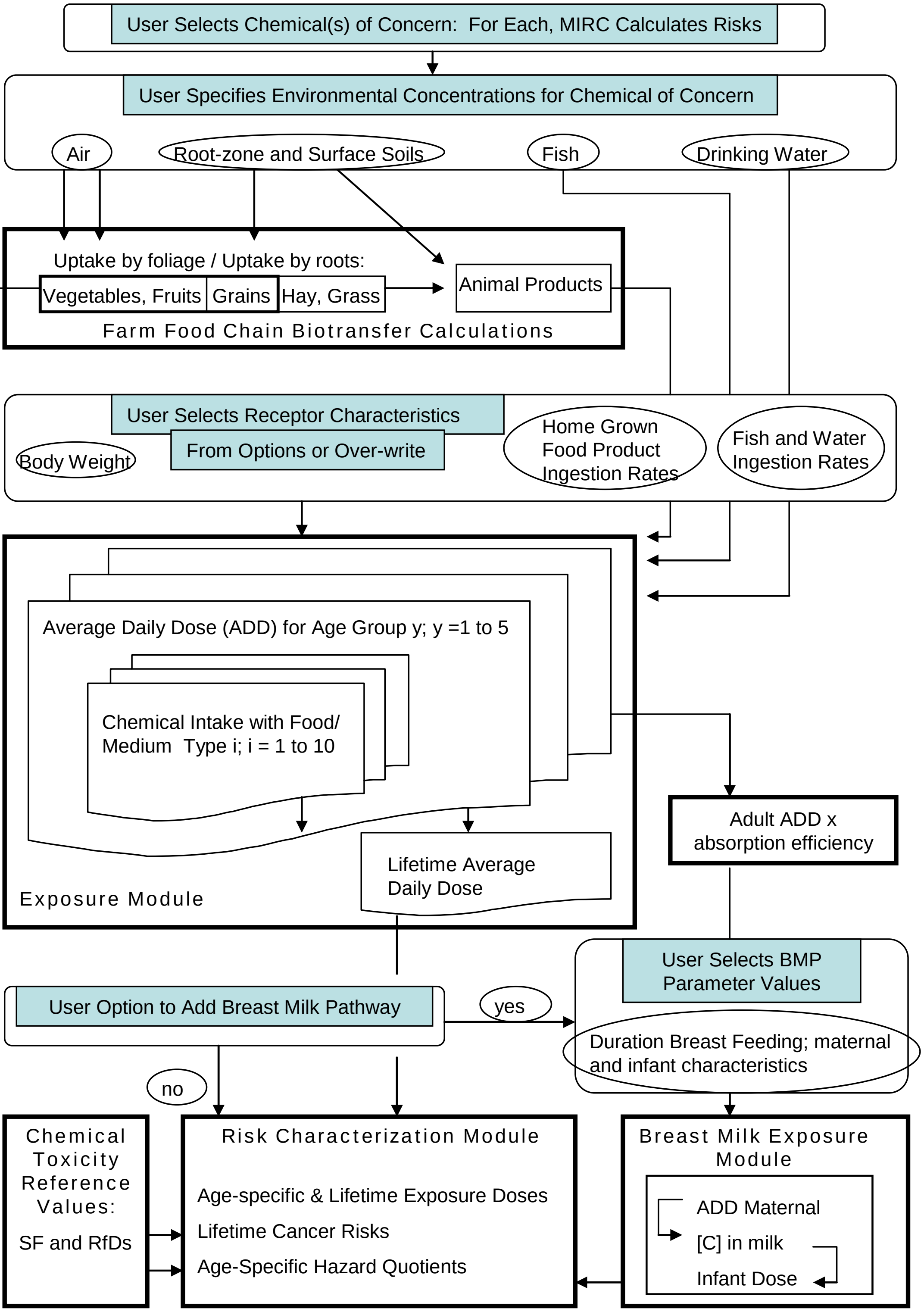
2.1. Software

The MIRC application includes the following components:

- A graphical user interface through which the user locates and accesses various input and output tables.
- Input tables in which the user can enter environmental concentrations of a chemical estimated for air, soil, drinking water, and fish tissue.
- Internal chemical transfer and exposure algorithms and database of options for FFC algorithm parameter value, chemical-specific inputs, and exposure factors.
- Tabulated outputs of calculated chemical concentrations in the various farm food products (e.g., fruits, vegetables, beef, eggs) and ADDs for those foods and for water and fish ingestion for each receptor category.
- Output tables with estimated cancer risks and non-cancer hazard estimates associated with total ingestion exposure to each chemical for each receptor category.

Exhibit_Add A2-1 provides a flowchart displaying the types of required and optional inputs and the general flow of calculations carried out by the tool.

Exhibit_Add A2-1. Overview of MIRC Software Application for Performing Farm-Food-Chain Ingestion Exposure and Risk Calculations



A form within the graphical user interface enables the user to construct specific scenarios by choosing ingestion sources, receptor ages, and other input choices (e.g., diet composition, body weight percentiles). This feature facilitates the analysis of various exposure scenarios. To begin an analysis, the user must supply values for the following chemical-specific parameters for the scenario being evaluated:

- Air concentration of total chemical,
- Fraction chemical in air in vapor-phase,
- Wet and dry deposition rates for particle-phase chemical,
- Drinking water concentration,
- Chemical concentration in surface soils (two locations; can be tilled and untilled),
- Chemical concentration in root-zone soils (two locations; can be tilled and untilled), and
- Chemical concentrations in pan fish and in game fish.

Users can input measured values or values estimated by TRIM.FaTE or other models for these parameters.

The MIRC application uses the input data and a variety of empirical transfer factor values (included in its database) to estimate chemical concentrations in nine categories of FFC food types (see Section 2.2 of this addendum). The FFC algorithms and transfer factor values included in MIRC are based on those presented in Chapter 5 of EPA's HHRAP (EPA 2005a).

For outputs, MIRC is designed to calculate individual cancer risk and non-cancer hazard quotients for one chemical at a time. It is up to the risk assessor to determine if cancer risks or hazard quotients may be additive across two or more chemicals (i.e., if they cause toxic effects in the same target organ by the same mode of action, such as multiple polycyclic aromatic hydrocarbons (PAHs) that are carcinogenic by a mutagenic mode of action).

The tool assumes that an individual is exposed via all of the pathways specified (e.g, fruits and vegetables, animal products, soil, etc.). The tool therefore is useful in estimating risk to the maximally exposed individuals in a risk assessment. To evaluate other receptor populations, the user must specify the each exposure scenario separately.

2.2. Exposure Pathways

MIRC estimates the concentrations of chemicals in FFC food categories grown in an area of airborne chemical deposition using algorithms and parameter values provided in HHRAP (EPA 2005a). FFC foods are evaluated in ten categories: exposed fruit, protected fruit, exposed vegetables, protected vegetables, root vegetables, beef, total dairy, pork, poultry, and eggs. Exhibit_Add A2-2 summarizes the pathways by which chemicals are transferred to these food media. Note that for a general Tier 1 screening-level assessment, all of the pathways can be modeled, as is the case for EPA's *Risk and Technology Review* (RTR) calculation of screening threshold emission rates for persistent and bioaccumulative hazardous air pollutants (PB-HAPs) (EPA 2008b).

Exhibit_Add A2-2. Transfer Pathways for Modeled Farm Food Chain (FFC) Media

Farm Food Media	Chemical Transfer Pathways
Exposed fruit and vegetables	• Direct deposition from air of particle-bound chemical • Air-to-plant transfer of vapor phase chemical • Root uptake from soil
Protected fruit and vegetables (including root vegetables)	• Root uptake from soil
Beef and total dairy (including milk)	• Ingestion of forage, silage, and grain[a] • Soil ingestion
Pork	• Ingestion of silage and grain[a] • Soil ingestion
Poultry and eggs	• Ingestion of grain[a] • Soil ingestion

[a] Chemical concentrations in forage, silage, and grain are estimated via intermediate calculations analogous to those used for aboveground produce.

Produce types included in the FFC can accumulate a chemical directly from air and/or soil. For exposed produce, chemical mass is assumed to be transferred to plants from the air in two ways. First, particle-bound chemical can deposit directly on the plant surface. Second, the uptake of vapor-phase chemicals by plants through their foliage can occur. For both exposed and protected produce, the concentration in the plant derived from exposure to the chemical in soil is estimated using an empirical bioconcentration factor (BCF) that relates the concentration in the plant to the concentration present in the soil. For belowground root vegetables, a root concentration factor is applied. The algorithms used to estimate produce concentrations are presented in Section 3.1.1 of this addendum.

Chemical concentrations in animal products are estimated based on the amount of chemical consumed through the diet, including incidental ingestion of soil while grazing. The diet options for farm animals in MIRC include forage (plants grown on-site for animal grazing, such as grass), silage (wet forage grasses, fresh-cut hay, or other fresh plant material that has been stored and fermented), and feed grain products grown on the farm (e.g., corn, soybeans). All three animal feed products are assumed to accumulate chemical via root uptake from the soil. Forage and silage also can accumulate chemical via direct deposition of particle-bound chemical and vapor transfer.

The algorithms in MIRC are based on the assumptions that beef and dairy cattle consume all three feed products, while pigs consume only silage and grain and chickens consume only grain. The incidental ingestion of the chemical in soils during grazing or consumption of foods placed on the ground is estimated using empirical soil ingestion values. For secondary animal products (dairy products and eggs), chemical concentrations are estimated by applying a biotransfer factor to the estimated concentration in the "source" animal (cows and chickens, respectively). The algorithms used to estimate animal product concentrations are described in Section 3.1.2 of this addendum.

2.3. Receptor Groups

As noted in EPA risk assessment guidelines (EPA 2005b,c,d, 2008a), exposures of children are expected to differ from exposures of adults due to differences in body weights, ingestion rates, dietary preferences, and other factors. It is important, therefore, to evaluate the contribution of exposures during childhood to total lifetime risk using appropriate exposure factor values.

EPA’s HHRAP (Chapter 4, EPA 2005a) recommends assessing exposures for children and adults separately, but considers all non-infant children in one category. Specifically, HHRAP recommends eight categories of receptor: farmer, child farmer, resident, child resident, fisher, child fisher, acute receptor, and nursing infant. Over time, different EPA programs have used different child age groupings to evaluate body weights, ingestion rates, and other parameter values needed to estimate chemical exposures and risks to children.

To improve the match between age groups used to estimate values across exposure parameters, in 2005, EPA recommended a standard set of child age categories for exposure and risk assessments (EPA 2005b). EPA recommended four age groups for infants: birth to < 1 month; 1 to < 3 months; 3 to < 6 months; and 6 to < 12 months. For young children, EPA recommended an additional four age groups: 1 to < 2 years; 2 to < 3 years; 3 to < 6 years; and 6 to < 11 years. Two age groupings were recommended for teenagers and young adults: 11 to < 16 years; and 16 to < 21 years. These age groupings correspond to different developmental stages and reflect different food ingestion rates per unit body weight, with the highest ingestion rates occurring for the youngest, most rapidly growing, age groups.

For purposes of RTR assessment using MIRC, the selection of age categories is limited by the categories for which most of the FFC food ingestion rates have been calculated. In Chapter 13 of both its *Exposure Factors Handbook* (EFH; EPA 2011a) and its *Child-Specific Exposure Factors Handbook* (CSEFH; EPA 2008a), EPA summarized home-grown/raised food ingestion rates for four children’s age groups: 1 to < 3 years; 3 to < 6 years; 6 to < 12 years; and 12 to < 20 years. Intake rates were not calculated for children younger than 1 year because infants are unlikely to consume those foods. They are more likely to be nursing or to be fed formula and other commercial baby-food products.

Although the age groupings used to estimate FFC ingestion rates do not match precisely the groupings that EPA recommended in 2005 for Agency exposure assessments (EPA 2005b), they are the only age-groupings for which such data are available. The U.S. Department of Agriculture’s (USDA’s) 1987-1988 *Nationwide Food Consumption Survey* (USDA 1992, 1993, 1994a) remains the most recent survey of ingestion rates for home-grown foods, and EPA’s analysis of those data, published in its 2011 EFH, remains the most recently published major analysis of those data. Because ingestion of home-grown produce and animal products are the primary exposure pathways for which MIRC was developed, those are the age groupings used for all child parameter values used to estimate exposure and risk in MIRC.

Thus, in MIRC, values for each exposure parameter were estimated for adults (20 to 70 years) and five children’s age groups:

- infants under 1 year (i.e., 0 to < 1 year);
- children ages 1 through 2 years (i.e., 1 to < 3 years);
- children ages 3 through 5 years (i.e., 3 to < 6 years);
- children ages 6 through 11 years (i.e., 6 to < 12 years); and
- children ages 12 through 19 years (i.e., 12 to < 20 years).

See Sections 5.1 and 5.2 for descriptions of the risk characterization algorithms used to calculate cancer and non-cancer effects, respectively, for the above age groupings. Exposure and risks to infants under 1 year of age are estimated only for the breast-milk-ingestion pathway.

For assessment of cancer risks from early-life exposure, EPA recognizes that infants and children may be more sensitive to a carcinogenic chemical than adults, with cancers appearing earlier in life or with lower doses experienced during childhood (EPA 2005c, d). Thus, the "potency" of a carcinogen might be higher for infants and children than for adults. To date, however, data by which to evaluate the relative sensitivity of children and adults to the same daily dose of a carcinogen remain limited. Based on analyses of radioactive and other carcinogenic chemicals, EPA recommends evaluating two lifestages for children separately from adults for chemicals that cause cancer by a mutagenic mode of action (MOA): from birth to < 2 years and from 2 to < 16 years (EPA 2005c,d). EPA also suggests that, as data become available regarding carcinogens with a mutagenic MOA, further refinements of these age groupings may be considered.

For assessing risks from exposures to carcinogenic chemicals that act via a mutagenic MOA, the two early lifestages recommended by EPA (EPA 2005c,d) also are included in MIRC:

- children under the age of 2 years (i.e., 0 to < 2 years); and
- children from 2 through 15 years (i.e., 2 to < 16 years).

Different age groupings are needed for the assessment of risks from carcinogenic chemicals with a mutagenic MOA and other carcinogens with other or unknown MOAs. Currently in MIRC, the only PB-HAPs with a mutagenic mode of carcinogenesis are the carcinogenic PAHs. See Section 5.1 for a description of the age-dependent adjustment factors (ADAFs) that are used to calculate cancer risks for chemicals with a mutagenic MOA.

3. Exposure Algorithms

The exposure algorithms in MIRC are described below in four sections. Section 3.1 of this addendum presents the algorithms used to estimate chemical concentrations in FFC foods from chemical concentrations in soil and air. Pathway-specific algorithms used to estimate chemical intakes by adults and non-infant children are described in Section 3.2, and total chemical intake calculations are described in Section 3.3. Finally, the sets of algorithms used to estimate chemical intake via consumption of breast milk by nursing infants are described in Section 3.4. As noted previously, the exposure algorithms used in MIRC are based on those presented in HHRAP (EPA 2005b). Any differences between MIRC and HHRAP are explained in this section.

3.1. Farm Food Chain Algorithms

The algorithms and parameters used to estimate chemical concentrations in produce and animal products are described in Sections 3.1.1 and 3.1.2 of this addendum, respectively. Discussions of the parameter value options and the values selected as defaults in MIRC for RTR risk assessment are provided in Section 6.2. The use of TRIM.FaTE to model chemical fate and transport in the environment prior to FFC calculations drives the most significant difference between the FFC algorithms included in HHRAP and the equations used for RTR. The approach in HHRAP uses estimated ambient air concentrations and deposition rates from dispersion model simulations that use unit emission rates. Chemical-specific emission rates (adjusted for vapor and particle-bound fractions) are then incorporated into some of the HHRAP FFC algorithms to calculate concentrations in FFC media. Soil concentrations are calculated using a similar approach in HHRAP. For assessment of multipathway exposures for RTR, TRIM.FaTE is used to estimate air concentrations, air-to-surface deposition rates, and soil concentrations, and these outputs are used in the FFC algorithms.

3.1.1. Estimating Chemical Concentrations in Produce

Produce (vegetables and fruits) can become contaminated directly by deposition of airborne chemicals to foliage and fruits or indirectly by uptake of chemicals deposited to the soil. Given these two contamination processes, produce is divided into two main groups: aboveground and belowground produce. Aboveground produce is divided into fruits and vegetables. These groups are further subdivided into “exposed” and “protected” depending on whether the edible portion of the plant is exposed to the atmosphere or is protected by a husk, hull, or other outer covering.

Exhibit_Add A2-3 lists the pathways by which chemicals are transferred to the FFC produce categories. Note that for a general screening-level assessment, all of the pathways can be modeled, as was done for EPA’s calculation of Tier 1 screening threshold emission rates for PB-HAPs in its RTR assessments (EPA 2008b), and as described in the Technical Support Document. Sections 3.1.1.1 and 3.1.1.2 below describe the transfer pathways and algorithms for aboveground and belowground produce, respectively.

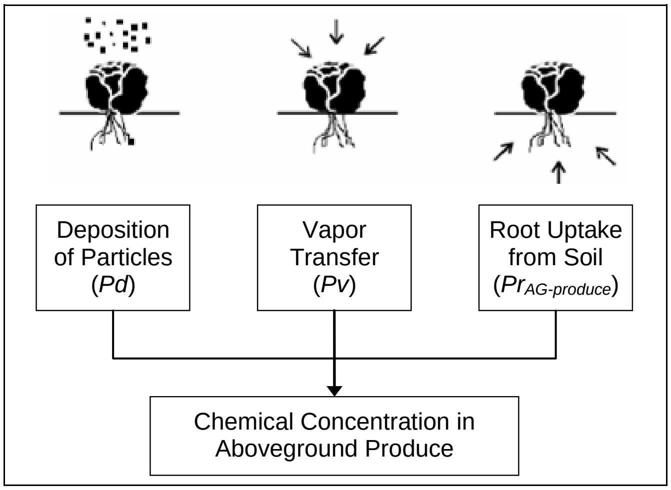
Exhibit_Add A2-3. Chemical Transfer Pathways for Produce

Farm Food Media		Chemical Transfer Pathways
Aboveground Produce	Exposed fruits and vegetables	Direct deposition from air of particle-bound chemical Air-to-plant transfer of vapor phase chemical Root uptake from soil
	Protected fruits and vegetables	Root uptake from soil
Belowground Produce	Root vegetables	Root uptake from soil

3.1.1.1. Aboveground Produce

For aboveground *exposed* produce, chemical mass is assumed to be transferred to plants from the air in three ways, as illustrated in Exhibit_Add A2-4. First, particle-bound chemical can deposit directly on the plant surface via deposition (*Pd*). The amount of chemical accumulated is estimated based on the areal fraction of chemical deposition intercepted by the plant surface, minus a loss factor that is intended to account for removal of deposited chemical by wind and rain and changes in concentration due to growth dilution. Second, for chemical present in air in the vapor phase, the concentration of chemical accumulated by the plant’s foliage is estimated using an empirical air-to-plant biotransfer factor (*Pv*). Third, the chemical concentration in the plant due to root uptake from the soil ($Pr_{AG\text{-}produce}$) is estimated using an empirical bioconcentration factor ($Br_{AG\text{-}produce}$) that relates the chemical

Exhibit_Add A2-4. Estimating Chemical Concentration in Aboveground Produce



concentration in the plant to the average chemical concentration in the soil at the root-zone depth in the produce-growing area ($Cs_{root\text{-}zone\_produce}$).

The edible portions of aboveground *protected* produce are not subject to contamination via particle deposition (Pd) or vapor transfer (Pv). Therefore, root uptake of chemicals is the primary mechanism through which aboveground protected produce becomes contaminated. As shown below, the chemical concentration in the aboveground plant due to root uptake from soil ($Pr_{AG\text{-}produce\text{-}DW}$) is estimated using an empirical bioconcentration factor ($Br_{AG\text{-}produce\text{-}DW}$) that relates the chemical concentration in the plant to the average chemical concentration in the soil at the root-zone depth in the produce-growing area ($Cs_{root\text{-}zone\_produce}$). These equations all assume measurements on a dry-weight (DW) basis.

Equation 2-1. Chemical Concentration in Aboveground Produce

$$C_{AG-produce-DW(i)} = \mathrm{P}r_{AG-produce-DW(i)} + Pd_{(i)} + Pv_{(i)}$$

where:

$C_{AG\text{-}produce\text{-}DW(i)}$ = Concentration of chemical in edible portion of aboveground produce type i, exposed or protected, on a dry-weight (DW) basis (mg/kg produce DW)

$Pd_{(i)}$ = Chemical concentration in edible portion of aboveground produce type i due to deposition of particles (mg/kg produce DW); for protected aboveground produce, Pd equals zero

$Pr_{AG\text{-}produce\text{-}DW(i)}$ = Chemical concentration in edible portion of aboveground produce type i, exposed or protected, due to root uptake from soil at the root-zone depth of the produce growing area (mg/kg produce DW)

$Pv_{(i)}$ = Chemical concentration in edible portion of aboveground produce type i due to air-to-plant transfer (µg/g [or mg/kg] produce DW); for protected aboveground produce, Pv equals zero

Equation 2-2. Chemical Concentration in Aboveground Produce Due to Root Uptake

$$\mathrm{P}r_{AG-produce-DW(i)} = Cs_{\text{root-zone\_produce}} \times Br_{AG-produce-DW(i)}$$

where:

$Pr_{AG\text{-}produce\text{-}DW(i)}$ = Concentration of chemical in edible portion of aboveground produce type *i*, *exposed* or *protected*, due to root uptake from soil at root-zone depth in the produce-growing area, on a dry-weight (DW) basis (mg/kg produce DW)

$Cs_{root\text{-}zone\_produce}$ = Average chemical concentration in soil at root-zone depth in produce-growing area (mg/kg soil DW)

$Br_{AG\text{-}produce\text{-}DW(i)}$ = Chemical-specific plant/soil chemical bioconcentration factor for edible portion of aboveground produce type *i*, *exposed* or *protected* (g soil DW / g produce DW)

Equation 2-3. Chemical Concentration in Aboveground Produce Due to Deposition of Particle-phase Chemical

$$Pd_{(i)} = \frac{1{,}000 \times (Drdp + (Fw \times Drwp)) \times Rp_{(i)} \times (1 - e^{(-kp(i)*Tp(i))})}{Yp_{(i)} \times kp_{(i)}}$$

where:

$Pd_{(i)}$ = Chemical concentration in aboveground produce type *i* on a dry-weight (DW) basis due to particle deposition (mg/kg produce DW); set equal to zero for *protected* aboveground produce

$Drdp$ = Average annual dry deposition of particle-phase chemical (g/m^2-yr)

Fw = Fraction of wet deposition that adheres to plant surfaces; 0.2 for anions, 0.6 for cations and most organics (unitless)

$Drwp$ = Average annual wet deposition of particle-phase chemical (g/m^2-yr)

$Rp_{(i)}$ = Interception fraction of the edible portion of plant type *i* (unitless)

$kp_{(i)}$ = Plant surface loss coefficient for plant type *i* (yr^{-1})

$Tp_{(i)}$ = Length of exposure to deposition in the field per harvest of the edible portion of plant type *i* (yr)

$Yp_{(i)}$ = Yield or standing crop biomass of the edible portion of plant type i (kg produce DW/m^2)

Note that Equation 2-3 differs from Equation 5-14 in HHRAP, from which it is derived. In HHRAP, Equation 5-14 includes the term *Q* x (*1 – Fv*) to indicate the emissions rate, in g/sec, of chemical from the source and the proportion of the chemical that remains in, or partitions to, the particle-phase in the air. Also in HHRAP, the dry and wet particle phase deposition rates, *Dydp* and *Dywp,* respectively, are normalized to the emission rate and are expressed in units of sec/m^2-yr.

With MIRC, the user inputs both the dry and wet particle-phase deposition rates, *Drdp* and *Drwp*, respectively, in units of g/m^2-yr for a specific location relative to an emissions source. Those deposition rates might be values measured near that location or estimated using a fate and transport model, such as TRIM.FaTE, in conjunction with local meteorological information and emissions rate data. The chemical emissions term used in HHRAP, *Q*, therefore, is not used in MIRC's Equation 2-3. In addition, in MIRC, *Drdp* and *Drwp*, the average annual dry- and wet-particle-phase deposition rates, respectively, are in units of g/m^2-yr. Users of TRIM.FaTE should note that the dry- and wet-particle-deposition rates output from TRIM.FaTE are in units of g/m^2-day; therefore, users must adjust the TRIM.FaTE output values to units of g/m^2-yr (i.e., multiply by 365 days/yr) before inputting values for *Drdp* and *Drwp* into MIRC.

Equation 2-4. Chemical Concentration in Aboveground Produce Due to Air-to-Plant Transfer of Vapor-phase Chemical

$$Pv_{(i)} = \frac{Ca \times Fv \times Bv_{AG(i)} \times VG_{AG(i)}}{\rho_a}$$

where:

$Pv_{(i)}$ = Concentration of chemical in edible portion of aboveground produce type *i* from air-to-plant transfer of vapor-phase chemical on a dry-weight (DW) basis (µg/g produce DW); set equal to zero for *protected* aboveground produce

Ca = Average annual *total* chemical concentration in air (g/m^3)

Fv = Fraction of airborne chemical in vapor phase (unitless)

$Bv_{AG(i)}$ = Air-to-plant biotransfer factor for aboveground produce type *i* for vapor-phase chemical in air ([mg/g produce DW] / [mg/g air], i.e., g air/ g produce DW)

$VG_{AG(i)}$ = Empirical correction factor for aboveground *exposed* produce type *i* to address possible overestimate of the diffusive transfer of chemical from the outside to the inside of bulky produce, such as fruit (unitless)

ρ_a = Density of air (g/m^3)

Note that Equation 2-4 differs from Equation 5-18 in HHRAP, from which it is derived. In HHRAP, Equation 5-18 includes the term *Q* x *Fv* to indicate the emissions rate, in g/sec, of chemical from the source and the fraction of the chemical in vapor phase in the air. HHRAP also includes the parameter *Cyv*, or the unitized yearly average air concentration of vapor-phase chemical in units of µg-sec/g-m^3. For MIRC, the user inputs the average annual total air concentration of the chemical, *Ca*, for a specific location relative to the source in units of g/m^3; MIRC includes a chemical-specific default value for *Fv* for chemicals included in its database. The air concentration might be a value measured near that location or a value estimated by a fate and transport model such as TRIM.FaTE. Users of TRIM.FaTE should note that the average annual concentration of the total chemical in air (i.e., total of both vapor and particulate phases), *Ca*, output from TRIM.FaTE is in units µg/m^3; therefore, the user must adjust the value to units of g/m^3 (i.e., divide by 1,000 µg/g) before entering it in MIRC.

The calculations of chemical concentration in aboveground produce, ($C_{AG\text{-}produce\text{-}DW}$), shown above, are on a dry-weight (DW) basis. The family FFC food ingestion rates, on the other hand, are on a fresh- or wet-weight (WW) basis. MIRC therefore calculates the concentration in aboveground produce on a wet-weight basis, $C_{AG\text{-}produce\text{-}WW}$, using Equation 2-5 and the moisture content (*MAF*) of the FFC food category.

Equation 2-5. Conversion of Aboveground Produce Chemical Concentration from Dry- to Wet-Weight Basis

$$C_{AG-produce-WW(i)} = C_{AG-produce-DW(i)} \times \left(\frac{(100 - MAF_{(i)})}{100} \right)$$

where:

$C_{AG\text{-}produce\text{-}WW(i)}$ = Chemical concentration in edible portion of aboveground produce type i on a wet-weight (WW) basis (mg/kg produce WW)

$C_{AG\text{-}produce\text{-}DW(i)}$ = Chemical concentration in edible portion of aboveground produce type i on a dry-weight (DW) basis (mg/kg produce DW)

$MAF_{(i)}$ = Moisture adjustment factor for aboveground produce type i to convert the chemical concentration estimated for dry-weight produce to the corresponding chemical concentration for full-weight fresh produce (percent water)

3.1.1.2. Belowground Produce

The equations by which chemical concentrations are estimated in belowground produce are different for nonionic organic chemicals than for inorganic chemicals and ionic organic chemicals.

3.1.1.2.1. Nonionic Organic Chemicals

For belowground produce, the nonionic organic chemical concentration in the tuber or root vegetable is derived from exposure to the chemical in soil and is estimated using an empirical root concentration factor (*RCF*) and the average chemical concentration in the soil at the root-zone depth in the produce-growing area ($Cs_{root\text{-}zone\_produce}$), as shown in Equation 2-6. The RCF relates the chemical concentration in the plant on a wet-weight basis to the average chemical concentration in the root-zone soil ($Cs_{root\text{-}zone\_produce}$) on a dry-weight basis. Belowground produce (i.e., tubers or root vegetables) are protected from the deposition and vapor transfer by being covered by soil. Therefore, root uptake of chemicals is the primary mechanism through which belowground produce becomes contaminated.

Equation 2-6. Chemical Concentration in Belowground Produce: Nonionic Organic Chemicals

$$\mathrm{C}_{\text{BG-produce-WW}} = \frac{Cs_{root-zone\_produce} \times RCF \times VG_{rootveg}}{Kds \times UCF}$$

where:

$C_{BG\text{-}produce\text{-}WW}$ = Concentration of chemical in belowground (BG) produce (i.e., tuber or root vegetable) on a wet-weight (WW) basis (mg chemical/kg produce WW)*

$Cs_{root\text{-}zone\_produce}$ = Average chemical concentration in soil at root-zone depth in produce-growing area, on a dry-weight (DW) basis (mg chemical/kg soil DW)

RCF = Chemical-specific root concentration factor for tubers and root produce (L soil pore water/kg root WW)*

$VG_{rootveg}$ = Empirical correction factor for belowground produce (i.e., tuber or root vegetable) to account for possible overestimate of the diffusive transfer of chemicals from the outside to the inside of bulky tubers or roots (based on carrots and potatoes) (unitless) *

Kds = Chemical-specific soil/water partition coefficient (L soil pore water/kg soil DW)

UCF = Units conversion factor of 1 kg/L

*Note that there is only one type of BG produce; hence there are no plant-type-specific subscripts.

The RCF, as developed by Briggs *et al*. (1982), is the ratio of the chemical concentration in the edible root on a wet-weight basis to its concentration in the soil pore water. RCFs are based on experiments with growth solutions (hydroponic) instead of soils; therefore, it is necessary to divide the soil concentration by the chemical-specific soil/water partition coefficient (*Kds*). There is no conversion of chemical concentrations in belowground produce from DW to WW because the values are already on a WW basis.

For nonionic organic chemicals, it is possible to predict RCF values and Kds values (for a specified soil organic carbon content) from an estimate of the chemical's K_{ow} from empirically derived regression models. Those models are shown in HHRAP Appendix A-2, Equations A-2-14 and A-2-15 (RCF) and in Equations A-29 and A-2-10 (Kds). The RCF and Kds values so calculated for many of the chemicals in HHRAP are included in the MIRC database (including the values for PAHs and dioxins).

3.1.1.2.2. Inorganic and Ionic Organic Chemicals

For inorganic chemicals and ionized organic chemicals, it is not possible to predict RCF or Kds values from K_{ow} . For inorganic chemicals, chemical specific empirical values for the root/soil bioconcentration factor must be used. The root/soil bioconcentration factor, now specified as $Br_{BG\text{-}produce\text{-}DW}$, must be obtained from the literature for each inorganic chemical on a DW basis. For inorganic chemicals, therefore, Equation 2-7 is used instead of Equation 2-6.

Equation 2-7. Chemical Concentration in Belowground Produce: Inorganic Chemicals

$$C_{BG\text{-}produce\text{-}DW} = \frac{Cs_{root-zone\_produce} \times Br_{BG-produce-DW} \times VG_{rootveg}}{1}$$

where:

$C_{BG\text{-}produce\text{-}DW}$ = Concentration of chemical in edible portion of aboveground produce, due to root uptake from soil at root-zone depth in the produce-growing area, on a dry-weight (DW) basis (mg/kg produce DW)

$Cs_{root\text{-}zone\_produce}$ = Average chemical concentration in soil at root-zone depth in produce-growing area (mg/kg soil DW)

$Br_{BG\text{-}produce\text{-}DW}$ = Chemical-specific root/soil chemical bioconcentration factor for edible portion of belowground produce (g soil DW / g produce DW)

$VG_{rootveg}$ = Empirical correction factor for belowground produce (as in Equation 2-6) (unitless)

As for the aboveground produce, the DW estimate of concentration of chemical in the root vegetables must be transformed to a WW estimate, as shown in Equation 2-8.

Equation 2-8. Conversion of Belowground Produce Chemical Concentration from Dry- to Wet-Weight Basis

$$C_{BG-produce-WW} = C_{BG-produce-DW} \times \left(\frac{(100 - MAF_{BG})}{100} \right)$$

where:

$C_{BG\text{-}produce\text{-}WW}$ = Chemical concentration in edible portion of belowground produce on a weight-weight (WW) basis (mg/kg produce WW)

$C_{BG\text{-}produce\text{-}DW}$ = Concentration of chemical in edible portion of aboveground produce, due to root uptake from soil at root-zone depth in the produce-growing area, on a dry-weight (DW) basis (mg/kg produce DW)

$MAF_{(BG)}$ = Moisture adjustment factor (as in Equation 2-5, but single value for below ground produce) (percent water)

3.1.2. Estimating Chemical Concentrations in Animal Products

Chemical concentrations in animal products are estimated based on the amount of chemical consumed by each animal group *m* through each plant feed type *i* ($Plant_{Ch\text{-}Intake(i,m)}$) and incidental ingestion of soil for ground-foraging animals ($Soil_{Ch\text{-}Intake(m)}$). Exhibit_Add A2-5 summarizes the pathways by which chemicals are transferred to these home- or farm-raised animal food products. Note that for a general screening-level assessment, all of the pathways can be modeled, as is done for EPA's RTR calculation of screening threshold emission rates for PB-HAPs (EPA 2008b).

The feed options for farm animals in MIRC include forage (plants grown on-site for animal grazing, such as grass), silage (wet forage grasses, fresh-cut hay, or other fresh plant material that has been stored and fermented), and grain products grown on the farm. As seen in Exhibit_Add A2-5, the algorithms in MIRC for chemical intake with plant feeds ($Plant_{Ch\text{-}Intake(i,m)}$) are based on the assumptions that beef and dairy cattle consume all three plant feed products, while pigs consume only silage and grain, and chickens consume only grain.

Exhibit_Add A2-5. Chemical Transfer Pathways for Animal Products

Farm Food Media		Chemical Transfer Pathways
Animal Products	Beef and total dairy (including milk)	• Ingestion of forage, silage, and grain[a] • Incidental soil ingestion
	Pork	• Ingestion of silage and grain[a] • Incidental soil ingestion
	Poultry and eggs	• Ingestion of grain[a] • Incidental soil ingestion

[a] Chemical concentrations in plant feed (i.e., forage, silage, and grain) are estimated via intermediate calculations (see Equation 2-13, Equation 2-14, Equation 2-3, and Equation 2-4).

Forage and silage are exposed to the air and can accumulate chemicals via direct deposition of particle-bound chemical and transfer of vapor-phase chemical, while all animal feed grains are assumed to be protected from the air by a husk or pod (e.g., corn, soybeans). All three animal feed products are assumed to accumulate chemical via root uptake.

Chemical concentrations are estimated for animal feeds using algorithms analogous to those for aboveground farm produce described above. MIRC uses Equation 2-9 to calculate the concentration of chemical in beef, pork, or total dairy and Equation 2-10 to calculate the concentration of chemical in poultry or eggs. The chemical concentration in mammalian farm animals (i.e., beef and pigs) is adjusted using a metabolism factor (*MF*) that accounts for endogenous degradation of the chemical (see Equation 2-9). *MF* is set to 1.0 for chemicals that are not metabolized and for chemicals for which the metabolic degradation rate is unknown. Although other vertebrates, including birds, are likely to have similar metabolic pathways for most chemicals, the health protective assumption is that birds do not metabolize any chemicals; therefore, the *MF* is omitted from Equation 2-10 for poultry and eggs.

Equation 2-9. Chemical Concentration in Beef, Pork, or Total Dairy

$$C_{mammal(m)} = Ba_{(m)} \times MF \times \left(Soil_{Ch-Intake(m)} + \sum_{i=1}^{n} Plant_{Ch-Intake(i,m)} \right)$$

where:

$C_{mammal(m)}$ = Concentration of chemical in mammalian animal product *m*, where *m* = beef, pork, or total dairy (mg chemical/kg animal product WW)

$Ba_{(m)}$ = Chemical-specific biotransfer factor for chemical in diet to chemical in animal food product *m*, where *m* = beef, pork, or total dairy ([mg chemical/kg animal product WW] / [mg chemical intake/day] or day/kg WW)

MF = Chemical-specific mammalian metabolism factor that accounts for endogenous degradation of the chemical (unitless)

$Soil_{Ch\text{-}Intake(m)}$ = Incidental ingestion of chemical in surface soils by livestock type *m* during grazing or consumption of foods placed on the ground (mg/day); see Equation 2-11 below

$Plant_{Ch\text{-}Intake(i,m)}$ = For livestock (animal product) type *m*, ingestion of chemical from plant feed type *i* (mg chemical/kg livestock WW); see Equation 2-12 below

(If *m* =beef or total dairy, then *n* = 3 and *i* = forage, silage, and grain; *m* = pork, then *n* = 2 and *i* = silage and grain; *m* = poultry, then *n* = 1 and *I* = grain.)

Equation 2-10. Chemical Concentration in Poultry or Eggs

$$C_{poultry(m)} = Ba_{(m)} \times \left(Soil_{Ch-Intake(m)} + Plant_{Ch-Intake(i,m)}\right)$$

where:

$C_{poultry(m)}$ = Concentration of chemical in food product *m*, where *m* = poultry or eggs (mg chemical/kg animal product WW)

$Ba_{(m)}$ = Chemical-specific biotransfer factor for food product *m*, where *m* = poultry or eggs (day/kg animal product WW)

$Soil_{Ch\text{-}Intake(m)}$ = Incidental ingestion of chemical in surface soils by consumption of food on the ground (mg chemical/day) where *m* = poultry; see Equation 2-11

$Plant_{Ch\text{-}Intake(i,m)}$ = For poultry (and eggs), animal *m*, ingestion of the chemical in plant feed type *i* (mg chemical/day), which for poultry is limited to grain; see Equation 2-12

In MIRC, the incidental ingestion of the chemical in soils by livestock during grazing or consumption of feed placed on the ground ($Soil_{Ch\text{-}Intake(m)}$) is estimated using empirical soil ingestion rates (*Qs*) and a soil bioavailability factor for livestock (*Bs*), as shown in Equation 2-11. At this time, the default value for *Bs* in MIRC for all chemicals is 1.0 (i.e., the chemical in soil is assumed to be 100 percent bioavailable to the animal). This assumption may be reasonably accurate for the soil surface to which airborne chemical is deposited. MIRC allows the user to enter a surface soil concentration for areas where livestock forage, $Cs_{S\text{-}livestock}$, that is distinct from the surface soil concentration input for areas where produce may be grown and where humans might incidentally ingest soils (see Section 6.1 of this addendum).

Equation 2-11. Incidental Ingestion of Chemical in Soil by Livestock

$$Soil_{Ch-Intake(m)} = Qs \times Cs_{s-livestock} \times Bs$$

where:

$Soil_{Ch\text{-}Intake(m)}$ = Incidental ingestion of the chemical in surface soils by livestock type *m* during grazing or consumption of foods placed on the ground (mg chemical/day)

$Qs_{(m)}$ = Quantity of soil eaten by animal type *m* each day (kg soil DW/day)

$Cs_{s\text{-}livestock}$ = Chemical concentration in surface soil in contaminated area where livestock feed (mg chemical/kg soil DW)

Bs = Soil bioavailability factor for livestock (unitless) (assumed to be the same for birds and mammals)

Animal ingestion of the chemical in feed is calculated for each type of livestock based on their assumed diets. For *m* = beef and dairy cattle, chemical intake is estimated for all three feed types: *i* = forage, silage, and grain. For pork, chemical intake is estimated only for silage and grain. The chemical intake for poultry is based on grain consumption only. The intake of chemical with each feed type, *i*, $Plant_{Ch\text{-}Intake(i,m)}$, is calculated separately according to Equation 2-12. Note that the animal feed ingestion rates are on a dry-weight (DW) basis; hence, no DW to wet weight (WW) conversion is needed.

Equation 2-12. Ingestion of Chemical in Feed by Livestock

$$Plant_{Ch-Intake(i,m)} = F_{(i,m)} \times Qp_{(i,m)} \times C_{feed(i)}$$

where:

$Plant_{\ Ch\text{-}Intake(i,m)}$ = Ingestion of chemical in plant feed type *i* (mg chemical/day), where *i* = forage, silage, or grain, for livestock type *m*

$F_{(i,m)}$ = Fraction of plant feed type *i* obtained from contaminated area used to grow animal feed, where *I* = forage, silage, or grain (unitless) for livestock type *m*

$Qp_{(i,m)}$ = Quantity of plant feed type *i* consumed per animal per day (kg plant feed DW/day), where *i* = forage, silage, or grain, for livestock type *m*

$C_{feed(i)}$ = Concentration of chemical in ingested plant feed type *i* (mg chemical/kg plant feed DW), where *i* = forage, silage, or grain

The concentrations of chemical in the three different types of plant feeds for livestock are calculated according to Equation 2-13. The equation is the same as that for aboveground produce in Equation 2-1, with the exception that the concentrations are for plants used as animal feeds (not produce consumed by humans) and all types of plant feed (i.e., forage, silage, and grain) are aboveground.

Equation 2-13. Chemical Concentration in Livestock Feed (All Aboveground)

$$C_{feed(i)} = Pr_{feed(i)} + Pd_{(i)} + Pv_{(i)}$$

where:

$C_{feed(i)}$ = Concentration of chemical in plant feed type *i* on a dry-weight (DW) basis (mg chemical/kg plant feed DW), where *i* = forage, silage, or grain

$Pr_{feed(i)}$ = Concentration of chemical in plant feed type *i* due to root uptake from soil (mg/kg DW), where *i* = forage, silage, or grain; see Equation 2-14 below

$Pd_{(i)}$ = Concentration of chemical in plant feed type *i* due to wet and dry deposition of particle-phase chemical (mg/kg DW), where *i* = forage, silage, or grain; when *i* = grain, the *Pd* term equals zero

$Pv_{(i)}$ = Concentration of chemical in plant feed type *i* due to air-to-plant transfer of vapor-phase chemical (µg/g [or mg/kg] DW) where *i* = forage, silage, or grain; when *i* = grain, the *Pd* term equals zero

MIRC calculates the chemical concentration in animal feed due to root uptake from the soil using Equation 2-14. The equation is the same as Equation 2-2, except that a *Br* value appropriate to grasses is used and MIRC allows for different soil concentrations in the area used to grow animal feed than in the area used to grow produce for human consumption (see Section 6.1 of this addendum, user inputs). Note that for feed type *i* = grains, the *Pd* and *Pv* terms do not apply (are set to zero), because the feed products (i.e., corn kernels, soy beans) are protected from the air (i.e., by husks, pods).

Equation 2-14. Chemical Concentration in Livestock Feed Due to Root Uptake

$$\mathrm{P}r_{feed\,(i)} = Cs_{root-zone\_feed\,(i)} \times Br_{feed\,(i)}$$

where:

$Pr_{feed(i)}$ = Concentration of chemical in plant feed type *i* due to root uptake from soil on a dry-weight (DW) basis (mg chemical/kg plant feed DW), where *i* = forage, silage, or grain

$Cs_{root\text{-}zone\_feed(i)}$ = Average chemical concentration in soil at root-zone depth in area used to grow plant feed type *i* (mg chemical/kg soil DW), where *i* = forage, silage, or grain

$Br_{feed(i)}$ = Chemical-specific plant-soil bioconcentration factor for plant feed type *i* (kg soil DW/kg plant feed DW), where *i* = forage, silage, or grain

The algorithms used to calculate $Pd_{(i)}$ and $Pv_{(i)}$ when plant feed type *i* = forage and silage are identical to those used to calculate $Pd_{(i)}$ and $Pv_{(i)}$ for aboveground exposed produce (i.e., Equation 2-3 and Equation 2-4, respectively).

There are no conversions of DW feed to WW feed, because all feed ingestion rates for livestock are based on DW feed.

3.2. Chemical Intake Calculations for Adults and Non-Infant Children

MIRC calculates human chemical intake rates from the ingestion of home-grown foods as average daily doses (ADDs) normalized to body weight for each age group, chemical, and food type separately. ADDs, calculated using Equation 2-15, are expressed in milligrams of chemical per kilogram of receptor body weight per day (mg/kg-day).

Equation 2-15. Average Daily Dose for Specified Age Group and Food Type

$$ADD_{(y,i)} = \left(\frac{C_{(i)} \times IR_{(y,i)} \times FC_{(i)} \times ED_{(y)}}{BW_{(y)} \times AT_{(y)}} \right) \left(\frac{EF_{(y)}}{365\text{ days}} \right)$$

where:

$ADD_{(y,i)}$ = Average daily dose for age group *y* from food type or ingestion medium *i* (mg chemical/kg body weight-day)

$C_{(i)}$ = Concentration of chemical in food type *i* harvested from the contaminated area (mg chemical/kg food or mg food/L water)

$IR_{(y,i)}$ = Ingestion rate for age group *y* of food type *i* (kg/day or L/day)

$FC_{(i)}$ = Fraction of food type *i* that was harvested from contaminated area (unitless)

$ED_{(y)}$ = Exposure duration for age group *y* (years)

$BW_{(y)}$ = Body weight for age group *y* (kg)

$AT_{(y)}$ = Averaging time for calculation of daily dose (years) for age group *y*, set equal to ED in MIRC

$EF_{(y)}$ = Annual exposure frequency for age group *y* (days)

Equation 2-15 takes into account the chemical concentration in each food type *i* (or in water), the quantity of food brought into the home for consumption, the loss of some of the mass of the foods due to preparation and cooking, how much of the food is consumed per year, the amount of the food obtained from contaminated areas, and the consumer's body weight (EPA 2011a, 2003a). In MIRC, ADDs are calculated separately for each chemical, home-grown food type, and consumer age group.

ADD values, expressed as intakes, not absorbed doses, are appropriate for comparison with RfDs and for use with cancer slope factors (CSFs) to estimate risk, as discussed in Section 5 of this addendum. An exception is for the breast-milk exposure pathway, where calculating the dose available to and absorbed by the nursing infant is related to the dose absorbed by the mother as discussed in Section 3.4 of this addendum.

MIRC evaluates only one exposure scenario at a time. For screening-level assessments, all components of this equation are assumed to remain constant for consumers in a given age group over time (e.g., seasonal and annual variations in diet are not explicitly taken into account). To calculate an $ADD_{(y,i)}$ from the contaminated area for food group *i* over an entire lifetime of exposure, age-group-specific ingestion rates and body weights are used for the age groups described in Section 2.3 of this addendum. In MIRC, the averaging time used to calculate the daily dose for an age group (AT_y) is equal to the exposure duration for that group (ED_y); therefore these variables drop out of Equation 2-15.

For each chemical included in a screening scenario, total average daily exposure for age group *y* ($ADD_{(y)}$) is estimated as the sum of chemical intake from all ingestion pathways combined: Note that the last exposure pathway is limited to infants.

- Incidental soil ingestion;
- Ingestion of fish;
- Ingestion of homegrown fruits (exposed and protected);
- Ingestion of homegrown vegetables (exposed, protected, and root);
- Ingestion of animal products from home-raised animals:
  - Milk and other dairy products from cows,

  - Beef products,
  - Pork products, and
  - Poultry and eggs;
- Ingestion of drinking water from specified source; and
- Ingestion of breast milk by infants.

The algorithms for the first six exposure pathways listed above are described in Sections 3.2.1 through 3.2.6 of this addendum. The algorithms for the breast-milk ingestion pathway are described in Section 3.4.

3.2.1. Chemical Intake from Soil Ingestion

Equation 2-16 shows the equation used to estimate chemical intake through incidental ingestion of soil.

Equation 2-16. Chemical Intake from Soil Ingestion

$$ADD_{Soil\,(y)} = \left(\frac{C_{Soil} \times IR_{Soil(y)} \times FC_{Soil} \times 0.001\ \frac{mg}{\mu g}}{BW_{(y)}} \right) \left(\frac{EF}{365\ \text{days}} \right)$$

where:

$ADD_{Soil(y)}$ = Average daily chemical intake from incidental ingestion of soil or ingestion by child in age group *y* (mg chemical/kg body weight-day)
C_{Soil} = Concentration of chemical in soil from contaminated area on a dry-weight (DW) basis (µg/g soil DW)
$IR_{Soil(y)}$ = Soil ingestion rate for age group *y* (g DW/day)
FC_{Soil} = Fraction of soil ingested that is from contaminated area (unitless)
$BW_{(y)}$ = Body weight for age group *y* (kg)
EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤ 365 days)

Note: MIRC saves soil ingestion rates in units of mg/day (not g/day); therefore, there is an additional 0.001 g/mg conversion unit in the actual MIRC algorithm than shown here.

3.2.2. Chemical Intake from Fish Ingestion

Ingestion of locally caught fish is included as a possible exposure pathway in MIRC (Equation 2-17). Two types of fish are included in the exposure algorithm: trophic level 3.5 (abbreviated as TL3) fish, equivalent to benthic carnivores such as catfish and trophic level 4 (TL4) fish in the water column, equivalent to game fish such as lake trout and walleye. The chemical concentration in fish in Equation 2-17 is estimated as the consumption-weighted chemical concentration using Equation 2-18.

Equation 2-17. Chemical Intake from Fish Ingestion

$$ADD_{Fish(y)} = (1 - L1_{Fish}) \times (1 - L2_{Fish}) \times \frac{\left(C_{Fish} \times IR_{Fish(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{Fish}\right)}{BW_{(y)}} \times \left(\frac{EF}{365\text{ days}}\right)$$

Equation 2-18. Consumption-weighted Chemical Concentration in Fish

$$\mathrm{C_{Fish}} = (\mathrm{C_{FishTL3}} \times \mathrm{F_{TL3}}) + (\mathrm{C_{FishTL4}} \times \mathrm{F_{TL4}})$$

where:

$ADD_{Fish(y)}$ = Average daily chemical intake from ingestion of local fish for age group *y* (mg/kg-day)

$L1_{Fish}$* = Weight of fish brought into home that is discarded during preparation (e.g., head, bones, liver, other viscera, belly fat, skin with fat) (unitless)

$L2_{Fish}$* = Loss of weight during cooking, such as evaporation and loss of fluids into pan (unitless)

$C_{FishTL3}$ = Chemical concentration in whole fish for trophic level 3.5 (TL3) fish on a wet-weight (WW) basis (mg/kg WW)

$C_{FishTL4}$ = Chemical concentration in whole fish for trophic level 4 (TL4) fish on a wet-weight (WW) basis (mg/kg WW)

F_{TL3} = Fraction of fish intake that is from TL3 (unitless)

F_{TL4} = Fraction of fish intake that is from TL4 (unitless)

C_{Fish} = Consumption-weighted mean chemical concentration in total fish (i.e., as specified by Equation 2-18) (mg/kg WW)

FC_{Fish} = Fraction of local fish consumed derived from contaminated area (unitless)

$BW_{(y)}$ = Body weight for age *y* (kg)

$IR_{Fish(y)}$* = Local fish ingestion rate for age *y* (g WW/day)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤ 365 days)

*Parameter values must be internally consistent. In contrast to the tables included in MIRC for ingestion rate options for homegrown food products, which are based on the products as brought into the home from the field (see Section 6.3.3 of this addendum), the tables of fish ingestion rate options included in MIRC are on an “as consumed” basis (i.e., after preparation and cooking losses), and L1 and L2 therefore are set equal to zero. If the user wishes to enter local fish ingestion rates on an “as harvested” basis, the user also should enter L1 and L2 values as specified in Section 6.4.3 of this addendum.

When whole fish are prepared for cooking, it is usual for the viscera, head, and fins to be removed, particularly for larger fish. Many persons also remove (or do not eat) the skin, bones, and belly fat. EPA has, therefore, estimated the proportion of the weight of whole fish that tends to be lost during preparation and cooking across a variety of fish species (EFH; EPA 2011a) and included those losses in its HHRAP algorithms for chemical intake from fish ($L1_{Fish}$ and $L2_{Fish}$ in Equation 2-17).

3.2.3. Chemical Intake from Fruit Ingestion

Average daily doses of a chemical from homegrown exposed fruits are calculated separately for exposed and protected fruits (Equation 2-19 and Equation 2-20, respectively).

Equation 2-19. Chemical Intake from Consumption of Exposed Fruits

$$ADD_{ExpFruit(y)} = \left(1 - L1_{ExpFruit}\right) \times \left(1 - L2_{ExpFruit}\right) \times \left(C_{ExpFruit} \times IR_{ExpFruit(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{ExpFruit}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

Equation 2-20. Chemical Intake from Consumption of Protected Fruits

$$ADD_{ProFruit(y)} = \left(1 - L1_{ProFruit}\right) \times \left(C_{ProFruit} \times IR_{ProFruit(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{ProFruit}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

where:

$ADD_{ExpFruit(y)}$ $ADD_{ProFruit(y)}$ = Average daily chemical intake from ingestion of exposed fruit or protected fruit (depending on subscript) (mg chemical/kg body weight-day)

$L1_{ExpFruit}$ = Mean reduction in fruit weight resulting from removal of skin or peel, core or pit, stems or caps, seeds and defects, and from draining liquids from canned or frozen forms (unitless)

$L1_{ProFruit}$ = Mean reduction in fruit weight that results from paring or other preparation techniques for protected fruits (unitless)

$L2_{ExpFruit}$ = Mean reduction in fruit weight that results from draining liquids from cooked forms of the fruit (unitless)

$C_{ExpFruit}$ $C_{ProFruit}$ = Chemical concentration in whole exposed fruits or whole protected fruits (depending on subscript) on a wet-weight (WW) basis (mg chemical/kg exposed fruit WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario ($\leq$ 365 days)

$FC_{ExpFruit}$ $FC_{ProFruit}$ = Fraction of exposed fruits or protected fruits (depending on subscript) obtained from contaminated area (unitless)

$IR_{ExpFruit(y)}$ $IR_{ProFruit(y)}$ = Ingestion rate of home-grown exposed fruits or protected fruits (depending on subscript) for age *y* (g WW/kg body weight-day)

Fruit ingestion rates in the survey were based on weights of unprepared fruits (e.g., one apple; one pear) or the weight of a can of fruit (e.g., 8 oz can). The weight of the fruit ingested is less than the initial weight owing to common preparation actions ($L1_{ExpFruit}$ and $L1_{ProFruit}$; e.g., coring apples and pears; peeling apples; pitting cherries). Cooking of exposed fruit (e.g., berries, apples, peaches) often results in further weight loss that results from liquids lost during cooking and drained from the cooking vessel ($L2_{ExpFruit}$). EPA has assumed that cooking of protected fruit results in no loss of weight for the fruit.

3.2.4. Chemical Intake from Vegetable Ingestion

MIRC includes three separate algorithms for homegrown vegetables adapted from EPA's HHRAP Modeling System (EPA 2005a): one for exposed vegetables such as asparagus, broccoli, lettuce, and tomatoes (although they are actually a fruit); one for protected vegetables such as corn, cabbage, soybeans, and peas; and one for root vegetables such as carrots, beets, and potatoes (see Equation 2-21, Equation 2-22, and Equation 2-23, respectively).

Equation 2-21. Chemical Intake from Exposed Vegetables

$$ADD_{ExpVeg(y)} = \left(1 - L1_{ExpVeg}\right) \times \left(C_{ExpVeg} \times IR_{ExpVeg(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{ExpVeg}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

Equation 2-22. Chemical Intake from Protected Vegetables

$$ADD_{ProVeg(y)} = \left(1 - L1_{ProVeg}\right) \times \left(C_{ProVeg} \times IR_{ProVeg(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{ProVeg}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

Equation 2-23. Chemical Intake from Root Vegetables

$$ADD_{RootVeg(y)} = \left(1 - L1_{RootVeg}\right) \times \left(1 - L2_{RootVeg}\right) \times \left(C_{RootVeg} \times IR_{RootVeg(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{RootVeg}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

where:

$ADD_{ExpVeg(y)}$, $ADD_{ProVeg(y)}$, $ADD_{RootVeg(y)}$ = Average chemical intake from ingestion of exposed vegetables, protected vegetables, or root vegetables (depending on subscript) for age group *y* (mg chemical/kg body weight-day)

$L1_{ExpVeg}$ = Mean net preparation and cooking weight loss for exposed vegetables (unitless); includes removing stalks, paring skins, discarding damaged leaves

$L1_{ProVeg}$ = Mean net cooking weight loss for protected vegetables (unitless); includes removing husks, discarding pods of beans and peas, removal of outer leaves

$L1_{RootVeg}$ = Mean net cooking weight loss for root vegetables (unitless); includes losses from removal of tops and paring skins

$L2_{RootVeg}$ = Mean net post cooking weight loss for root vegetables from draining cooking liquids and removal of skin after cooking (unitless)

C_{ExpVeg}, C_{ProVeg}, $C_{RootVeg}$ = Chemical concentration in exposed vegetables, protected vegetables, or root vegetables (depending on subscript) on a wet-weight (WW) basis (mg chemical/kg vegetable WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤365 days)

FC_{ExpVeg}, FC_{ProVeg}, $FC_{RootVeg}$ = Fraction of exposed vegetables, protected vegetables, or root vegetables (depending on subscript) obtained from contaminated area (unitless)

$IR_{ExpVeg(y)}$, $IR_{ProVeg(y)}$, $IR_{RootVeg(y)}$ = Ingestion rate of exposed vegetables, protected vegetables, or root vegetables (depending on subscript) for age group *y* (g vegetable WW/kg body weight-day)

3.2.5. Chemical Intake from Animal Product Ingestion

Calculations of chemical intake from the consumption of farm animals and related food products are provided below in Equation 2-24 through Equation 2-28 for homegrown beef, dairy (milk), pork, poultry, and eggs, respectively.

Equation 2-24. Chemical Intake from Ingestion of Beef

$$ADD_{Beef(y)} = (1 - L1_{Beef}) \times (1 - L2_{Beef}) \times \left(C_{Beef} \times IR_{Beef(y)} \times 0.001 \frac{\text{kg}}{\text{g}} \times FC_{Beef} \right) \times \left(\frac{EF}{365\ \text{days}} \right)$$

where:

$ADD_{Beef(y)}$ = Average daily chemical intake from ingestion of beef for age group y (mg/kg-day)

$L1_{Beef}$ = Mean net cooking loss for beef (unitless)

$L2_{Beef}$ = Mean net post cooking loss for beef (unitless)

C_{Beef} = Concentration of contaminant in beef (mg/kg WW))

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤ 365 days)

$IR_{Beef(y)}$ = Ingestion rate of contaminated beef for age group y (g WW/kg-day)

FCBeef = Fraction of beef consumed raised on contaminated area or fed contaminated silage and grains (unitless)

Equation 2-25. Chemical Intake from Dairy Ingestion

$$ADD_{Dairy(y)} = \left(C_{Dairy} \times IR_{Dairy(y)} \times 0.001 \frac{\text{kg}}{\text{g}} \times FC_{Dairy} \right) \times \left(\frac{EF}{365\ \text{days}} \right)$$

where:

$ADD_{Dairy(y)}$ = Average daily chemical intake from ingestion of total dairy for age group *y* (mg/kg-day)

C_{Dairy} = Average concentration of contaminant in total dairy (mg/kg WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤ 365 days)

$IR_{Dairy(y)}$ = Ingestion rate of contaminated total dairy for age group *y* (g WW/kg-day)

FC_{Dairy} = Fraction of total dairy products from contaminated area (unitless)

Equation 2-26. Chemical Intake from Pork Ingestion

$$ADD_{Pork(y)} = (1 - L1_{Pork}) \times (1 - L2_{Pork}) \times \left(C_{Pork} \times IR_{Pork(y)} \times 0.001 \frac{\text{kg}}{\text{g}} \times FC_{Pork} \right) \times \left(\frac{EF}{365\ \text{days}} \right)$$

where:

$ADD_{Pork(y)}$ = Average daily chemical intake from ingestion of pork for age group *y* (mg/kg-day)

$L1_{Pork}$ = Mean net cooking loss for pork (unitless); includes dripping and volatile losses during cooking; averaged over various cuts and preparation methods

$L2_{Pork}$ = Mean net post cooking loss for pork (unitless); includes losses from cutting, shrinkage, excess fat, bones, scraps, and juices; averaged over various cuts and preparation methods

C_{Pork} = Concentration of contaminant in pork (mg/kg WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤365 days)

$IR_{Pork(y)}$ = Ingestion rate of contaminated pork for age *y* (g WW/kg-day)

FC_{Pork} = Fraction of pork obtained from contaminated area (unitless)

Equation 2-27. Chemical Intake from Poultry Ingestion

$$ADD_{Poultry(y)} = \left(1 - L1_{Poultry}\right) \times \left(1 - L2_{Poultry}\right) \times \left(C_{Poultry} \times IR_{Poultry(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{Poultry}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

where:

ADDPoultry(y) = Average daily dose (chemical intake) from ingestion of poultry (mg/kg-day)

L1Poultry = Mean net cooking loss for poultry (unitless)

L2Poultry = Mean net post cooking loss for poultry (unitless)

CPoultry = Concentration of chemical in poultry (mg/kg WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤365 days)

IRPoultry(y) = Ingestion rate of poultry for age group *y* (g WW/kg-day)

$FC_{Poultry}$ = Fraction of poultry from contaminated area or fed contaminated grains (unitless)

The reduction in the weight of beef, pork, and poultry during and after cooking may correlate with an increase or decrease in the concentration of the chemical in the food as consumed depending on the chemical and depending on the cooking method.

Equation 2-28. Chemical Intake from Egg Ingestion

$$ADD_{Egg(y)} = \left(C_{Egg} \times IR_{Egg(y)} \times 0.001\frac{\text{kg}}{\text{g}} \times FC_{Egg}\right) \times \left(\frac{EF}{365\ \text{days}}\right)$$

where:

$ADD_{Egg(y)}$ = Average daily chemical intake from ingestion of eggs for age group *y* (mg/kg-day)

C_{Egg} = Concentration of contaminant in eggs (mg/kg WW)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤ 365 days)

$IR_{Egg(y)}$ = Ingestion rate of contaminated eggs for age group *y* (g WW/kg-day)

FC_{Egg} = Fraction of eggs obtained from contaminated area (unitless)

3.2.6. Chemical Intake from Drinking Water Ingestion

If the user chooses to evaluate chemical ingestion via drinking water, the user specifies a chemical concentration in g/L (equivalent to mg/mL) based on their particular scenario. The chemical concentration could represent water from groundwater wells, community water, nearby surface waters, or other source. For this exposure pathway, ingestion rates are in units of milliliters of water per day (mL/day) (see Equation 2-29).

Equation 2-29. Chemical Intake from Drinking Water Ingestion

$$ADD_{DW(y)} = \left(\frac{C_{DW} \times IR_{DW(y)} \times FC_{DW}}{BW_{(y)}}\right) \times \left(\frac{EF}{365\text{ days}}\right)$$

where:

$ADD_{DW(y)}$ = Average daily chemical intake from ingestion of drinking water from local residential water source for age group *y* (mg/kg-day)

C_{DW} = Concentration of contaminant in drinking water (g/L)

$IR_{DW(y)}$ = Drinking water ingestion rate for age group *y* (mL/day)

FC_{DW} = Fraction of drinking water obtained from contaminated area (unitless)

$BW_{(y)}$ = Body weight of age group *y* (kg)

EF = Exposure frequency; number of days per year of exposure for family(ies) as specified for scenario (≤365 days)

3.3. Total Chemical Intake

To estimate the total ADD, or intake of a chemical from all of the exposure media that a single individual in each age group is expected to contact (e.g., soil, local fish, five types of home-grown produce, and five types of home-raised animals or animal products), the media-specific chemical intakes are summed for each age group. Total average daily exposure for a particular age group *y* ($ADD_{(y)}$) is estimated as the sum of chemical intake from all ingestion pathways combined, as illustrated in Equations 2-30 through Equation 2-35 below.

Equations 2-30 to 2-35. Total Average Daily Dose of a Chemical for Different Age Groups

Equation 2-30. $ADD_{(<1)} = ADD_{breastmilk}$

Equation 2-31. $ADD_{(1-2)} = \sum_{i=1}^{n} ADD_{(1-2,i)}$

Equation 2-32. $ADD_{(3-5)} = \sum_{i=1}^{n} ADD_{(3-5,i)}$

Equation 2-33. $ADD_{(6-11)} = \sum_{i=1}^{n} ADD_{(6-11,i)}$

Equation 2-34. $ADD_{(12\text{–}19)} = \sum_{i=1}^{n} ADD_{(12\text{–}19,i)}$

Equation 2-35. $ADD_{(adult)} = \sum_{i=1}^{n} ADD_{(adult,i)}$

where *i* represents the i^{th} food type or ingestion medium and *n* equals the total number of food types or ingestion media, and *ADD* parameters are defined below:

$ADD_{(<1)}$ = Total average daily dose of chemical for infants less than one year from ingestion of breast milk (mg/kg-day)

$ADD_{(1\text{–}2)}$ = Total average daily dose of chemical from all ingestion sources for children ages 1 through 2 years (mg/kg-day)

$ADD_{(3\text{–}5)}$ = Total average daily dose for children ages 3 through 5 years (mg/kg-day)

$ADD_{(6\text{–}11)}$ = Total average daily dose for children ages 6 through 11 years (mg/kg-day)

$ADD_{(12\text{–}19)}$ = Total average daily dose for children ages 12 through 19 years (mg/kg-day)

$ADD_{(adult)}$ = Total average daily dose for adult age 20 up to 70 years (mg/kg-day)

The lifetime average daily dose (*LADD*) is calculated as the time-weight average of the *ADD* values for each age group (Equation 2-36).

Equation 2-36. Lifetime Average Daily Dose (LADD)

$$LADD = ADD_{(<1)}\left(\frac{1}{70}\right) + ADD_{(1\text{-}2)}\left(\frac{2}{70}\right) + ADD_{(3\text{-}5)}\left(\frac{3}{70}\right) + ADD_{(6\text{-}11)}\left(\frac{6}{70}\right) + ADD_{(12\text{-}19)}\left(\frac{8}{70}\right) + ADD_{(adult)}\left(\frac{50}{70}\right)$$

The time-weighting factors simply equal the duration of exposure for the specified age category in years divided by the total lifespan, assumed to be 70 years.

3.4. Chemical Intake Calculations for Nursing Infants

The scientific literature indicates that infants can be exposed to some chemicals via their mothers' breast milk. The magnitude of the exposure can be estimated from information on the mother's exposure, data on the partitioning of the chemical into various compartments of the mother's body and into breast milk, and information on the infant's consumption of milk and absorption of the chemical. To add this exposure pathway to the MIRC application, we adapted exposure algorithms and default assumptions from EPA's *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* (EPA 1998), hereafter referred to as MPE, as explained below.

Note that this pathway generally is of most concern for *lipophilic* bioaccumulative chemicals (e.g., dioxins) that can cause developmental effects. The period of concern for the more *hydrophilic* chemicals that cause developmental effects generally is earlier, that is, from conception to birth. Hydrophilic chemicals generally exchange well between the maternal and fetal blood supplies at the placenta.

3.4.1. Infant Average Daily Absorbed Dose

The average daily dose of chemical *absorbed* by the infant (DAI_{inf}) is estimated in MIRC with Equation 2-37. This basic exposure equation relies on the concentration of the chemical in the breast milk, the infant's breast-milk ingestion rate (IR_{milk}), the absorption efficiency of the chemical by the oral route of exposure (AE_{inf}), the bodyweight of the infant (BW_{inf}), and the duration of breast feeding (ED). Equation 2-37 is EPA's (EPA 1998) modification of an average daily dose for the infant model first published by Smith (1987) and includes variables for both the concentration of the chemical in the breast milk fat ($C_{milkfat}$) and the concentration of the chemical in the aqueous phase of breast milk ($C_{aqueous}$). The remainder of the DAI_{inf}-associated equations assume that most chemicals of concern will partition *either* to the lipid phase *or* to the aqueous phase of breast milk, although some chemicals may partition significantly to both phases of milk. Thus, the remaining equations in MIRC assume that either $C_{milkfat}$ or $C_{aqueous}$ is equal to zero and hence drops out of the equation.

For the parameters in Equation 2-37 (and the equations that follow) that are not calculated from another equation, an EPA default value and options for other values available in MIRC for the infant breast-milk-exposure pathway are described in Section 6.4 of this addendum. The user also can overwrite those parameter values with a different value from the literature as appropriate.

Equation 2-37. Average Daily Dose of Chemical to the Nursing Infant

$$DAI_{inf} = \frac{\left[\left(C_{milkfat} \times f_{mbm}\right) + \left(C_{aqueous} \times \left(1 - f_{mbm}\right)\right)\right] \times IR_{milk} \times AE_{inf} \times ED}{BW_{inf} \times AT}$$

where:

DAI_{inf} = Average daily dose of chemical absorbed by infant (mg chemical/kg body weight-day)

$C_{milkfat}$ = Concentration of chemical in lipid phase of maternal milk (mg chemical/kg milk lipid; calculated using Equation 2-38)

f_{mbm} = Fraction of fat in breast milk (unitless)

$C_{aqueous}$ = Concentration of chemical in aqueous phase of maternal milk (mg chemical/kg aqueous phase milk; calculated using Equation 2-42)

IR_{milk} = Infant milk ingestion rate over the duration of nursing (kg milk/day)

AE_{inf} = Absorption efficiency of the chemical by the oral route of exposure (i.e., chemical-specific fraction of ingested chemical that is absorbed by the infant) (unitless)

ED = Exposure duration, i.e., duration of breast feeding (days)

BW_{inf} = Body weight of infant averaged over the duration of nursing (kg)

AT = Averaging time associated with exposure of interest; equal to ED (days)

As mentioned above, Equation 2-37 includes terms for the chemical in both the lipid- and non-lipid phases of milk. The remaining equations, however, assume that a chemical of concern will partition to the lipid or aqueous phase of breast milk, but not to both. Different models are used to estimate $C_{milkfat}$ (described in Section 3.4.2 of this addendum) and $C_{aqueous}$ (described in Section 3.4.3 of this addendum).

3.4.2. Chemical Concentration in Breast Milk Fat

When developing the Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions (MPE) (EPA 1998), EPA reviewed three first-order kinetics models for estimating chemical concentration in breast milk fat. The model selected for use in MIRC is the model selected in MPE. The other two models were not considered in MPE because one used a biotransfer factor (BTF) approach considered more of a screening model than a predictive tool (Travis *et al.* 1988) and the other assumed that the contaminant concentration in the maternal fat compartment is at steady state and that the concentration in breast milk fat is the same as in maternal body fat (Smith 1987). The model in MIRC is a changing-concentration model that EPA adapted from a model by Sullivan *et al*. (1991). The model, shown in Equation 2-38, estimates the average chemical concentration in the breast milk over the entire period of breast feeding by reference to a maximum theoretical steady-state concentration. Studies of lipophilic chemicals such as dioxins suggest that concentrations in the maternal milk are highest during the first few weeks of breast feeding and then decrease over time (ATSDR 1998). Equation 2-38 accounts for the changing concentration in breast milk fat, but estimates one average value to represent the concentration over the entire duration of breast feeding. The model is dependent on the maternal body burden of the chemical and assumes that the chemical concentration in breast milk fat is the same as the concentration in general maternal body fat. According to reviewers of the model, this assumption warrants further investigation because milk fat appears to be synthesized in the mammary glands and may have lower chemical concentrations than general body fat stores (EPA 2001a).

Equation 2-38. Chemical Concentration in Breast Milk Fat

$$C_{milkfat} = \frac{DAI_{mat} \times f_f}{k_{elim} \times f_{fm}} \times \left[\frac{k_{elim}}{k_{fat\_elac}} + \frac{1}{k_{fat\_elac} \times t_{bf}} \left(1 - e^{-k_{elim} t_{pn}} - \frac{k_{elim}}{k_{fat\_elac}} \right) \left(1 - e^{-k_{fat\_elac} t_{bf}} \right) \right]$$

where:

$C_{milkfat}$ = Concentration of chemical in lipid phase of maternal milk (mg chemical/kg lipid)

DAI_{mat} = Daily absorbed maternal chemical dose (mg chemical/kg maternal body weight-day; calculated using Equation 2-39)

f_f = Fraction of total maternal body burden of chemical that is stored in maternal fat (mg chemical in body fat / mg total chemical in whole body; value from literature or EPA default - see Section 6.5 of this addendum)

k_{elim} = Chemical-specific total elimination rate constant for elimination of the chemical by non-lactating women (per day; e.g., via urine, bile to feces, exhalation; value from literature or calculated using Equation 2-40)

f_{fm} = Fraction of maternal body weight that is fat stores (unitless)

k_{fat_elac} = Chemical-specific rate constant for total elimination of chemical in the lipid phase of milk during nursing (per day; value from literature or calculated using Equation 2-41)

t_{bf} = Duration of breast feeding (days)

t_{pn} = Duration of mother's exposure prior to parturition and initiation of breast feeding (days)

Equation 2-38 relies on the daily maternal absorbed intake (DAI_{mat}) to determine the concentration of the chemical in the breast milk fat. DAI_{mat} is multiplied by the fraction of the chemical that is stored in maternal fat (f_f) to determine the amount (i.e., mass) of chemical in the fat. This product, divided by the chemical-specific elimination rate constant (k_{elim}) for non-lactating adult women and the fraction of the mother's weight that is fat (f_{fm}), represents the maximum theoretical steady-state concentration of the chemical in an adult woman. If used alone to estimate the chemical concentration in breast milk fat, the equation as explained thus far is likely to overestimate the chemical concentration in milk fat because it does not account for losses due to breast feeding. Alone, this term ($DAI_{mat}\, f_f \,/\, k_{elim}\, f_{fm}$) also assumes that the biological half-life of the chemical in the mother's breast milk fat is small relative to the duration of the mother's exposure. However, for chemicals with half-lives that are longer than the exposure duration, which are the chemicals of concern in the applications of MIRC to date, an additional term is needed to determine the average concentration in the milk fat over the duration of her exposure.

To account for breast feeding losses and longer chemical half-lives in the mother than the exposure duration, an additional term is included in Equation 2-38. This term includes a fraction dependent on two rate constants, k_{elim} and the elimination constant for a lipophilic chemical in lactating women via the lipid phase of breast milk (k_{fat_elac}), the duration of the mother's chemical exposure prior to nursing (t_{pn}), and the duration of breast feeding (t_{bf}). The whole body concentration ($DAI_{mat}\, f_f \,/\, k_{elim}\, f_{fm}$), the maximum theoretical steady-state concentration, is multiplied by the rate of elimination averaged over the duration of the mother's exposure, including her exposure prior to and during lactation. To review the derivation of Equation 2-38, see Appendix B of MPE (EPA 1998).

To estimate an average daily dose *absorbed* by an infant's mother, or DAI_{mat}, the average daily dose (*ADD*) (in mg/kg-day) for the chemical from all sources that MIRC calculates for adults ($ADD_{(adult)}$, described in Section 3.3 of this addendum, Equation 2-35), is multiplied by an absorption efficiency (AE_{mat}) or fraction of the chemical absorbed by the oral route of exposure, as shown in Equation 2-39. The value for AE_{mat} can be estimated from absorption efficiencies for adults in general. Available data for some chemicals, in particular some inorganic compounds, indicate AE values for ingestion exposures of substantially less than 100 percent. For a few of these chemicals, data also indicate lower AEs for the chemical when ingested in food or in soil than when ingested in water (e.g., cadmium). For a screening level assessment, however, it is reasonable to either assume 100 percent for the AE_{mat} or to use the higher AE_{mat} of the food and water AE_{mat} values if available; hence, a single AE_{mat} parameter is included in Equation 2-39.

Equation 2-39. Daily Maternal Absorbed Intake

$$DAI_{mat} = ADD_{(adult)} \times AE_{mat}$$

where:

DAI_{mat}	=	Daily maternal dose of chemical absorbed from medium *i* (mg/kg-day)
$ADD_{(adult)}$	=	Average daily dose to the mother (mg/kg-day) (calculated by MIRC – see Section 3.3 of this addendum, Equation 2-35)
AE_{mat}	=	Absorption efficiency of the chemical by the oral route of exposure (i.e., chemical-specific fraction of ingested chemical that is absorbed) by the mother (unitless) (value from literature or EPA default – see Section 6.4 of this addendum)

Equation 2-35, used to calculate $ADD_{(adult)}$, is based on many medium-specific ingestion rates that are normalized to body weight. The adult body weights to which the homegrown food ingestion rates are normalized are the body weights of the consumers in the original USDA survey (see Section 6.3.3 of this addendum), which included both males and females. An assumption in the breast-milk exposure pathway is that those ingestion rates also are applicable to nursing mothers. The original data for ingestion rates for soil, drinking water, and fish are on a per person basis for males and females combined. MIRC divides those chemical intakes by an adult body weight for males and females combined as specified by the user (e.g., 71.4 kg mean value) to estimate the ADD normalized to body weight from those sources. If the user finds that those exposure media contribute the majority of the chemical intake for the risk scenario under consideration, the user may use alternative ingestion rates for those media and alternative body weights for nursing women, as described in Section 6.5 of this addendum.

Elimination rates for chemicals often are reported as the half-life of the chemical in the body following a known dose of chemical. Many chemicals exhibit a two-phase elimination process, the first being more rapid than the second. For screening risks for persistent and bioaccumulative chemicals, the half-life of the slower phase of elimination, presumably from non-blood compartments of the body, is the more important of the two. Assuming first-order kinetics, Equation 2-40 is used to convert a measured half-life for elimination of a chemical for adults or non-lactating women to an elimination rate constant (EPA 1998). The equation can be used to estimate any kind of chemical loss rate constant from a measured chemical half-life.

Equation 2-40. Biological Elimination Rate Constant for Chemicals for Non-lactating Women

$$k_{elim} = \frac{\ln 2}{h}$$

where:

k_{elim} = Chemical-specific elimination rate constant for elimination of the chemical for non-lactating women (per day; e.g., via urine, bile to feces, exhalation)

$ln2$ = Natural log of 2 (unitless constant)

h = Chemical-specific biological half-life of chemical for non-lactating women (days)

For chemicals transferred from the body of lactating women to breast milk, the rate of chemical elimination is augmented by the rate of chemical loss via the milk through breast feeding. The total elimination rate for lactating women sometimes is measured directly and reported in the literature. Where direct measurements are not available, and for chemicals that partition predominantly to the lipid-phase of milk, EPA has used Equation 2-41 to estimate the total chemical elimination rate for lactating women, k_{fat_elac} (EPA 1998).

Equation 2-41. Biological Elimination Constant for Lipophilic Chemicals for Lactating Women

$$k_{fat\_elac} = k_{elim} + \frac{IR_{milk} \times f_f \times f_{mbm}}{f_{fm} \times BW_{mat}}$$

where:

k_{fat_elac} = Rate constant for total elimination of chemical during nursing (per day); accounts for both elimination by adults in general and the additional chemical elimination via the lipid phase of milk in nursing women

k_{elim} = Elimination rate constant for chemical from adults, including non-lactating women (per day; e.g., via urine, bile to feces, exhalation; chemical-specific; value from literature or calculated from half-life using Equation 2-40)

IR_{milk} = Infant milk ingestion rate over the duration of nursing (kg/d)

f_f = Fraction of total maternal body burden of chemical that is stored in maternal fat (mg chemical in body fat / mg chemical total in body; value from literature or EPA default)

f_{mbm} = Fraction of fat in breast milk (unitless)

f_{fm} = Fraction of maternal body weight that is fat stores (unitless)

BW_{mat} = Maternal body weight over the entire duration of the mother's exposure to the chemical including during pregnancy and lactation (kg)

Equation 2-41 is based on a model from Smith (1987) and accounts for the additional elimination pathway for lipophilic chemicals via the breast milk fat. The term K_{fat_elac} is estimated by adding an estimate of the first-order elimination constant for breast feeding losses to k_{elim}, which is the chemical-specific total elimination rate constant for non-lactating women. The breast feeding losses are estimated from the infant's intake rate of breast milk (IR_{milk}), the fraction of the total maternal body burden of the chemical that is stored in maternal body fat (f_f), the fraction of the mother's breast milk that consists of fat (lipids) (f_{mbm}), the mother's body weight (BW_{mat}), and the fraction of the mother's weight that is body fat (f_{fm}). In Equation 2-41, the value for the mother's body weight should be specific to women of child-bearing age, as opposed to a body weight value for both males and females that is used to estimate an adult average daily dose and the mother's absorbed daily intake in Equation 2-39. Body weight values for the mother are described in Section 6.5 of this addendum. Smith's (1987) model assumes that the chemical partitions to the lipid-phase of breast milk to the same degree that it partitions into the mother's body fat. For highly lipophilic compounds, losses from breast feeding can be larger than losses by all other pathways (EPA 1998).

3.4.3. Chemical Concentration in Aqueous Phase of Breast Milk

When developing MPE (EPA 1998), EPA also considered models to estimate chemical concentrations in the aqueous phase of breast milk ($C_{aqueous}$). EPA adapted Smith's (1987) steady state concentration model for estimating $C_{milkfat}$ and developed the $C_{aqueous}$ model shown in Equation 2-42 (EPA 1998). Chemicals that would partition to the aqueous phase of human milk include water-soluble chemicals, such as salts of metals, and other hydrophilic chemicals that may be in equilibrium with bound forms of the chemical in different tissues. The $C_{aqueous}$ equation assumes that the chemical concentration in the aqueous phase of milk is directly proportional to the chemical concentration in the mother's blood plasma. The portion of chemical sequestered in red blood cells (e.g., bound to RBC proteins) is assumed to be unavailable for direct transfer to breast milk.

Equation 2-42. Chemical Concentration in Aqueous Phase of Breast Milk

$$C_{aqueous} = \frac{DAI_{mat} \times f_{pl} \times Pc_{bm}}{k_{aq\_elac} \times f_{pm}}$$

where:

$C_{aqueous}$ = Concentration of chemical in aqueous phase of maternal milk (mg/kg)

DAI_{mat} = Daily absorbed maternal chemical dose (mg/kg-day; calculated by Equation 2-39)

f_{pl} = Fraction of chemical in the body (based on absorbed intake) that is in the blood plasma compartment (unitless; value from literature or calculated by Equation 2-43)

Pc_{bm} = Partition coefficient for chemical between the plasma and breast milk in the aqueous phase (unitless); assumed to equal 1.0

k_{aq_elac} = Chemical-specific rate constant for total elimination of chemical in the aqueous phase of milk during nursing (per day; value from literature or calculated in Equation 2-44)

f_{pm} = Fraction of maternal weight that is blood plasma (unitless)

Equation 2-42 is a steady-state concentration model that, like the Equation 2-38 for $C_{milkfat}$, is dependent on the maternal absorbed daily intake (DAI_{mat}). In Equation 2-42, DAI_{mat} is multiplied by the fraction of the absorbed chemical that is circulating in the blood plasma compartment (f_{pl}) and a partitioning coefficient for the chemical between plasma and the aqueous phase of breast milk (Pc_{bm}). For highly water-soluble chemicals that are not transported via special carrier molecules, the chemical is assumed to diffuse passively from the mother's blood serum to the aqueous phase of her milk, in which case Pc_{bm} would equal 1.0. The denominator includes the biological elimination constant for the chemical in the aqueous phase of breast milk in lactating women (k_{aq_elac}) and the fraction of the mother's weight that is plasma (f_{pl}). Because the model assumes steady-state, it does not account for chemical species with long half-lives in the body or for body burden losses due to lactation. These factors are important for highly lipophilic chemicals and for non-lipophilic chemicals such as methyl mercury, lead, and cadmium that partition into body compartments such as red blood cells and bone. While these latter chemicals or forms of these chemicals are water-soluble when free, they have relatively long half-lives because they are in equilibrium with the chemical bound to macromolecules in some tissue compartments. Lead is of particular concern because it can be released from the bone into the blood during lactation, and thus into the breast milk (EPA 2001a). Due to this limitation, the model may over- or underestimate exposure to the infant.

Because Equation 2-42 is based on the relationship between the chemical concentrations in the aqueous phase of breast milk and the blood plasma, a value for the fraction of the chemical in the mother's blood plasma (f_{pl}) is required. Ideally, an empirical value for f_{pl} should be used. If empirical values are not available, f_{pl} can be estimated from Equation 2-43, provided that an empirical value can be found for the fraction of the chemical in the body that is in the mother's whole blood compartment (f_{bl}; EPA 1998).

Equation 2-43. Fraction of Total Chemical in Body in the Blood Plasma Compartment

$$f_{pl} = \frac{f_{bl} \times f_{bp}}{f_{bp} + Pc_{RBC}\left(1 - f_{bp}\right)}$$

where:

f_{pl} = Fraction of chemical in body (based on absorbed intake) that is in the blood plasma compartment (unitless); chemical-specific

f_{bl} = Fraction of chemical in body (based on absorbed intake) in the whole blood compartment (unitless); chemical-specific

f_{bp} = Fraction of whole blood that is plasma (unitless)

$PcRBC$ = Partition coefficient for chemical between red blood cells and plasma (unitless); chemical-specific

If the fraction of the total chemical in the body that is in the whole blood compartment (f_{bl}) is known for a given chemical, then the fraction of that chemical that is in blood plasma depends only on the partition coefficient for the chemical between the red blood cells and the plasma (Pc_{RBC}) and the fraction of whole blood that is plasma (f_{bp}).

Another parameter for which a value is needed to solve Equation 2-42 is the total chemical elimination rate for lactating women for hydrophilic chemicals, k_{aq_elac}. As for k_{fat_elac} for lipophilic chemicals, k_{aq_elac} for hydrophilic chemicals would be equal to k_{elim} plus the loss rate for the chemical in the aqueous phase of breast-milk during lactation. In the case of hydrophilic chemicals, EPA has yet to propose a term for the additional elimination of a chemical in the aqueous phase of milk from breast feeding. Given basic physiological mechanisms, we assume that chemical loss rates via urine are likely to be significantly higher than loss rates from nursing, however. This is because the counter-current anatomy of kidney tubules allows substantial concentration of chemicals in the tubules for elimination in urine compared with the concentration in circulating blood and because of active secretion of some chemicals into urine. Therefore, the best estimation of elimination of hydrophilic chemicals by lactating women is simply k_{elim}, the elimination of the chemical from a non-lactating woman, as shown in Equation 2-40. The extent to which k_{elim} is an underestimate of k_{aq_elac} for a given chemical will determine the extent of health protective bias in k_{aq_elac}.

Equation 2-44. Biological Elimination Rate Constant for Hydrophilic Chemicals

$$k_{aq\_elac} = k_{elim}$$

where:

k_{aq_elac} = Chemical-specific rate constant for total elimination of chemical by lactating women for hydrophilic chemicals (per day)

k_{elim} = Chemical-specific rate constant for total elimination of chemical by non-lactating women (per day; e.g., via urine, bile to feces, exhalation; value from literature or calculated from half-life using Equation 2-40)

3.4.4. Alternative Model for Infant Intake of Methyl Mercury

In this version of MIRC, we were unable to fully parameterize the aqueous model for mercury. In particular, no empirical value could be found for the steady-state fraction of total hydrophilic chemical body burden in the mother that is in the blood plasma (f_{pl}, see Exhibit_Add A2-29). This parameter could be estimated using Equation 2-43 if a suitable chemical-specific fraction of chemical in the body that is in the whole blood (f_{bl}) could be found. However, the value found for f_{bl} is based on a single-dose study and is not considered reliable for use in chronic exposure calculations.

We therefore conducted a literature search to identify existing physiologically based toxicokinetic (PBTK) models of lactational transfer of methylmercury (MeHg) in humans. Most PBTK models that we identified focused on gestational transfer of mercury between mother and fetus, including a PBTK dynamic compartmental model for gestational transfer of MeHg in humans developed by Gearhart *et al*. (1995, 1996), and reparameterized by Clewell *et al*. (1999).

We did find, however, that Byczkowski and Lipscomb (2001) had added a lactational transfer module to the Clewell *et al*. (1999) model. Byczkowski and Lipscomb compared their model's predictions to epidemiological data from mother-nursing-infant pairs obtained following an accidental high-dose poisoning in Iraq (Amin-Zaki *et al*. 1976) and from 34 mother-nursing-infant pairs examined in a low-dose, chronic exposure environment (Fujita and Takabatake 1977). Using data from the Iraq incident, Byczkowski and Lipscomb (2001) found good agreement between their model's predictions and the clinical data relating MeHg concentrations in breast milk to MeHg concentrations in infant's blood with time following the poisoning. To compare their model's predictions to data from chronic exposure to low doses of MeHg, Byczkowski and Lipscomb (2001) simulated MeHg intake for 500 days prior to conception, continued through gestation, and 6.5 months (200 days) of lactation. Their model's predictions were consistent with Fujita and Takabatake's (1977) study, although use of hair/blood partition coefficients based on the results of the 1977 study precluded use of this comparison as model validation. Both the model predictions and the mean values from the 1977 data indicated that the concentration of MeHg in the blood of nursing infants was close to the MeHg concentration in their mothers' blood (approximately 0.025 to 0.027 mg/L, Figure 4 of report). At those blood concentrations, the PBTK model estimated the average maternal intake of MeHg to be 0.68 ± 0.33 (SD) µg/kg-day and the average infant intake of MeHg to be 0.80 ± 0.38 µg/kg-day. Therefore, for purposes of MIRC, the DAI_{inf} of MeHg is estimated to be the same as the maternal intake per unit body weight (Equation 2-42).

Equation 2-45. Calculation of Infant Average Daily Absorbed Dose of Methyl Mercury

$$DAI_{inf\_MeHg} = DAI_{mat\_MeHg}$$

where:

DAI_{inf_MeHg} = Average daily dose of MeHg absorbed by infant from breast milk (mg/kg-day)

DAI_{mat_MeHg} = Average daily dose of methyl mercury absorbed by the mother, predominantly from fish (mg/kg-day)

4. Dose-Response Values Used for Assessment

Chemical dose-response values included in MIRC include carcinogenic potency slope factors for ingestion and non-cancer oral reference doses (RfDs) for chronic exposures. The dose-response values currently used in MIRC for RTR assessments are shown in Exhibit_Add A2-6 For some chemicals, OAQPS has identified dose-response values for use in RTR (EPA 2007a), and these dose-response values are used in MIRC for RTR assessments. In general, OAQPS chose these values based on the following hierarchy of sources: EPA's Integrated Risk Information System (IRIS); the Centers for Disease Control's Agency for Toxic Substances and Disease Registry (ATSDR); and the California Environmental Protection Agency's (CalEPA's) Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database. For PB-HAP chemicals that are currently evaluated in MIRC but do not currently have dose-response values identified by OAQPS for RTR, alternative methods for deriving values were used (see Sections 4.2 and 4.4 of this addendum).

Exhibit_Add A2-6. Oral Dose-response Values Used to Calculate RTR Screening Threshold Emission Rates for PB-HAP Chemicals[a]

Chemical	CAS No.	Cancer Slope Factor		Reference Dose	
		Value (mg/kg-day)$^{-1}$	Source	Value (mg/kg-day)	Source
Inorganics					
Cadmium compounds in food[b]	7440439	not available		1.0E-03	IRIS
Mercury (elemental)	7439976	not available		not available	
Mercuric chloride	7487947	not available		3.0E-04	IRIS
Methyl mercury (MeHg)	22967926	not available		1.0E-04	IRIS
Dioxins					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822469	1.50E+03	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562394	1.50E+03	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673897	1.50E+03	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227286	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,7,8-Hexachlorodibenzofuran	70648269	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653857	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,6,7,8-Hexachlorodibenzofuran	57117449	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408743	6.20E+03	IRIS	not available	
1,2,3,7,8,9-Hexachlorodibenzofuran	72918219	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
2,3,4,6,7,8-Hexachlorodibenzofuran	60851345	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	3268879	4.50E+01	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	39001020	4.50E+01	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321764	1.50E+05	Derived from WHO 2005 TEFs[c]	not available	
1,2,3,7,8-Pentachlorodibenzofuran	57117416	4.50E+03	Derived from WHO 2005 TEFs[c]	not available	
2,3,4,7,8-Pentachlorodibenzofuran	57117314	4.50E+04	Derived from WHO 2005 TEFs[c]	not available	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	1.50E+05	EPA ORD	7E-10	IRIS
2,3,7,8-Tetrachlorodibenzofuran	51207319	1.50E+04	Derived from WHO 2005 TEFs[c]	not available	

Exhibit_Add A2-6. Oral Dose-response Values Used to Calculate RTR Screening Threshold Emission Rates for PB-HAP Chemicals[a]

Chemical	CAS No.	Cancer Slope Factor		Reference Dose	
		Value (mg/kg-day)$^{-1}$	Source	Value (mg/kg-day)	Source
Polycyclic Organic Matter					
1-Methylnaphthalene	90120	5.0E-01	EPA 1999, POM Group 72002[d]	7.0E-02	ATSDR
2-Acetylaminofluorene	53963	1.0E+01	EPA 1999, POM Group 75002[d]	not available	
2-Chloronaphthalene	91587	5.0E-01	EPA 1999, POM Group 72002[d]	not available	
2-Methylnaphthalene	91576	5.0E-01	EPA 1999, POM Group 72002[d]	5.0E-02	ATSDR
3-Methylcholanthrene	56495	2.2E+1	CalEPA	not available	
7,12-Dimethylbenz(a)anthracene	57976	2.5E+02	CalEPA	not available	
Acenaphthene	83329	5.0E-01	EPA 1999, POM Group 72002[d]	6.0E-02	IRIS
Acenaphthylene	208968	5.0E-01	EPA 1999, POM Group 72002[d]	not available	
Anthracene	120127	0	IRIS	3.0E-01	IRIS
Benz(a)anthracene	56553	1.2E+00	CalEPA	not available	
Benzo(a)pyrene	50328	7.3E+00	IRIS	not available	
Benzo(b)fluoranthene	205992	1.2E+00	CalEPA	not available	
Benzo(e)pyrene	192972	5.0E-01	EPA 1999, POM Group 72002[d]	not available	
Benzo(g,h,i)perylene	191242	5.0E-01	EPA 1999, POM Group 72002[d]	not available	
Benzo(k)fluoranthene	207089	1.2E+00	CalEPA	not available	
Carbazole	86748	2.0E-02	HEAST	not available	
Chrysene	218019	1.2E-01	CalEPA	not available	
Dibenzo(a,h)anthracene	53703	4.1E+00	CalEPA	not available	
Dibenzo(a,i)pyrene	189559	1.2E+03	CalEPA	not available	
Dibenzo(a,j)acridine	224420	1.2E+00	CalEPA	not available	
Fluoranthene	206440	5.0E-01	EPA 1999, POM Group 72002[d]	4.0E-02	IRIS
Fluorene	86737	5.0E-01	EPA 1999, POM Group 72002[d]	4.0E-02	IRIS
Indeno(1,2,3-c,d)pyrene	193395	1.2E+00	CalEPA	not available	
PAH, total	234	5.0E-01	EPA 1999, POM Group 71002[d]	not available	
Perylene	198550	5.0E-01	EPA 1999, POM Group 72002[d]	not available	
Phenanthrene	85018	0	IRIS	0	IRIS
Polycyclic Organic Matter	246	5.0E-01	EPA 1999, POM Group 71002[d]	not available	

Exhibit_Add A2-6. Oral Dose-response Values Used to Calculate RTR Screening Threshold Emission Rates for PB-HAP Chemicals[a]

Chemical	CAS No.	Cancer Slope Factor		Reference Dose	
		Value (mg/kg-day)$^{-1}$	Source	Value (mg/kg-day)	Source
Pyrene	129000	0	IRIS	3.0E-02	IRIS
Retene	483658	5.0E-01	EPA 1999, POM Group 72002[d]	not available	

ATSDR = Agency for Toxic Substances and Disease Registry, IRIS = Integrated Risk Information System, EPA OAQPS = EPA's Office of Air Quality Planning and Standards, CalEPA = California EPA, EPA ORD = EPA's Office of Research and Development, HEAST = EPA Health Effects Assessment Tables, TEF = toxic equivalency factor

[a] Values as of June 2012; these values may be updated as newer ones become available.

[b] There are RfDs for both water ingestion and food ingestion for cadmium – the RfD for food is used.

[c] Dose-response values for these dioxin congeners are not available from EPA sources. CSFs for these congeners were derived as discussed in Section 4.2 of this addendum.

[d] The method to assign oral cancer slope factors to polycyclic organic matter (POM) without CSFs available from other EPA sources is the same as that used in the 1999 National Air Toxics Assessment (EPA 1999). A complete description of the methodology is available at: http://www.epa.gov/ttn/atw/nata1999/99pdfs/pomapproachjan.pdf and is summarized in Section 4.4 of this addendum.

4.1. Cadmium

EPA has developed two chronic RfDs for cadmium (Cd), one for food and one for water, based on data in IRIS indicating a lower absorption efficiency of cadmium from food than from water. The default RfD set in MIRC is the higher RfD for Cd compounds in food (as described in Section A.2.3, the drinking water exposure pathway is not modeled in the screening scenario because the likelihood that humans would use a lake as a drinking water source is assumed to be low). Users of MIRC who assess exposures via drinking water would need to use the RfD for Cd compounds in water (i.e., 5.0E-04 mg/kg-day).

4.2. Dioxins (2,3,7,8-TCDD)

For chemicals for which the critical health effect is developmental, either *in utero* and/or during the first months or years of life, the exposure duration and timing of exposure for comparison with the RfD (or comparable values) require special consideration. The most sensitive health endpoints for both mercury and 2,3,7,8-TCDD are neurological effects during development that have long-lasting effects on learning and social behaviors. To ensure a protective risk characterization for these chemicals, it is important to use the shortest exposure duration appropriate, at the appropriate life stage, for comparison with the toxicity reference values. This approach avoids "dilution" of an estimated average ADD that would result from averaging the lower daily chemical intake rates normalized to body weight for older children and adults with the potentially higher daily intake rates of infants over a longer exposure averaging period.

The convention for assessing risk from mixtures of dioxins is by application of toxic equivalency factors (TEFs) to dioxin concentrations, which are then expressed as toxic equivalents (TEQs). Of the dioxin congeners, 2,3,7,8-TCDD is the most widely studied and considered to be one of the most toxic congeners. It is therefore assigned a TEF of 1, with the other dioxin congener TEQ concentrations scaled relative to 2,3,7,8-TCDD concentrations on the basis of toxicity. For risk assessment of dioxins for RTR (with one exception), the World Health Organization (WHO) 2005 TEFs presented in Exhibit_Add A2-7 were used to derive the CSFs (shown in Exhibit_Add A2-6) for dioxin congeners without available EPA dose response values. The one exception is 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin, whose TEF was based on data from IRIS.

Exhibit_Add A2-7. WHO 2005 Toxic Equivalency Factors (TEFs) for Dioxin Congeners

Dioxin Congener	CAS No.	WHO 2005 Toxic Equivalency Factor[a]
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822469	0.01
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562394	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673897	0.01
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227286	0.1
1,2,3,4,7,8-Hexachlorodibenzofuran	70648269	0.1
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653857	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	57117449	0.1
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin[b]	19408743	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	72918219	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	60851345	0.1
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	3268879	3E-04
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	39001020	3E-04
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321764	1
1,2,3,7,8-Pentachlorodibenzofuran	57117416	0.03
2,3,4,7,8-Pentachlorodibenzofuran	57117314	0.3
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	1
2,3,7,8-Tetrachlorodibenzofuran	51207319	0.1

[a] Source: van den Berg et al. 2006, with the one exception in the next footnote.

[b] For 1,2,3,7,8,9-HexCDD, OAQPS identified an oral cancer slope factor from IRIS. For the purposes of these multipathway analyses, EPA uses the TEF derived from this IRIS oral CSF (6200 1/mg/kd/d, equaling a TEF of 0.041) rather than the WHO 2005 TEF of 0.1.

4.3. Mercury

The RfD applies to the pregnant mother as well as young children. EPA has not specified the minimum exposure duration at the RfD level of exposure that is appropriate to use in characterizing risk; we assume 10 years for women of childbearing age and 1 year for infants. We note that human exposures to MeHg are primarily through the consumption of fish and shellfish (EPA 2001b). EPA found that, on average, approximately 76 percent of the exposure to MeHg for women of childbearing age could be attributed to ingestion of mercury in freshwater and estuarine fish and shellfish, with the remaining 24 percent derived from marine fish and shellfish. Other sources accounted for less than 0.06 percent of total exposures (EPA 2001b).

4.4. Polycyclic Organic Matter

Dose-response values for some of the POM species that are included in the screening analysis were not identified by OAQPS; for these POM species, an alternative methodology for identifying CSFs was needed. Previously, for risk assessment of inhalation exposures to polycyclic organic matter (POM) for EPA's National-Scale Air Toxics Assessments (NATA) and for RTR, OAQPS developed an approach for characterizing risks associated with the individual POM species and POM groups reported in the National Emissions Inventory (NEI). Individual POMs were assigned to one of eight POM groups according to cancer potencies derived by EPA for IRIS and by CalEPA, and based on assumptions regarding relative carcinogenicity. OAQPS then estimated an inhalation CSF for each POM group. The same approach was used to derive oral CSFs for POMs without available CSFs. Each POM group (with all its member

POM species reported in NEI, not just the species currently evaluated in this analysis) and the corresponding CSFs using this methodology are presented in Exhibit_Add A2-8. These group CSFs are used only when OAQPS has not, for the purposes of RTR, identified a CSF specific to the individual chemical.

Exhibit_Add A2-8. Oral Dose-response Values for Polycyclic Organic Matter (POM) Groups[a]

Individual POM or POM Group	CAS No.	Cancer Slope Factor[b] (mg/kg-day)$^{-1}$
POM Group 71002		
Benz(a)anthracene/chrysene (7-PAH)	103	0.5
Total PAH	234	
Polycyclic organic matter	246	
16-PAH	40	
16-PAH–7-PAH	75040	
POM Group 72002		
Anthracene	120127	0.5
Pyrene	129000	
Benzo(g,h,i) perylene	191242	
Benzo(e)pyrene	192972	
Benzo(c)phenanthrene	195197	
Perylene	198550	
Benzo(g,h,i)fluoranthene	203123	
Benzo(a)fluoranthene	203338	
Fluoranthene	206440	
Acenaphthylene	208968	
1-Methylpyrene	2381217	
12-Methylbenz(a)anthracene	2422794	
Methylbenzopyrenes	247	
Methylchrysene	248	
Methylanthracene	26914181	
Benzofluoranthenes	56832736	
9-Methylbenz(a)anthracene	779022	
1-Methylphenanthrene	832699	
Acenaphthene	83329	
Phenanthrene	85018	
Fluorene	86737	
2-Methylnaphthalene	91576	
2-Chloronaphthalene	91587	
POM Group 73002		
7,12-Dimethylbenz(a)anthracene	57976	1000
POM Group 74002		
Dibenzo(a,i)pyrene	189559	100
Dibenzo(a,h)pyrene	189640	

Exhibit_Add A2-8. Oral Dose-response Values for Polycyclic Organic Matter (POM) Groups[a]

Individual POM or POM Group	CAS No.	Cancer Slope Factor[b] (mg/kg-day)$^{-1}$
POM Group 75002		
3-Methylcholanthrene	56495	10
Dibenzo(a,e)pyrene	192654	
5-Methylchrysene	3697243	
Benzo(a)pyrene	**50328**	
Dibenzo(a,h)anthracene	53703	
POM Group 76002		
Benzo(b+k)fluoranthene	102	1
Indeno(1,2,3-c,d)pyrene	193395	
Benzo(j)fluoranthene	205823	
Benzo(b)fluoranthene	205992	
Benzo(k)fluoranthene	207089	
Dibenzo(a,j)acridine	224420	
Benz(a)anthracene	56553	
POM Group 77002		
Chrysene	218019	0.1
POM Group 78002		
7-PAH	75	0.5

[a] These group CSFs are used only when OAQPS has not, for the purposes of RTR, identified a CSF specific to the individual chemical.

[b] The method to assign oral cancer slope factors to POM groups was the same as that used in the 1999 National Air Toxics Assessment (EPA 1999). A complete description of the methodology is available at: http://www.epa.gov/ttn/atw/nata1999/99pdfs/pomapproachjan.pdf.

5. Risk Estimation

For persistent and bioaccumulative hazardous air pollutants (PB-HAPs), risks from inhalation of a chemical directly from air generally will be negligible compared with risks from ingestion of the chemical from foodstuffs grown in an area subject to air deposition of the chemical. Risk characterization for carcinogens with a linear mode of action at low doses is described in Section 5.1 of this addendum. Risk characterization for chemicals likely to exhibit a threshold for response (e.g., non-cancer hazards) is described in Section 5.2.

5.1. Cancer Risks

The estimated risk of developing cancer from exposure to a chemical from a specified source is characterized as the excess lifetime cancer risk (ELCR). The ELCR represents the incremental probability of an individual developing cancer over a lifetime as a result of lifetime exposure to the chemical. For a known or suspected carcinogen with a low-dose linear mode of action, the estimated ELCR is calculated as the product of the lifetime average daily dose (LADD) and the cancer slope factor (CSF):

Equation 2-46. Calculation of Excess Lifetime Cancer Risk

$$ELCR = LADD \times CSF$$

where:

$ELCR$ = Estimated excess lifetime cancer risk from a chemical summed across all exposure pathways and media (unitless)

$LADD$ = Lifetime average total daily dose from all exposure pathways and media (mg/kg-day)

CSF = Oral carcinogenic potency slope factor for chemical (per mg/kg-day)

As described in Section 3.3 of this addendum, the *LADD* (in mg/kg-day) for a chemical is calculated to reflect age-related differences in exposure rates that are experienced by a hypothetical individual throughout his or her lifetime of exposure. The total chemical intake is normalized to a lifetime, which for the purposes of this assessment is assumed to be 70 years.

EPA considers the possibility that children might be more sensitive than adults to toxic chemicals, including chemical carcinogens (EPA 2005b,c). Where data allow, EPA recommends development of lifestage-specific cancer potency CSFs. To date, EPA has developed a separate slope factor for early lifestage exposure for only one chemical (i.e., 1,1,1-trichloroethane; EPA 2007b), and current data availability for most chemicals preclude this approach. EPA has, therefore, examined options for default adjustments of the CSF to protect children. To date, the only mode of action (MOA) for carcinogenesis for which EPA has adequate data to develop a reasonable quantitative default approach is mutagenesis (EPA 2005b,c). For carcinogens with a mutagenic MOA for cancer, EPA concluded that the carcinogenic potency of a chemical may be approximately tenfold greater for the first 2 years of life (i.e., birth up to second birthday) and threefold greater for the next 14 years of life (i.e., ages 2 through 15) than for adults (EPA 2005c). These conclusions are represented by age-dependent adjustment factors (ADAFs) of 10, 3, and 1 for the first two lifestages and for adults, respectively.

These three lifestages do not match the age categories for the home-grown food ingestion rates, the age categories in MIRC. As a consequence, ADAFs for the age groups in MIRC are adapted as time-weighted average values as follows:

$$ADAF_{(<1)} = 10$$

$$ADAF_{(1\text{-}2)} = \frac{(10 \times 1\,\text{yr}) + (3 \times 1\,\text{yr})}{2} = 6.5$$

$$ADAF_{(3\text{-}5)} = 3$$

$$ADAF_{(6\text{-}11)} = 3$$

$$ADAF_{(12\text{-}19)} = \frac{(3 \times 4\ \text{yrs}) + (1 \times 4\ \text{yrs})}{8} = 2$$

$$ADAF_{(adult)} = 1$$

To estimate total lifetime risk from a lifetime of exposure to such a chemical, EPA recommends estimating the cancer risk for each of the three lifestages separately and then adding the risks for *i* = 1 to 6 age groups.

Equations 2-47 to 2-53. Lifetime Cancer Risk: Chemicals with a Mutagenic MOA for Cancer

Equation 2-47. $Risk_{(<1)} = ADD_{(0-<1)} \times 10 \times CSF \times (1\ yr/70\ yr)$

Equation 2-48. $Risk_{(1-2)} = ADD_{(1-2)} \times 6.5 \times CSF \times (2\ yr/70\ yr)$

Equation 2-49. $Risk_{(3-5)} = ADD_{(3-5)} \times 3 \times CSF \times (3\ yr/70\ yr)$

Equation 2-50. $Risk_{(6-11)} = ADD_{(6-11)} \times 3 \times CSF \times (6\ yr/70\ yr)$

Equation 2-51. $Risk_{(12-19)} = ADD_{(12-19)} \times 2 \times CSF \times (8\ yr/70\ yr)$

Equation 2-52. $Risk_{(adult)} = ADD_{(adult)} \times 1 \times CSF \times (50\ yr/70\ yr)$

Equation 2-53. $\boldsymbol{ELCR} = \sum_{i=1}^{n} Risk_{(i)}$

In other words, Equation 2-53 indicates that the total excess lifetime cancer risk (ELCR) equals the sum of the age-group-specific risks estimated by Equations 2-47 through Equation 2-52, where:

$Risk_{(<1)}$ = Risk from chemical ingestion in first year of life
$Risk_{(1\text{-}2)}$ = Risk from chemical ingestion from first birthday through age 2 years
$Risk_{(3\text{-}5)}$ = Risk from chemical ingestion from age 3 through 5 years of age
$Risk_{(6\text{-}11)}$ = Risk from chemical ingestion from age 6 through 11 years of age
$Risk_{(12\text{-}19)}$ = Risk from chemical ingestion from age 12 through 19 years of age
$Risk_{(adult)}$ = Risk from chemical ingestion from age 20 to 70 years age
$ADD_{(<1)}$ = Average daily dose for infants under one year of age (mg/kg-day)
$ADD_{(1\text{-}2)}$ = Average daily dose from first birthday through age 2 years of age (mg/kg-day)
$ADD_{(3\text{-}5)}$ = Average daily dose from age 3 through 5 years of age (mg/kg-day)
$ADD_{(6\text{-}11)}$ = Average daily dose from age 6 through 11 years of age (mg/kg-day)
$ADD_{(12\text{-}19)}$ = Average daily dose from age 12 through 19 years of age (mg/kg-day)
$ADD_{(adult)}$ = Average daily dose for adults age 20 to 70 years of age (mg/kg-day)
CSF = Oral carcinogenic potency slope factor for chemical (per mg/kg-day)
$Risk_{(i)}$ = Risk from chemical ingestion for the i^{th} age group
$ELCR$ = Total extra lifetime cancer risk (incremental or extra risk)
n = Number of age groups (i.e., 6)

5.2. Non-cancer Hazard Quotients

Non-cancer risks are presented as hazard quotients (HQs), that is, the ratio of the estimated daily intake (i.e., ADD) to the reference dose (e.g., chronic RfD). If the HQ for a chemical is equal to or less than 1, EPA believes that there is no appreciable risk that non-cancer health effects will occur. If the HQ is greater than 1 then there is at least some possibility for an adverse health effect. The larger the HQ value, the more likely it is that an adverse health effect may occur.

5.2.1. Hazard Quotients for Chemicals with a Chronic RfD

For chemicals with a chronic RfD, MIRC calculates an HQ for each age group separately using Equation 2-54 to indicate the potential for adverse health effects associated with chronic exposure via ingestion pathways. The HQ is the ratio of a long-term, daily average exposure normalized to the receptor's body weight (i.e., ADD) to the RfD for that chemical. HQs are threshold effects and are not additive across age groups.

Equation 2-54. Hazard Quotient for Chemicals with a Chronic RfD

$$HQ = \frac{ADD}{RfD}$$

where:

HQ = Hazard quotient for chemical (unitless)

ADD = Average daily ingested dose of chemical (mg/kg-day) from all food types and ingested media for the age group

RfD = Chronic oral reference dose for chemical (mg/kg-day)

5.2.2. Hazard Quotients for Chemicals with RfD Based on Developmental Effects

For chemicals for which the toxicity reference value is an RfD based on developmental effects, a shorter exposure duration (ED) and averaging time (AT) may be required. For this type of chemical (e.g., methylmercury, 2,3,7,8-TCDD), the appropriate ED/AT and sensitive lifestage for exposure may need to be estimated from the information provided in the critical developmental study(ies) from which the RfD was derived (e.g., in consultation with the RfD documentation in EPA’s IRIS or in a toxicological profile developed for the chemical). For screening-level risk assessments, however, a health protective approach is to compare the highest ADD from among the child age categories provided in MIRC to the RfD, as is done for all PB-HAPs. This approach ensures that the highest exposure from among the various age groups evaluated is taken into consideration, regardless of which age group might be most relevant to the health effect of interest (i.e., the age group on which the RfD is based).

5.2.3. Hazard Index for Chemicals with RfDs

When conducting screening-level assessments for multiple chemicals, it can be informative to calculate a hazard index (HI) for toxicologically similar chemicals (EPA 2000). The HI is the sum of HQs across chemicals (not age groups) as shown in Equation 2-55. As with the HQ, if the HI value is less than 1, adverse health effects are not expected for that suite of chemicals. If the screening level HI exceeds 1, however, the risk assessor may in some instances, evaluate the assumptions of the screening-level assessment to determine if more realistic local values are available for parameters that drive risk. In addition, the risk assessor may need to examine the mode of action (MOA) and target organ(s) for the chemicals with the highest HQs to develop an appropriate approach to assessing their potential joint action.

Equation 2-55. Hazard Index Calculation

$$HI = HQ_1 + HQ_2 \ldots\ HQ_n$$

where:

HI = Hazard index (unitless)
HQ_1 = Hazard Quotient for chemical 1 (unitless)
HQ_2 = Hazard Quotient for chemical 2 (unitless)
HQ_n = Hazard Quotient for chemical *n* (unitless)

The HI approach can be appropriate for chemicals with the same MOA and same target organ; however, MOA often is difficult to determine. An HI usually is "developed for each exposure route of interest, and for a single toxic effect or for toxicity to a single target organ" (EPA 2000; p 79). If a receptor is exposed to multiple chemicals that affect different target organs or that operate by different MOAs, and if more than one HQ is close to 1, the risk assessor in some circumstances, may consider whether chemical interactions play a role in chemical toxicity (EPA 2000). Exposures to more than one chemical can result in a greater or lesser toxic response than might be predicted on the basis of one or the other chemical acting alone (toxicologically independent) or acting in concert (toxicologically similar chemicals). Users are referred to EPA's *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures* for approaches to assessing the potential for adverse health effects from exposure to multiple chemicals (EPA 2000).

Note that users of MIRC are responsible for determining how to interpret HQs for multiple chemicals.

6. Model Input Options

This section describes the input options currently included in MIRC. Required user inputs for environmental media concentrations and air deposition rates, such as those predicted by (output of) TRIM.FaTE, are described in Section 6.1 of this addendum. Values for farm-food-chain (FFC) parameters for specific types of produce and animal products are discussed in Section 6.2. Options for parameterizing receptor characteristics are described in Section 6.3, including age-group-specific values for body weight, water ingestion, and food ingestion by food type. Options for other exposure parameter values in MIRC, such as exposure frequency and loss of chemical during food preparation and cooking, are provided in Section 6.4.

Where values for chemical-specific parameters are presented, values are presented only for PB-HAP chemicals currently evaluated using the TRIM-based RTR screening scenario. The database included with MIRC contains chemical-specific parameter values for a large number of chemicals (more than 500), because all of the chemical-specific input data compiled by EPA for use in HHRAP were uploaded into MIRC. However, only chemicals that are PB-HAPs evaluated for RTR are discussed in this document (see Sections 2.1 and A.2.2), and the HHRAP inputs provided for other chemicals have not been reviewed or verified. The data presented in this chapter were reviewed and used to develop the set of modeling defaults used to calculate screening threshold emission rates for RTR. Note that the default values used to estimate RTR screening thresholds, and the justification for selecting a specific value from the data sets described in this chapter, are discussed in Chapter 7.

6.1. Environmental Concentrations

As noted in Section 2 of this addendum, MIRC is intended to estimate exposures and risks to self-sufficient farming and fishing families from ingestion of FFC media in an area of airborne chemical deposition. The tool analyzes one exposure scenario at a time (e.g., adult farmer exposed to dioxin from ingestion of beef); therefore, it is best used to evaluate a maximally exposed individual (MEI) or family when MIRC is used to screen for possible risks.

The following values specific to the air pollutant of concern are required inputs to MIRC:

- a single air concentration (in g/m^3);
- the fraction of chemical in the air that is in the vapor phase;
- air-to-surface deposition rates for both vapor- and particle-phase chemical in the air (in g/m^2-yr);
- two fish tissue concentrations, one each for forage and game fish (i.e., fish in TL 3 and TL 4) (in mg/kg wet weight);
- concentrations in drinking water (in g/L); and
- four chemical concentrations in soil (in µg/g dry weight), one each for:
  - surface soil in produce growing area,
  - surface soil where livestock feed,
  - root-zone soil in produce growing area, and
  - root-zone soil in livestock feed growing area.

The MIRC software is configured to estimate ingestion exposures via drinking water for a specified chemical concentration in the drinking water source (e.g., groundwater well). However, no exposure via drinking water is assumed to occur when calculating the Tier 1 screening thresholds. As discussed in Section A.2.3, the drinking water exposure pathway is not modeled for the scenario developed for the Tier 1 analysis because the likelihood that humans would use a lake as a drinking water source is assumed to be low.

The user must provide the inputs listed above; no default values are included for these parameters in MIRC. Media concentrations output by TRIM.FaTE can be entered into the tool manually from model output files or can be imported directly from the TRIM.FaTE output files. For RTR evaluations, a tool to facilitate this process was developed using a Microsoft® Excel™ routine written in Visual Basic.

6.2. Farm-Food-Chain Parameter Values

Using the chemical information specified in Section 6.1 above as inputs, MIRC calculates chemical concentrations in foods that are commonly grown or raised on family farms: exposed and protected fruits; exposed and protected vegetables; root vegetables; beef; total dairy products; pork; and poultry and eggs.

6.2.1. List of Farm-Food-Chain (FFC) Parameters

MIRC estimates chemical concentrations in the produce identified above using algorithms from HHRAP (EPA 2005a) as described in Section 3.2 of this addendum. Parameter values required for these HHRAP algorithms, including chemical-specific media transfer factors (e.g., soil-to-plant transfer coefficients) and plant- and animal-specific properties (e.g., plant interception fraction, quantity of forage consumed by cattle), are included in tables in MIRC. As described in Section 7 of this addendum, the HHRAP-recommended parameter values are the default values in MIRC; however, these and other inputs in MIRC can be revised as needed.   describes the parameters that are included in the algorithms used to estimate chemical concentrations in the farm food categories. The parameter names and symbols are referenced in this section for plants/produce and animal products.

Exhibit_Add A2-9. MIRC Parameters Used to Estimate Chemical Concentrations in Farm Foods

Parameter	Description	Units
Plants/Produce		
$Br_{AG\text{-}produce\text{-}DW(i)}$	Chemical-specific plant/soil chemical bioconcentration factor for edible portion of aboveground produce type i, exposed or protected	Unitless (g soil DW / g produce DW)
$Bv_{AG(i)}$	Chemical-specific air-to-plant biotransfer factor for aboveground produce type i for vapor-phase chemical in air	Unitless ([mg chemical / g DW plant] / [mg chemical / g air])
Fw	Fraction of wet deposition that adheres to plant surfaces; 0.2 for anions, 0.6 for cations and most organics	Unitless
Kds	Chemical-specific soil/water partition coefficient	L soil pore water / kg soil DW
$kp_{(i)}$	Plant-specific surface loss coefficient for aboveground exposed produce and animal forage and silage	yr^{-1}
$MAF_{(i)}$	Moisture adjustment factor for aboveground produce type *i* to convert the chemical concentration estimated for dry-weight produce to the corresponding chemical concentration for full-weight fresh produce	Percent water
RCF	Chemical-specific root concentration factor for tubers and root produce on a wet-weight (WW) basis	L soil pore water/ kg root WW
$Rp_{(i)}$	Plant-specific interception fraction for the edible portion of aboveground exposed produce or animal forage and silage	Unitless
$Tp_{(i)}$	Length of plant exposure to deposition per harvest of the edible portion of aboveground exposed produce or animal forage and silage	Year
$VG_{AG(i)}$	Empirical correction factor for aboveground exposed produce type i to address possible overestimate of the diffusive transfer of chemical from the outside to the inside of bulky produce, such as fruit	Unitless
$VG_{rootveg}$	Empirical correction factor for belowground produce (i.e., tuber or root vegetable) to account for possible overestimate of the diffusive transfer of chemicals from the outside to the inside of bulky tubers or roots (based on carrots and potatoes)	Unitless
$Yp_{(i)}$	Plant-specific yield or standing crop biomass of the edible portion of produce or animal feed	kg produce DW/m^2
Animal Products		
Bs	Soil bioavailability factor for livestock	Unitless
MF	Chemical-specific mammalian metabolism factor that accounts for endogenous degradation of the chemical	Unitless

Exhibit_Add A2-9. MIRC Parameters Used to Estimate Chemical Concentrations in Farm Foods

Parameter	Description	Units
$Ba_{(beef)}$	Chemical-specific biotransfer factor for chemical in diet of cow to chemical in beef on a fresh-wet (FW; equivalent to WW) basis	mg chemical/kg FW tissue/mg chemical/day or day/kg FW tissue
$Ba_{(dairy)}$	Biotransfer factor in dairy	day/kg FW tissue
$Ba_{(pork)}$	Biotransfer factor in pork	day/kg FW tissue
$Ba_{(poultry)}$	Biotransfer factor in poultry	day/kg FW tissue
$Ba_{(eggs)}$	Biotransfer factor in eggs	day/kg FW tissue
$Qs_{(m)}$	Quantity of soil eaten by animal type m each day	kg/day
$Qp_{(i,m)}$	Quantity of plant feed type i consumed per animal type m each day	kg/day

Source: EPA Source: EPA 2005a
DW = dry weight; FW = fresh weight; WW = wet weight

6.2.2. Produce Parameter Values

Exhibit_Add A2-10 and Exhibit_Add A2-11 provide the chemical-specific input values that are the current defaults for produce FFC food types in MIRC. Exhibit_Add A2-12 presents additional non-chemical-specific input values for parameters used in the algorithms that calculate chemical concentrations in produce. Unless otherwise noted, the default parameter values were obtained from HHRAP. Options for other parameter values are not included in MIRC at this time; however, the user can overwrite values if appropriate. Refer to HHRAP (EPA 2005a, Chapter 5 and associated appendices) for detailed descriptions of these parameters and documentation of input values.

Exhibit_Add A2-10. Chemical-Specific Inputs for Produce Parameters for Chemicals Included in MIRC

Chemical	Fraction of Wet Deposition (*Fw*) (unitless)[a]	Root Concentration Factor (*RCF*) (belowground) (L/kg)[b]	Soil-Water Partition Coefficient (*Kds*) (L/kg)[c]	Chemical Air-to-Plant Biotransfer Factor ($Bv_{AG(i)}$) (unitless)[d]
Inorganics				
Cadmium compounds	0.6	NA	7.5E+01	NA [e]
Mercury (elemental)	0.6	NA	1.0E+03	0 [f]
Mercuric chloride	0.6	NA	5.8E+04	1.8E+03
Methyl mercury	0.6	NA	7.0E+03	0 [f]
PAHs				
2-Methylnaphthalene	0.6	2.2E+02	5.0E+01	1.4E+00
7,12-Dimethylbenz(a)anthracene	0.6	6.8E+03	4.0E+03	4.2E+04
Acenaphthene	0.6	2.4E+02	3.9E+01	4.6E+00
Acenaphthylene	0.6	2.8E+02	6.8E+01	8.1E+00
Benz(a)anthracene	0.6	6.7E+03	2.9E+03	6.8E+03
Benzo(a)pyrene	0.6	9.2E+03	7.8E+03	1.7E+05

Exhibit_Add A2-10. Chemical-Specific Inputs for Produce Parameters for Chemicals Included in MIRC

Chemical	Fraction of Wet Deposition (*Fw*) (unitless)[a]	Root Concentration Factor (*RCF*) (belowground) (L/kg)[b]	Soil-Water Partition Coefficient (*Kds*) (L/kg)[c]	Chemical Air-to-Plant Biotransfer Factor ($Bv_{AG(i)}$) (unitless)[d]
Benzo(b)fluoranthene	0.6	6.6E+03	3.8E+03	1.7E+05
Benzo(g,h,i)perylene	0.6	3.0E+04	2.6E+04	2.3E+06
Benzo(k)fluoranthene	0.6	8.7E+03	5.5E+03	2.8E+05
Chrysene	0.6	6.0E+03	3.4E+03	1.4E+04
Dibenz(a,h)anthracene	0.6	2.3E+04	1.4E+04	6.2E+06
Fluoranthene	0.6	2.2E+03	3.9E+02	9.0E+02
Fluorene	0.6	3.8E+02	6.2E+01	1.6E+01
Indeno(1,2,3-cd)pyrene	0.6	3.5E+04	3.2E+04	2.8E+06
Dioxins				
OctaCDD, 1,2,3,4,6,7,8,9-	0.6	4.8E+05	7.8E+05	2.4E+06
OctaCDF, 1,2,3,4,6,7,8,9-	0.6	3.4E+05	4.9E+05	2.3E+06
HeptaCDD, 1,2,3,4,6,7,8-	0.6	3.4E+05	4.9E+05	9.1E+05
HeptaCDF, 1,2,3,4,6,7,8-	0.6	1.2E+05	1.2E+05	8.3E+05
HeptaCDF, 1,2,3,4,7,8,9-	0.6	4.8E+04	3.9E+04	8.3E+05
HexaCDD, 1,2,3,4,7,8-	0.6	2.4E+05	3.1E+05	5.2E+05
HexaCDF, 1,2,3,4,7,8-	0.6	5.7E+04	4.9E+04	1.6E+05
HexaCDD, 1,2,3,6,7,8-	0.6	4.9E+05	8.0E+05	5.2E+05
HexaCDF, 1,2,3,6,7,8-	0.6	2.9E+05	4.1E+05	1.6E+05
HexaCDD, 1,2,3,7,8,9 -	0.6	4.9E+05	8.0E+05	5.2E+05
HexaCDF, 1,2,3,7,8,9-	0.6	1.6E+05	1.9E+05	1.6E+05
HexaCDF, 2,3,4,6,7,8-	0.6	2.9E+05	4.1E+05	1.6E+05
PentaCDD, 1,2,3,7,8-	0.6	9.2E+04	9.2E+04	2.4E+05
PentaCDF, 1,2,3,7,8-	0.6	3.9E+04	3.0E+04	9.8E+04
PentaCDF, 2,3,4,7,8-	0.6	2.3E+04	1.6E+04	9.8E+04

Exhibit_Add A2-10. Chemical-Specific Inputs for Produce Parameters for Chemicals Included in MIRC

Chemical	Fraction of Wet Deposition (Fw) (unitless)[a]	Root Concentration Factor (RCF) (belowground) (L/kg)[b]	Soil-Water Partition Coefficient (Kds) (L/kg)[c]	Chemical Air-to-Plant Biotransfer Factor ($Bv_{AG(i)}$) (unitless)[d]
TetraCDD, 2,3,7,8-	0.6	4.0E+04	3.1E+04	6.6E+04
TetraCDF, 2,3,7,8-	0.6	1.2E+04	6.2E+03	4.6E+04

Source: EPA 2005a. NA = not applicable.

[a] 6E-01 is the value for cations and most organic chemicals. As described in HHRAP (EPA 2005a), Appendix B (available at http://www.epa.gov/osw/hazard/tsd/td/combust/finalmact/ssra/05hhrapapb.pdf), EPA estimated this value (EPA 1994a, 1995a) from a study by Hoffman et al. (1992) in which soluble gamma-emitting radionuclides and insoluble particles tagged with gamma-emitting radionuclides were deposited onto pasture grass via simulated rain. Note that the values developed experimentally for pasture grass may not accurately represent all aboveground produce-specific values. Also note that values based on the behavior of insoluble particles tagged with radionuclides may not accurately represent the behavior of organic compounds under site-specific conditions.

[b] For nonionic organic chemicals, as described in HHRAP (EPA 2005a), Appendix A (available at http://www.epa.gov/osw/hazard/tsd/td/combust/finalmact/ssra/05hhrapapa.pdf), RCF is used to calculate the below-ground transfer of contaminants from soil to a root vegetable on a wet-weight basis as shown in Equation 2-6. EPA estimated chemical-specific values for RCF from empirical regression equations developed by Briggs et al. (1982) based on their experiments measuring uptake of compounds into barley roots from growth solution. Briggs' regression equations allow calculation of RCF values from log Kow. For metals and mercuric compounds, empirical values for soil to root vegetable transfer on a dry-weight basis are available in the literature, thus the RCF was not needed.

[c] As discussed in HHRAP (EPA 2005a), Appendix A, Kds describes the partitioning of a compound between soil pore-water and soil particles and strongly influences the release and movement of a compound into the subsurface soils and underlying aquifer. Kds values for mercuric compounds were obtained from EPA (1997b). Kds for cadmium compounds were obtained from EPA 1996. For all PAHs and dioxins, Kds was calculated by multiplying Koc times the screening scenario's fraction organic carbon content (0.008). Empirical information for Koc was available for acenaphthene, benz(a)anthracene, benzo(a)pyrene, dibenz(a,h)anthracene, fluoranthene, and fluorene in USEAP 1996. For all other organic compounds, the Koc was calculated using the correlation equations presented in USEAP 2005a.

[d] As discussed in HHRAP (EPA 2005a), Appendix A, the value for mercuric chloride was obtained from EPA 1997b. BvAG(i) values for PAHs were calculated using the correlation equation derived for azalea leaves as cited in Bacci et al. (1992), then reducing this value by a factor of 100, as suggested by Lorber (1995), who concluded that the Bacci factor reduced by a factor of 100 was similar to his own observations in various studies. The values for dioxins were obtained from Lorber and Pinsky (2000).

[e] It is assumed that metals, with the exception of vapor-phase elemental mercury, do not transfer significantly from air into leaves.

fSpeciation and fate and transport of mercury from emissions suggest that BvAG(i) values for elemental and methyl mercury are likely to be zero (EPA 2005a).

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Inorganics				
Cadmium compounds	Exp. Fruit	1.3E-01	-	1.0E+00
	Exp. Veg.	1.3E-01	-	1.0E+00
	Forage	3.6E-01	-	1.0E+00
	Grain	6.2E-02	-	-
	Prot. Fruit	1.3E-01	-	-
	Prot. Veg.	1.3E-01	-	-
	Root	6.4E-02	1.0E+00	-
	Silage	3.6E-01	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor-Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Mercury (elemental)	Exp. Fruit	-	-	1.0E+00
	Exp. Veg.	-	-	1.0E+00
	Forage	-	-	1.0E+00
	Grain	-	-	-
	Prot. Fruit	-	-	-
	Prot. Veg.	-	-	-
	Root	-	1.0E+00	-
	Silage	-	-	5.0E-01
Mercuric chloride	Exp. Fruit	1.5E-02	-	1.0E+00
	Exp. Veg.	1.5E-02	-	1.0E+00
	Forage	0.0E+00	-	1.0E+00
	Grain	9.3E-03	-	-
	Prot. Fruit	1.5E-02	-	-
	Prot. Veg.	1.5E-02	-	-
	Root	3.6E-02	1.0E+00	-
	Silage	0.0E+00	-	5.0E-01
Methyl mercury	Exp. Fruit	2.9E-02	-	1.0E-02
	Exp. Veg.	2.9E-02	-	1.0E-02
	Forage	0.0E+00	-	1.0E+00
	Grain	1.9E-02	-	-
	Prot. Fruit	2.9E-02	-	-
	Prot. Veg.	2.9E-02	-	-
	Root	9.9E-02	1.0E-02	-
	Silage	0.0E+00	-	5.0E-01
PAHs				
2-Methylnaphthalene	Exp. Fruit	2.3E-01	-	1.0E+00
	Exp. Veg.	2.3E-01	-	1.0E+00
	Forage	2.3E-01	-	1.0E+00
	Grain	2.3E-01	-	-
	Prot. Fruit	2.3E-01	-	-
	Prot. Veg.	2.3E-01	-	-
	Root	4.4E+00	1.0E+00	-
	Silage	2.3E-01	-	5.0E-01
7,12-Dimethylbenz(a)anthracene	Exp. Fruit	1.7E-02	-	1.0E-02
	Exp. Veg.	1.7E-02	-	1.0E-02
	Forage	1.7E-02	-	1.0E+00
	Grain	1.7E-02	-	-
	Prot. Fruit	1.7E-02	-	-
	Prot. Veg.	1.7E-02	-	-
	Root	1.7E+00	1.0E-02	-
	Silage	1.7E-02	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Acenaphthene	Exp. Fruit	2.1E-01	-	1.0E+00
	Exp. Veg.	2.1E-01	-	1.0E+00
	Forage	2.1E-01	-	1.0E+00
	Grain	2.1E-01	-	-
	Prot. Fruit	2.1E-01	-	-
	Prot. Veg.	2.1E-01	-	-
	Root	6.2E+00	1.0E+00	-
	Silage	2.1E-01	-	5.0E-01
Acenaphthylene	Exp. Fruit	1.9E-01	-	1.0E-02
	Exp. Veg.	1.9E-01	-	1.0E-02
	Forage	1.9E-01	-	1.0E+00
	Grain	1.9E-01	-	-
	Prot. Fruit	1.9E-01	-	-
	Prot. Veg.	1.9E-01	-	-
	Root	4.1E+00	1.0E-02	-
	Silage	1.9E-01	-	5.0E-01
Benz(a)anthracene	Exp. Fruit	1.7E-02	-	1.0E-02
	Exp. Veg.	1.7E-02	-	1.0E-02
	Forage	1.7E-02	-	1.0E+00
	Grain	1.7E-02	-	-
	Prot. Fruit	1.7E-02	-	-
	Prot. Veg.	1.7E-02	-	-
	Root	2.3E+00	1.0E-02	-
	Silage	1.7E-02	-	5.0E-01
Benzo(a)pyrene	Exp. Fruit	1.4E-02	-	1.0E-02
	Exp. Veg.	1.4E-02	-	1.0E-02
	Forage	1.4E-02	-	1.0E+00
	Grain	1.4E-02	-	-
	Prot. Fruit	1.4E-02	-	-
	Prot. Veg.	1.4E-02	-	-
	Root	1.2E+00	1.0E-02	-
	Silage	1.4E-02	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Benzo(b)fluoranthene	Exp. Fruit	1.8E-02	-	1.0E-02
	Exp. Veg.	1.8E-02	-	1.0E-02
	Forage	1.8E-02	-	1.0E+00
	Grain	1.8E-02	-	-
	Prot. Fruit	1.8E-02	-	-
	Prot. Veg.	1.8E-02	-	-
	Root	1.7E+00	1.0E-02	-
	Silage	1.8E-02	-	5.0E-01
Benzo(g,h,i)perylene	Exp. Fruit	5.7E-03	-	1.0E-02
	Exp. Veg.	5.7E-03	-	1.0E-02
	Forage	5.7E-03	-	1.0E+00
	Grain	5.7E-03	-	-
	Prot. Fruit	5.7E-03	-	-
	Prot. Veg.	5.7E-03	-	-
	Root	1.1E+00	1.0E-02	-
	Silage	5.7E-03	-	5.0E-01
Benzo(k)fluoranthene	Exp. Fruit	1.4E-02	-	1.0E-02
	Exp. Veg.	1.4E-02	-	1.0E-02
	Forage	1.4E-02	-	1.0E+00
	Grain	1.4E-02	-	-
	Prot. Fruit	1.4E-02	-	-
	Prot. Veg.	1.4E-02	-	-
	Root	1.6E+00	1.0E-02	-
	Silage	1.4E-02	-	5.0E-01
Chrysene	Exp. Fruit	1.9E-02	-	1.0E-02
	Exp. Veg.	1.9E-02	-	1.0E-02
	Forage	1.9E-02	-	1.0E+00
	Grain	1.9E-02	-	-
	Prot. Fruit	1.9E-02	-	-
	Prot. Veg.	1.9E-02	-	-
	Root	1.7E+00	1.0E-02	-
	Silage	1.9E-02	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Dibenz(a,h)anthracene	Exp. Fruit	6.8E-03	-	1.0E-02
	Exp. Veg.	6.8E-03	-	1.0E-02
	Forage	6.8E-03	-	1.0E+00
	Grain	6.8E-03	-	-
	Prot. Fruit	6.8E-03	-	-
	Prot. Veg.	6.8E-03	-	-
	Root	1.6E+00	1.0E-02	-
	Silage	6.8E-03	-	5.0E-01
Fluoranthene	Exp. Fruit	4.0E-02	-	1.0E-02
	Exp. Veg.	4.0E-02	-	1.0E-02
	Forage	4.0E-02	-	1.0E+00
	Grain	4.0E-02	-	-
	Prot. Fruit	4.0E-02	-	-
	Prot. Veg.	4.0E-02	-	-
	Root	5.6E+00	1.0E-02	-
	Silage	4.0E-02	-	5.0E-01
Fluorene	Exp. Fruit	1.5E-01	-	1.0E-02
	Exp. Veg.	1.5E-01	-	1.0E-02
	Forage	1.5E-01	-	1.0E+00
	Grain	1.5E-01	-	-
	Prot. Fruit	1.5E-01	-	-
	Prot. Veg.	1.5E-01	-	-
	Root	6.2E+00	1.0E-02	-
	Silage	1.5E-01	-	5.0E-01
Indeno(1,2,3-cd)pyrene	Exp. Fruit	5.1E-03	-	1.0E-02
	Exp. Veg.	5.1E-03	-	1.0E-02
	Forage	5.1E-03	-	1.0E+00
	Grain	5.1E-03	-	-
	Prot. Fruit	5.1E-03	-	-
	Prot. Veg.	5.1E-03	-	-
	Root	1.1E+00	1.0E-02	-
	Silage	5.1E-03	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
Dioxins				
OctaCDD, 1,2,3,4,6,7,8,9-	Exp. Fruit	7.1E-04	-	1.0E-02
	Exp. Veg.	7.1E-04	-	1.0E-02
	Forage	7.1E-04	-	1.0E+00
	Grain	7.1E-04	-	-
	Prot. Fruit	7.1E-04	-	-
	Prot. Veg.	7.1E-04	-	-
	Root	6.1E-01	1.0E-02	-
	Silage	7.1E-04	-	5.0E-01
OctaCDF, 1,2,3,4,6,7,8,9-	Exp. Fruit	9.2E-04	-	1.0E-02
	Exp. Veg.	9.2E-04	-	1.0E-02
	Forage	9.2E-04	-	1.0E+00
	Grain	9.2E-04	-	-
	Prot. Fruit	9.2E-04	-	-
	Prot. Veg.	9.2E-04	-	-
	Root	6.8E-01	1.0E-02	-
	Silage	9.2E-04	-	5.0E-01
HeptaCDD, 1,2,3,4,6,7,8-	Exp. Fruit	9.2E-04	-	1.0E-02
	Exp. Veg.	9.2E-04	-	1.0E-02
	Forage	9.2E-04	-	1.0E+00
	Grain	9.2E-04	-	-
	Prot. Fruit	9.2E-04	-	-
	Prot. Veg.	9.2E-04	-	-
	Root	6.8E-01	1.0E-02	-
	Silage	9.2E-04	-	5.0E-01
HeptaCDF, 1,2,3,4,6,7,8-	Exp. Fruit	2.0E-03	-	1.0E-02
	Exp. Veg.	2.0E-03	-	1.0E-02
	Forage	2.0E-03	-	1.0E+00
	Grain	2.0E-03	-	-
	Prot. Fruit	2.0E-03	-	-
	Prot. Veg.	2.0E-03	-	-
	Root	9.4E-01	1.0E-02	-
	Silage	2.0E-03	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
HeptaCDF, 1,2,3,4,7,8,9-	Exp. Fruit	4.0E-03	-	1.0E-02
	Exp. Veg.	4.0E-03	-	1.0E-02
	Forage	4.0E-03	-	1.0E+00
	Grain	4.0E-03	-	-
	Prot. Fruit	4.0E-03	-	-
	Prot. Veg.	4.0E-03	-	-
	Root	1.2E+00	1.0E-02	-
	Silage	4.0E-03	-	5.0E-01
HexaCDD, 1,2,3,4,7,8-	Exp. Fruit	1.2E-03	-	1.0E-02
	Exp. Veg.	1.2E-03	-	1.0E-02
	Forage	1.2E-03	-	1.0E+00
	Grain	1.2E-03	-	-
	Prot. Fruit	1.2E-03	-	-
	Prot. Veg.	1.2E-03	-	-
	Root	7.6E-01	1.0E-02	-
	Silage	1.2E-03	-	5.0E-01
HexaCDF, 1,2,3,4,7,8-	Exp. Fruit	3.5E-03	-	1.0E-02
	Exp. Veg.	3.5E-03	-	1.0E-02
	Forage	3.5E-03	-	1.0E+00
	Grain	3.5E-03	-	-
	Prot. Fruit	3.5E-03	-	-
	Prot. Veg.	3.5E-03	-	-
	Root	1.2E+00	1.0E-02	-
	Silage	3.5E-03	-	5.0E-01
HexaCDD, 1,2,3,6,7,8-	Exp. Fruit	7.0E-04	-	1.0E-02
	Exp. Veg.	7.0E-04	-	1.0E-02
	Forage	7.0E-04	-	1.0E+00
	Grain	7.0E-04	-	-
	Prot. Fruit	7.0E-04	-	-
	Prot. Veg.	7.0E-04	-	-
	Root	6.1E-01	1.0E-02	-
	Silage	7.0E-04	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
HexaCDF, 1,2,3,6,7,8-	Exp. Fruit	1.0E-03	-	1.0E-02
	Exp. Veg.	1.0E-03	-	1.0E-02
	Forage	1.0E-03	-	1.0E+00
	Grain	1.0E-03	-	-
	Prot. Fruit	1.0E-03	-	-
	Prot. Veg.	1.0E-03	-	-
	Root	7.1E-01	1.0E-02	-
	Silage	1.0E-03	-	5.0E-01
HexaCDD, 1,2,3,7,8,9-	Exp. Fruit	7.0E-04	-	1.0E-02
	Exp. Veg.	7.0E-04	-	1.0E-02
	Forage	7.0E-04	-	1.0E+00
	Grain	7.0E-04	-	-
	Prot. Fruit	7.0E-04	-	-
	Prot. Veg.	7.0E-04	-	-
	Root	6.1E-01	1.0E-02	-
	Silage	7.0E-04	-	5.0E-01
HexaCDF, 1,2,3,7,8,9-	Exp. Fruit	1.6E-03	-	1.0E-02
	Exp. Veg.	1.6E-03	-	1.0E-02
	Forage	1.6E-03	-	1.0E+00
	Grain	1.6E-03	-	-
	Prot. Fruit	1.6E-03	-	-
	Prot. Veg.	1.6E-03	-	-
	Root	8.5E-01	1.0E-02	-
	Silage	1.6E-03	-	5.0E-01
HexaCDF, 2,3,4,6,7,8-	Exp. Fruit	1.0E-03	-	1.0E-02
	Exp. Veg.	1.0E-03	-	1.0E-02
	Forage	1.0E-03	-	1.0E+00
	Grain	1.0E-03	-	-
	Prot. Fruit	1.0E-03	-	-
	Prot. Veg.	1.0E-03	-	-
	Root	7.1E-01	1.0E-02	-
	Silage	1.0E-03	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
PentaCDD, 1,2,3,7,8-	Exp. Fruit	2.4E-03	-	1.0E-02
	Exp. Veg.	2.4E-03	-	1.0E-02
	Forage	2.4E-03	-	1.0E+00
	Grain	2.4E-03	-	-
	Prot. Fruit	2.4E-03	-	-
	Prot. Veg.	2.4E-03	-	-
	Root	1.0E+00	1.0E-02	-
	Silage	2.4E-03	-	5.0E-01
PentaCDF, 1,2,3,7,8-	Exp. Fruit	4.6E-03	-	1.0E-02
	Exp. Veg.	4.6E-03	-	1.0E-02
	Forage	4.6E-03	-	1.0E+00
	Grain	4.6E-03	-	-
	Prot. Fruit	4.6E-03	-	-
	Prot. Veg.	4.6E-03	-	-
	Root	1.3E+00	1.0E-02	-
	Silage	4.6E-03	-	5.0E-01
PentaCDF, 2,3,4,7,8-	Exp. Fruit	6.8E-03	-	1.0E-02
	Exp. Veg.	6.8E-03	-	1.0E-02
	Forage	6.8E-03	-	1.0E+00
	Grain	6.8E-03	-	-
	Prot. Fruit	6.8E-03	-	-
	Prot. Veg.	6.8E-03	-	-
	Root	1.5E+00	1.0E-02	-
	Silage	6.8E-03	-	5.0E-01
TetraCDD, 2,3,7,8-	Exp. Fruit	4.5E-03	-	1.0E-02
	Exp. Veg.	4.5E-03	-	1.0E-02
	Forage	4.5E-03	-	1.0E+00
	Grain	4.5E-03	-	-
	Prot. Fruit	4.5E-03	-	-
	Prot. Veg.	4.5E-03	-	-
	Root	1.3E+00	1.0E-02	-
	Silage	4.5E-03	-	5.0E-01

Exhibit_Add A2-11. Chemical-Specific Inputs by Plant Type for Chemicals in MIRC

Compound Name	Plant Part	Plant-Soil Bio-Concentration Factor ($Br_{AG\text{-}produce\text{-}DW(i)}$) (unitless)[a]	Empirical Correction Factor- Belowground Produce ($VG_{rootveg}$) (unitless)[b]	Empirical Correction Factor- Aboveground Produce ($VG_{AG(i)}$) (unitless)[c]
TetraCDF, 2,3,7,8-	Exp. Fruit	1.2E-02	-	1.0E-02
	Exp. Veg.	1.2E-02	-	1.0E-02
	Forage	1.2E-02	-	1.0E+00
	Grain	1.2E-02	-	-
	Prot. Fruit	1.2E-02	-	-
	Prot. Veg.	1.2E-02	-	-
	Root	1.9E+00	1.0E-02	-
	Silage	1.2E-02	-	5.0E-01

[a] As discussed in HHRAP (EPA 2005a), the $Br_{AG\text{-}produce\text{-}DW(i)}$ for aboveground produce and forage accounts for the uptake from soil and the subsequent transport of contaminants through the roots to the aboveground plant parts. For organics, correlation equations to calculate values for *Br* on a dry weight basis were obtained from Travis and Arms (1988). For cadmium, *Br* values were derived from uptake slope factors provided in EPA 1992. Uptake slope is the ratio of contaminant concentration in dry weight plant tissue to the mass of contaminant applied per hectare soil. *Br* aboveground values for mercuric chloride and methyl mercury were calculated using methodology and data from Baes, et al. (1984). *Br* forage values for mercuric chloride and methyl mercury (on a dry weight basis) were obtained from EPA 1997b. The HHRAP methodology assumes that elemental mercury doesn't deposit onto soils. Therefore, it's assumed that there is no plant uptake through the soil.

[b] As discussed in HHRAP (EPA 2005a), Appendix B, $VG_{rootveg}$ represents an empirical correction factor that reduces produce concentration. Because of the protective outer skin, size, and shape of bulky produce, transfer of lipophilic chemicals (i.e., log K_{ow} greater than 4) to the center of the produce is not likely. In addition, typical preparation techniques, such as washing, peeling, and cooking, further reduce the concentration of the chemical in the vegetable as consumed by removing the high concentration of chemical on and in the outer skin, leaving the flesh with a lower concentration than would be the case if the entire vegetable were pureed without washing. For belowground produce, HHRAP (EPA 2005a) recommends using a $VG_{rootveg}$ value of 0.01 for PB-HAP with a log K_{ow} greater than 4 and a value of 1.0 for PB-HAP with a log K_{ow} less than 4 based on information provided in EPA 1994b. In developing these values, EPA (1994b) assumed that the density of the skin and the whole vegetable are equal (potentially overestimating the concentration of PB-HAP in belowground produce due to root uptake).

[c] As discussed in HHRAP (EPA 2005a), Appendix B, VG_{ag} represents an empirical correction factor that reduces aboveground produce concentration and was developed to estimate the transfer of PB-HAP into leafy vegetation versus bulkier aboveground produce (e.g., apples). Because of the protective outer skin, size, and shape of bulky produce, transfer of lipophilic PB-HAP (log K_{ow} greater than 4) to the center of the produce is not likely. In addition, typical preparation techniques, such as washing, peeling, and cooking, further reduces residues. For aboveground produce, HHRAP (EPA 2005a) recommends using a VG_{ag} value of 0.01 for PB-HAP with a log K_{ow} greater than 4 and a value of 1.0 for PB-HAP with a log K_{ow} less than 4 based on information provided in EPA 1994b. In developing these values, EPA (1994b) assumed the following: (1) translocation of compounds deposited on the surface of aboveground vegetation to inner parts of aboveground produce would be insignificant (potentially underestimating the concentration of PB-HAP in aboveground produce due to air-to-plant transfer); (2) the density of the skin and the whole vegetable are equal (potentially overestimating the concentration of PB-HAP in aboveground produce due to air-to-plant transfer); and (3) the thickness of vegetable skin and broadleaf tree skin are equal (effects on the concentration of PB-HAP in aboveground produce due to air-toplant transfer unknown).

For forage, HHRAP recommends a VG_{ag} value of 1.0, also based on information provided in EPA 1994b.

A VG_{ag} value for silage is not provided in EPA 1994b; the VGag value for silage of 0.5 was obtained from NC DEHNR (1997); however, NC DEHNR does not present a specific rationale for this recommendation. Depending on the composition of the site-specific silage, this value may under- or overestimate the actual value.

Exhibit_Add A2-12. Non-Chemical-Specific Produce Inputs

Plant Part	Interception Fraction ($Rp_{(i)}$) (unitless)[a]	Plant Surface Loss Coefficient ($kp_{(i)}$) (1/year)[b]	Length of Plant Exposure to Deposition ($Tp_{(i)}$) (year)[c]	Yield or Standing Crop Biomass ($Yp_{(i)}$) (kg/m^2)[d]	Plant Tissue-Specific Moisture Adjustment Factor ($MAF_{(i)}$) (percent)[e]
Exposed Vegetable	0.982	18	0.16	5.66	92
Protected Fruit	NA	NA	NA	NA	90
Protected Vegetable	NA	NA	NA	NA	80
Forage (animal feed)	0.5	18	0.12	0.24	92
Exposed Fruit	0.053	18	0.16	0.25	85
Root Vegetables	NA	NA	NA	NA	87
Silage (animal feed)	0.46	18	0.16	0.8	92
Grain (animal feed)	NA	NA	NA	NA	90

Source: EPA 2005a. NA = not applicable.

[a] Baes *et al*. (1984) used an empirical relationship developed by Chamberlain (1970) to identify a correlation between initial Rp values and pasture grass productivity (standing crop biomass [*Yp*]) to calculate *Rp* values for exposed vegetables, exposed fruits, forage, and silage. Two key uncertainties are associated with using these values for *Rp*: (1) Chamberlain's (1970) empirical relationship developed for pasture grass may not accurately represent aboveground produce. (2) The empirical constants developed by Baes *et al*. (1984) for use in the empirical relationship developed by Chamberlain (1970) may not accurately represent the site-specific mixes of aboveground produce consumed by humans or the site-specific mixes of forage or silage consumed by livestock.

[b] The term *kp* is a measure of the amount of chemical that is lost to natural physical processes (e.g., wind, water) over time. The HHRAP-recommended value of 18 yr^{-1} (also recommended by EPA 1994a and 1998) represents the midpoint of a range of values reported by Miller and Hoffman (1983). There are two key uncertainties associated with using these values for *kp*: (1) The recommended equation for calculating *kp* includes a health protective bias in that it does not consider chemical degradation processes. (2) Given the reported range of *kp* values from 7.44 to 90.36 yr^{-1}, plant concentrations could range from about 1.8 times higher to about 5 times lower than the plant concentrations estimated in FFC media using the midpoint *kp* value of 18.

[c] HHRAP (EPA 2005a) recommends using a *Tp* value of 0.16 years for aboveground produce and cattle silage. This is consistent with earlier reports by EPA (1994a, 1998) and NC DEHNR (1997), which recommended treating *Tp* as a constant based on the average period between successive hay harvests. Belcher and Travis (1989) estimated this period at 60 days. *Tp* is calculated as 60 days ÷ 365 days/year = 0.16 years. For forage, the average of the average period between successive hay harvests (60 days) and the average period between successive grazing (30 days) is used (that is, 45 days), and *Tp* is calculated as (60 days + 30 days)/ 2 ÷ 365 days/yr = 0.12 yr. Two key uncertainties are associated with use of these values for *Tp*: (1) The average period between successive hay harvests (60 days) may not reflect the length of the growing season or the length between successive harvests for site-specific aboveground produce crops. The concentration of chemical in aboveground produce due to direct (wet and dry) deposition (*Pd*) will be underestimated if the site-specific value of *Tp* is less than 60 days, or overestimated if the site-specific value of *Tp* is more than 60 days.

[d] *Yp* values for aboveground produce and forage were calculated using an equation presented in Baes *et al*. (1984) and Shor *et al*. (1982): $Yp = Y_{hi} / A_{hi}$, where Y_{hi} = Harvest yield of i^{th} crop (kg DW) and A_{hi} = Area planted to i^{th} crop (m2), and using values for Y_h and A_h from USDA (1994b and 1994c). A production-weighted U.S. average *Yp* of 0.8 kg DW/m2 for silage was obtained from Shor *et al*. 1982.

[e] *MAF* represents the plant tissue-specific moisture adjustment factor to convert dry-weight concentrations into wet-weight concentrations (which are lower owing to the dilution by water compared with dry-weight concentrations). Values obtained from Chapter 10 of EPA's 2003 SAB Review materials for 3MRA Modeling System, Volume II, "Farm Food Chain and Terrestrial Food Web Data" (EPA 2003a), which references EPA 1997c. Note that the value for grain used as animal feed is based on corn and soybeans, not seed grains such as barley, oats, or wheat.

6.2.3. Animal Product Parameter Values

MIRC also requires chemical-specific inputs for many of the animal product algorithms. The relevant values are shown in Exhibit_Add A2-13 for the chemicals included in MIRC to date. The HHRAP algorithms require additional inputs for the animal products calculations that are not specific to PB-HAPs, but are specific to the animal and animal product type. The soil and plant ingestion rates recommended in HHRAP for beef cattle, dairy cattle, swine, and chicken are provided in Exhibit_Add A2-14.

Exhibit_Add A2-13. Animal Product Chemical-specific Inputs for Chemicals Included in MIRC

Compound Name	Soil Bio-Availability Factor (*Bs*) (unitless)	Biotransfer Factors (Ba_m) (day/kg FW tissue)[a] and Metabolism Factors (MF) (unitless)[b]						
		Mammal				Non-mammal		
		Beef (Ba_{beef})	Dairy (Ba_{dairy})	Pork (Ba_{pork})	*MF*	Eggs (Ba_{eggs})	Poultry ($Ba_{poultry}$)	*MF*
Inorganics								
Cadmium compounds	1	1.2E-04	6.5E-06	1.9E-04	1	2.5E-03	1.1E-01	NA
Mercury (elemental)	1	0	0	0	1	0	0	NA
Mercuric chloride	1	1.1E-04	1.4E-06	3.4E-05	1	2.4E-02	2.4E-02	NA
Methyl mercury	1	1.2E-03	1.7E-05	5.1E-06	1	3.6E-03	3.6E-03	NA
PAHs								
2-Methylnaphthalene	1	2.4E-02	5.0E-03	2.9E-02	0.01	1.0E-02	1.7E-02	NA
7,12-Dimethylbenz(a)anthracene	1	3.9E-02	8.3E-03	4.8E-02	0.01	1.7E-02	2.9E-02	NA
Acenaphthene	1	2.5E-02	5.2E-03	3.0E-02	0.01	1.0E-02	1.8E-02	NA
Acenaphthylene	1	2.6E-02	5.5E-03	3.1E-02	0.01	1.1E-02	1.9E-02	NA
Benz(a)anthracene	1	3.9E-02	8.3E-03	4.8E-02	0.01	1.7E-02	2.9E-02	NA
Benzo(a)pyrene	1	3.8E-02	8.0E-03	4.6E-02	0.01	1.6E-02	2.8E-02	NA
Benzo(b)fluoranthene	1	3.9E-02	8.3E-03	4.8E-02	0.01	1.7E-02	2.9E-02	NA
Benzo(g,h,i)perylene	1	2.9E-02	6.1E-03	3.5E-02	0.01	1.2E-02	2.1E-02	NA
Benzo(k)fluoranthene	1	3.8E-02	8.0E-03	4.6E-02	0.01	1.6E-02	2.8E-02	NA
Chrysene	1	4.0E-02	8.4E-03	4.8E-02	0.01	1.7E-02	2.9E-02	NA
Dibenz(a,h)anthracene	1	3.1E-02	6.5E-03	3.8E-02	0.01	1.3E-02	2.3E-02	NA
Fluoranthene	1	4.0E-02	8.5E-03	4.9E-02	0.01	1.7E-02	3.0E-02	NA
Fluorene	1	2.9E-02	6.1E-03	3.5E-02	0.01	1.2E-02	2.1E-02	NA
Indeno(1,2,3-cd)pyrene	1	2.7E-02	5.8E-03	3.3E-02	0.01	1.2E-02	2.0E-02	NA
Dioxins								
OctaCDD, 1,2,3,4,6,7,8,9-	1	6.9E-03	1.4E-03	8.3E-03	1	2.9E-03	5.1E-03	NA
OctaCDF, 1,2,3,4,6,7,8,9-	1	8.8E-03	1.8E-03	1.1E-02	1	3.7E-03	6.5E-03	NA
HeptaCDD, 1,2,3,4,6,7,8-	1	8.8E-03	1.8E-03	1.1E-02	1	3.7E-03	6.5E-03	NA

Exhibit_Add A2-13. Animal Product Chemical-specific Inputs for Chemicals Included in MIRC

Compound Name	Soil Bio-Availability Factor (*Bs*) (unitless)	Biotransfer Factors (Ba_m) (day/kg FW tissue)[a] and Metabolism Factors (MF) (unitless)[b]						
		Mammal				Non-mammal		
		Beef (Ba_{beef})	Dairy (Ba_{dairy})	Pork (Ba_{pork})	*MF*	Eggs (Ba_{eggs})	Poultry ($Ba_{poultry}$)	*MF*
HeptaCDF, 1,2,3,4,6,7,8-	1	1.6E-02	3.5E-03	2.0E-02	1	6.9E-03	1.2E-02	NA
HeptaCDF, 1,2,3,4,7,8,9-	1	2.4E-02	5.1E-03	3.0E-02	1	1.0E-02	1.8E-02	NA
HexaCDD, 1,2,3,4,7,8-	1	1.1E-02	2.3E-03	1.3E-02	1	4.6E-03	8.1E-03	NA
HexaCDF, 1,2,3,4,7,8-	1	2.3E-02	4.8E-03	2.8E-02	1	9.6E-03	1.7E-02	NA
HexaCDD, 1,2,3,6,7,8-	1	6.8E-03	1.4E-03	8.2E-03	1	2.9E-03	5.0E-03	NA
HexaCDF, 1,2,3,6,7,8-	1	9.7E-03	2.0E-03	1.2E-02	1	4.1E-03	7.1E-03	NA
HexaCDD, 1,2,3,7,8,9 -	1	6.8E-03	1.4E-03	8.2E-03	1	2.9E-03	5.0E-03	NA
HexaCDF, 1,2,3,7,8,9-	1	1.4E-02	2.9E-03	1.7E-02	1	5.8E-03	1.0E-02	NA
HexaCDF, 2,3,4,6,7,8-	1	9.6E-03	2.0E-03	1.2E-02	1	4.1E-03	7.1E-03	NA
PentaCDD, 1,2,3,7,8-	1	1.8E-02	3.9E-03	2.2E-02	1	7.8E-03	1.4E-02	NA
PentaCDF, 1,2,3,7,8-	1	2.6E-02	5.5E-03	3.2E-02	1	1.1E-02	1.9E-02	NA
PentaCDF, 2,3,4,7,8-	1	3.1E-02	6.5E-03	3.8E-02	1	1.3E-02	2.3E-02	NA
TetraCDD, 2,3,7,8-	1	2.6E-02	5.5E-03	3.2E-02	1	1.1E-02	1.9E-02	NA
TetraCDF, 2,3,7,8-	1	3.6E-02	7.7E-03	4.4E-02	1	1.5E-02	2.7E-02	NA

Source: EPA 2005a, unless otherwise indicated. NA = not applicable.

[a] As discussed in HHRAP (EPA 2005a), Appendix A, biotransfer factors for mercury compounds were obtained from EPA 1997b. Considering speciation, fate, and transport of mercury from emission sources, elemental mercury is assumed to be vapor-phase and hence is assumed not to deposit to soil or transfer into aboveground plant parts. As a consequence, there is no transfer of elemental mercury into animal tissues. Biotransfer factors for cadmium compounds were obtained from EPA 1995b. Biotransfer factors for dioxins and PAHs were calculated from chemical octanol-water partitioning coefficients (K_{ow} values) using the correlation equation from RTI (2005) and assuming the following fat contents: milk - 4%; beef - 19%; pork - 23%; poultry -14%; and eggs - 8%.

[b] As discussed in HHRAP (EPA 2005a), EPA (1995c) recommends using a metabolism factor (MF) to account for metabolism of PAHs by mammals to offset the amount of bioaccumulation suggested by biotransfer factors. EPA has recommended an MF of 0.01 for bis(2-ethylhexyl)phthalate (BEHP) and 1.0 for all other chemicals (EPA 1995d). For MIRC, an MF of 0.01 is also used to calculate concentrations of PAHs in food products from mammalian species based on the work of Hofelt et al. (2001). This factor takes into account the P450-mediated metabolism of PAHs in mammals; applying this factor in our approach reduced the concentrations of chemicals in beef, pork, and dairy by two orders of magnitude.

Exhibit_Add A2-14. Soil and Plant Ingestion Rates for Animals

Animal	Soil Ingestion Rate – $Qs_{(m)}$ (kg/day)[a]	Plant Part Consumed by Animal	Plant Ingestion Rate – $Qp_{(l,m)}$ (kg/day)
Beef cattle[b]	0.5	Silage	2.5
		Forage	8.8
		Grain	0.47
Dairy cattle[c]	0.4	Silage	4.1
		Forage	13.2
		Grain	3.0
Swine[d]	0.37	Silage	1.4
		Grain	3.3
Chicken (eggs)[e]	0.022	Grain	0.2

Source: EPA 2005a HHRAP (Chapter 5).

[a] Beef cattle: NC DEHNR (1997) and EPA (1994b) recommended a soil ingestion rate for subsistence beef cattle of 0.5 kg/day based on Fries (1994) and NAS (1987). As discussed in HHRAP, Fries (1994) reported soil ingestion to be 4 percent of the total dry matter intake. NAS (1987) cited an average beef cattle weight of 590 kg, and a daily dry matter intake rate (non-lactating cows) of 2 percent of body weight. This results in a daily dry matter intake rate of 11.8 kg DW/day and a daily soil ingestion rate of about 0.5 kg/day.

Dairy cattle: NC DEHNR (1997) and EPA (1994b) recommended a soil ingestion rate for dairy cattle of 0.4 kg/day based on Fries (1994) and NAS (1987). As discussed in HHRAP, Fries (1994) reported soil ingestion to be 2 percent of the total dry matter intake. NAS (1987) cited an average beef cattle weight of 630 kg and a daily dry matter intake rate (non-lactating cows) of 3.2 percent of body weight. This resulted in a daily dry matter intake rate of 20 kg/day DW, and a daily soil ingestion rate of approximately 0.4 kg/day. Uncertainties associated with Qs include the lack of current empirical data to support soil ingestion rates for dairy cattle and the assumption of uniform contamination of soil ingested by cattle.

Swine: NC DEHNR (1997) recommended a soil ingestion rate for swine of 0.37, estimated by assuming a soil intake that is 8% of the plant ingestion rate of 4.3 kg DW/day. Uncertainties include the lack of current empirical data to support soil ingestion rates and the assumption of uniform contamination of the soil ingested by swine.

Chicken: HHRAP (EPA 2005a) assumes that chickens consume 10 percent of their total diet (which is approximately 0.2 kg/day grain) as soil, a percentage that is consistent with the study from Stephens *et al*. (1995). Uncertainties include the lack of current empirical data to support soil ingestion rates for chicken and the assumption of uniform contamination of soil ingested by chicken.

[b] The beef cattle ingestion rates of forage, silage, and grain are based on the total daily intake rate of about 12 kg DW/day (based on NAS [1987] reporting a daily dry matter intake that is 2 percent of an average beef cattle body weight of 590 kg) and are supported by NC DEHNR (1997), EPA (1994b and 1990), and Boone *et al*. (1981). The principal uncertainty associated with these *Qp* values is the variability between forage, silage, and grain ingestion rates for cattle.

[c] The dairy cattle ingestion rates of forage, silage, and grain are based on the total daily intake rate of about 20 kg DW/day (NAS 1987; EPA 1992) as recommended by NC DEHNR (1997). Uncertainties include the proportion of each food type in the diet, which varies from location to location. Assuming uniform contamination of plant materials consumed by cattle also introduces uncertainty.

[d] Swine are not grazing animals and are assumed not to eat forage (EPA 1998). EPA (1994b and 1998) and NC DEHNR (1997) recommended including only silage and grains in the diet of swine. EPA (1995c) recommended an ingestion rate of 4.7 kg DW/day for a swine, referencing NAS (1987). Assuming a diet of 70 percent grain and 30 percent silage (EPA 1990), HHRAP estimated ingestion rates of 3.3 kg DW/day (grain) and 1.4 kg DW/day (silage). Uncertainties associated with *Qp* include variability of the proportion of grain and silage in the diet, which varies from location to location.

[e] Chickens consume grain provided by the farmer. The daily quantity of grain feed consumed by chicken is assumed to be 0.2 kg/day (Ensminger (1980), Fries (1982), and NAS (1987). Uncertainties associated with this variable include the variability of actual grain ingestion rates from site to site. In addition, assuming uniform contamination of plant materials consumed by chicken introduces some uncertainty.

6.3. Adult and Non-Infant Exposure Parameter Values

The exposure parameters included in MIRC and their default and other value options are summarized in the following subsections. The default values were selected to result in a highly health protective screening scenario. Parameter value options were primarily obtained or estimated from EPA's *Exposure Factors Handbook* (EFH; EPA 2011a) and *Child-Specific Exposure Factors Handbook* (CSEFH; EPA 2008a). Where values were reported for age groupings other than those used in MIRC (see Section 2.3 above for MIRC age groups), time-weighted average values were estimated for the MIRC age groups from the available data.

In MIRC, ingestion rates for home-produced farm food items are included for exposed fruit, protected fruit, exposed vegetables, protected vegetables, root vegetables, beef, total dairy, pork, poultry, and eggs. Those ingestion rates are already normalized to body weight (i.e., $g_{wet\ weight}$/kg-day) (EPA 2011a). The body weight parameter values presented in Exhibit_Add A2-15, therefore, are not applied in the chemical intake (ADD) equations for these food types.

In MIRC, ingestion rates also are included for drinking water (mL/day), soil (mg/day), and fish (g/day). These ingestion rates, however, are on a per person basis (i.e., not normalized for body weight). The body weight parameter values presented in Exhibit_Add A2-15, therefore, are applied in the chemical intake (ADD) equations for these media.

6.3.1. Body Weights

Body weight (BW) options included in MIRC include mean, 5th, 10th, 50th, 90th, and 95th percentile values for adults and the five children's age groups: <1 year; 1–2 years; 3–5 years; 6–11 years; and 12–19 years. For its default screening assessment, EPA uses the mean BW for each age group. The BWs currently in the MIRC database are listed in Exhibit_Add A2-15.

In general, BW values for the five children's age groups were calculated from the summary data provided in Table 8-3 of EPA's 2008 CSEFH. For purposes of comparison, alternative BW values for children ages 12 through 19 years also were estimated using data from Portier *et al*. (2007). These values are listed in the last row of Exhibit_Add A2-15, but are not included in MIRC. The means calculated using the two methods for children ages 12 through 19 years were essentially identical at 64 kg. The other percentile values for this age group using the two methods differed by approximately 10 percent or less.

Exhibit_Add A2-15. Mean and Percentile Body Weight Estimates for Adults and Children

Lifestage (years)	Duration (years)	Body Weight (kg)					
		Mean	5th	10th	50th	90th	95th
Adult[a] (20-70)	50	80.0[a]	52.9	56	69.3	89.7	97.6
Child < 1[b]	1	7.83	6.03	6.38	7.76	9.24	9.66
Child 1-2[c]	2	12.6	9.9	10.4	12.5	14.9	15.6
Child 3-5[d]	3	18.6	13.5	14.4	17.8	23.6	26.2
Child 6-11[e]	6	36.0	22.1	24.0	33.5	51.2	58.6
Child 12-19[f]	8	64.2	39.5	45	64.2	83.5	89
[Child 12-19[g]	*8*	*64.3*	*41.1*	*44.6*	*60.9*	*88.5*	*98.4]*

[a] BW represents the recommended body weight from EPAs 2011 EFH. Although the 18 to 74 year age category in EPA's EFH does not match exactly the age 20 to 70 year categorization of adults in MIRC, the magnitude of error in the mean and percentile body weights is likely to be very small (i.e., less than 1%).

[b] Each BW represents a time-weighted average of body weights for age groups birth to <1 month, 1 to <3 months, 3 to <6 months, and 6 to <12 months from Table 8-3 of the 2008 CSEFH. Original sample sizes for each of these age groups can also be found in Table 8-3.

[c] Each BW represents a time-weighted average of body weights for age groups 1 to <2 years and 2 to <3 years from Table 8-3 of the 2008 CSEFH. Original sample sizes for each of these age groups can also be found in Table 8-3.

[d] BWs obtained directly from Table 8-3 of the 2008 CSEFH (age group 3 to <6 years).

[e] Each BW represents a time-weighted average of body weights for age groups 6 to <11 years and 11 to <16 years from Table 8-3 of the 2008 CSEFH. Original sample sizes for each of these age groups can also be found in Table 8-3.

[f] Mean BW estimated using Table 8-22 of the 2008 CSEFH, which is based on NHANES IV data as presented in Portier et al. (2007). This estimate was calculated as the average of the 8 single-year age groups from 12 to 13 years through 19 to 20 years. Values for the other percentiles were estimated using Portier et al., 2007.

[g] Each BW represents a time-weighted average of body weights for age groups 11 to <16 years and 16 to <21 years from Table 8-3 of the 2008 CSEFH. Estimated values include 11-year-olds and individuals through age 20, which contributes to uncertainty in the estimates for 12 to 19 years. Those values are provided for comparison purposes only and are not included in MIRC.

6.3.2. Water Ingestion Rates

MIRC also includes the option of calculating chemical ingestion via drinking water obtained from surface-water sources or from wells (i.e., from groundwater) in the contaminated area. Users have the option in MIRC to set drinking water ingestion rates to zero or to revise the drinking water ingestion rates in MIRC to better reflect site-specific water uses. The 2008 CSEFH recommends values for drinking water ingestion rates for children based on a study reported by Kahn and Stralka (2008). Table 3-4 of the CSEFH provides *per capita* estimates of community water ingestion rates by age categories. Community water ingestion includes both direct and indirect ingestion of water from the tap. *Direct ingestion* is defined as direct consumption of water as a beverage, while *indirect ingestion* includes water added during food or beverage preparation. The source of these data is the 1994-1996 and 1998 U.S. Department of Agriculture's (USDA's) *Continuing Survey of Food Intakes by Individuals* (CSFII) (USDA 2000). Exhibit_Add A2-16 includes the drinking water ingestion rates for children that are included in MIRC.

Mean and percentile adult drinking water ingestion rates were obtained from EPA (2004b), which presents estimated *per capita* water ingestion rates for various age categories based on data collected by the USDA's 1994–1996 and 1998 CSFII (USDA 2000). Adult ingestion rates, presented in Exhibit_Add A2-16, represent community water ingestion, both direct and indirect as defined above, for males and females combined, ages 20 years and older.

Exhibit_Add A2-16. Estimated Daily Per Capita Mean and Percentile Water Ingestion Rates for Children and Adults[a]

Lifestage (years)	Ingestion Rates, Community Water (mL/day)				
	Mean	50th	90th	95th	99th
Child <1[b]	504	482	969	1113	1440
Child 1-2[c]	332	255	687	903	1318
Child 3-5[d]	382	316	778	999	1592
Child 6-11[e]	532	417	1149	1499	2274
Child 12-19[f]	698	473	1641	2163	3467
Adult[g]	1219	981	2534	3087	4567

Sources: EPA 2004, 2008a

*The sample size does not meet minimum reporting requirements as described in EPA 2008a. For some of these MIRC age groupings, the values are based on the time-weighted average value for 2 or more age ranges from CSEFH Table 3-4. One or more age ranges within the group may not meet the minimum reporting requirements, but not necessarily all of them fall within this category.

[a] Source is Kahn and Stralka 2008, also presented in the CSEFH (EPA 2008a).

[b] Each IR represents a time-weighted average of ingestion rates for age groups birth to <1 month, 1 to <3 months, 3 to <6 months, and 6 to <12 months from Table 3-4 of the 2008 CSEFH.

[c] Each IR represents a time-weighted average of ingestion rates for age groups 1 to <2 years and 2 to <3 years from Table 3-4 of the 2008 CSEFH.

[d] Each IR represents the ingestion rate for age group 3 to <6 years from Table 3-4 of the 2008 CSEFH.

[e] Each IR represents the ingestion rate for age group 6 to <11 years from Table 3-4 of the 2008 CSEFH. This value represents a health protective (i.e., slightly low) estimate of IR for ages 6 through 11 years since 11-year olds are not included in this CSEFH age group.

[f] Each IR represents a time-weighted average of ingestion rates for age groups 11 to <16 years, 16 to <18, and 18 to <21 years from Table 3-4 of the 2008 CSEFH. Note that estimated values include 11-year-olds and individuals through age 20, which contributes to uncertainty in the estimates for 12 to 19 years.

[g] Adult drinking water ingestion rates were obtained from EPA (2004b), Appendix E, Part I, Table A1 for community water, both sexes (ages 20+), direct plus indirect water ingestion.

6.3.3. Local Food Ingestion Rates

MIRC includes mean, median, 90th, 95th, and 99th percentile food-specific ingestion rates (IRs) for consumers-only of farm food chain (FFC) media for adults and children. The mean and percentile values are from EPA's analysis of data from the USDA's 1987 to 1988 *Nationwide Food Consumption Survey* (NFCS) (USDA 1993), as presented in Chapter 13 of the Agency's *Exposure Factors Handbook* (i.e., Intake Rates for Various Home Produced Food Items) (EPA 2011a). Consumers-only means that individuals who did not report eating a specified type of food during the three-day period covered by the food ingestion part of the survey were not included in the analysis of ingestion rates for that food type. The questionnaire included the options for a household to self-identify in one or more of five categories: as a household that gardens, raises animals, hunts, fishes, or farms. As of September 2008, that survey was the most recent NFCS available (EPA 2008a, CSEFH), and we are not aware of any that might be more recent.[21]

For the adult age group in MIRC, data were compiled on food-specific IRs separately for two types of households as indicated in the "Response to Questionnaire" (EPA 2011a, Chapter 13): (1) households that farm (F) and (2) households that garden or raise animals (HG for homegrown). This division reflects EPA's data analysis. EPA tabulated IRs for fruits and vegetables separately for households that farm and households that garden. Similarly, EPA tabulated IRs for animals and animal products for households that farm and for households that raise animals. Thus, the first type of household, F, represents farmers who may both grow crops and raise animals and who are likely to consume more homegrown/raised foods than the second type of household. The second type of household, HG, represents the non-farming households that may consume lower amounts of home-grown or raised foods (i.e., HG encompasses both households that garden and households that raise animals).

The food-specific ingestion rates are based on the amount of each food type that households that farm (F) or households that garden and raise animals (HG) produced and brought into their homes for consumption and the number of persons consuming the food. EPA averaged the actual consumption rate for home-grown foods over the 1-week survey period.

The default food-specific ingestion rates in MIRC for adults are those for farming households (F) in Exhibit_Add A2-17. The user can specify use of the non-farming household (HG) ingestion rates if they are more appropriate for the user's exposure scenario.

Exhibit_Add A2-17. Summary of Age-Group Specific Food Ingestion Rates for Farm Food Items

Product	Child (age in yr)					Adult (20–70 yrs)
	<1	1–2	3–5	6–11	12–19	
Mean ingestion rates (g/kg-day)						
Beef[a]	N/A	4.14	4.00	3.77	1.72	1.93
Dairy[b]	N/A	91.6	50.9	27.4	13.6	2.96
Eggs[a]	N/A	2.46	1.42	0.86	0.588	0.606
Exposed Fruit[a]	N/A	6.14	2.60	2.52	1.33	1.19

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[21] Note that EPA's 2008 CSEFH does not distinguish between exposed and protected fruits and vegetables when recommending food ingestion rates based on the same data set for the same age categories. EPA's 1997 analysis for its EFH therefore remains the most appropriate data source for use in MIRC.

Exhibit_Add A2-17. Summary of Age-Group Specific Food Ingestion Rates for Farm Food Items

Product	Child (age in yr)					Adult (20–70 yrs)
	<1	1–2	3–5	6–11	12–19	
Exposed Vegetable[a]	N/A	3.48	1.74	1.39	1.07	1.38
Pork[a]	N/A	2.23	2.15	1.50	1.28	1.10
Poultry[a]	N/A	3.57	3.35	2.14	1.50	1.37
Protected Fruit[a]	N/A	16.6	12.4	8.50	2.96	5.19
Protected Vegetable[a]	N/A	2.46	1.30	1.10	0.78	0.862
Root Vegetable[a]	N/A	2.52	1.28	1.32	0.94	1.03
Water (mL/day)[c]	N/A	332	382	532	698	1218
Median ingestion rates (g/kg-day)						
Beef[a]	N/A	2.51	2.49	2.11	1.51	1.55
Dairy[b]	N/A	125	66.0	34.4	15.5	2.58
Eggs[a]	N/A	1.51	0.83	0.561	0.435	0.474
Exposed Fruit[a]	N/A	1.82	1.11	0.61	0.62	0.593
Exposed Vegetable[a]	N/A	1.89	1.16	0.64	0.66	0.812
Pork[a]	N/A	1.80	1.49	1.04	0.89	0.802
Poultry[a]	N/A	3.01	2.90	1.48	1.30	0.922
Protected Fruit[a]	N/A	7.59	5.94	3.63	1.23	2.08
Protected Vegetable[a]	N/A	1.94	1.04	0.79	0.58	0.564
Root Vegetable[a]	N/A	0.46	0.52	0.57	0.56	0.59
Water (mL/day)[c]	N/A	255	316	417	473	981
90th percentile ingestion rates (g/kg-day)[d]						
Beef[a]	N/A	9.49	8.83	11.4	3.53	4.41
Dairy[b]	N/A	185	92.5	57.4	30.9	6.16
Eggs[a]	N/A	4.90	3.06	1.90	1.30	1.31
Exposed Fruit[a]	N/A	12.7	5.41	6.98	3.41	2.37
Exposed Vegetable[a]	N/A	10.7	3.47	3.22	2.35	3.09
Pork[a]	N/A	4.90	4.83	3.72	3.69	2.23
Poultry[a]	N/A	7.17	6.52	4.51	3.13	2.69
Protected Fruit[a]	N/A	44.8	32.0	23.3	7.44	15.1
Protected Vegetable[a]	N/A	3.88	2.51	2.14	1.85	1.81
Root Vegetable[a]	N/A	7.25	4.26	3.83	2.26	2.49
Water (mL/day)[c]	N/A	687	778	1149	1640	2534
95th percentile ingestion rates (g/kg-day)						
Beef[a]	N/A	12.9	12.5	12.5	3.57	5.83
Dairy[b]	N/A	167	89.9	56.0	32.3	7.80
Eggs[a]	N/A	5.38	3.62	2.37	1.43	1.59
Exposed Fruit[a]	N/A	14.6	6.07	11.7	4.78	3.38
Exposed Vegetable[a]	N/A	11.9	6.29	5.47	3.78	4.46
Pork[a]	N/A	6.52	6.12	4.73	6.39	2.60
Poultry[a]	N/A	8.10	7.06	5.07	3.51	3.93

Exhibit_Add A2-17. Summary of Age-Group Specific Food Ingestion Rates for Farm Food Items

Product	Child (age in yr)					Adult (20–70 yrs)
	<1	1–2	3–5	6–11	12–19	
Protected Fruit[a]	N/A	48.3	35.1	26.9	11.4	19.2
Protected Vegetable[a]	N/A	9.42	5.10	3.12	2.20	2.83
Root Vegetable[a]	N/A	10.4	4.73	5.59	3.32	3.37
Water (mL/day)[c]	N/A	903	999	1499	2163	3087
99th percentile ingestion rates (g/kg-day)						
Beef[a]	N/A	20.9	19.8	13.3	4.28	6.84
Dairy[b]	N/A	180	87.2	54.8	34.7	9.20
Eggs[a]	N/A	16.2	11.2	8.19	4.77	1.83
Exposed Fruit[a]	N/A	25.2	32.5	15.7	5.9	13.0
Exposed Vegetable[a]	N/A	12.1	7.36	13.3	5.67	8.42
Pork[a]	N/A	8.71	9.74	6.61	4.29	3.87
Poultry[a]	N/A	9.63	10.24	6.12	4.60	4.93
Protected Fruit[a]	N/A	109	71.2	58.2	19.1	34.4
Protected Vegetable[a]	N/A	9.42	5.31	5.40	2.69	5.56
Root Vegetable[a]	N/A	10.4	4.73	7.47	5.13	7.57
Water (mL/day)[c]	N/A	1318	1592	2274	3467	4567

[a] Primary source for values was the 1987–1988 NFCS survey; compiled results are presented in Chapter 13 of 2011 Exposure Factors Handbook (EPA, 2011a). When data were unavailable for a particular age group, intake rate for all age groups was used multiplied by the age-specific ratio of intake based on national population intake rates from CSFII.

[b] Primary source for values was 1987–1988 NFCS survey, compiled results presented in Chapter 13 of 2011 Exposure Factors Handbook (EPA, 2011a). When data were unavailable for a particular age group, intake rate for all age groups was used multiplied by the age-specific ratio of intake based on national population intake rates from an NHANES 2003–2006 analysis in Chapter 11 of the Exposure Factors Handbook.

[c] Primary source for children less than 3 years of age was a Kahn and Stralka (2008) analysis of CSFII data, and from EPA's analysis of NHANES 2003–2006 data for children and adults greater than three. All data tables that were used and justifications for data sources are presented in Chapter 3 of the 2011 Exposure Factors' Handbook.

[d] Default ingestion rate percentile used in MIRC for Tier 1 assessments and chemical threshold calculations.

For children, EPA estimated food-specific IRs for four age categories (EPA 2011a): 1–2 years, 3–5 years, 6–11 years, and 12–19 years. Sample sizes were insufficient to distinguish IRs for children in different types of households; hence, for children, a single IR value represents both F and HG households for a given food type and age category (Exhibit_Add A2-17). For some food types and age categories, there were insufficient data for EPA to provide consumer-only intake rates (i.e., data set for the subpopulation consisted of fewer than 20 observations). The HHRAP methodology, Section 6.2.2.2, recommends a method by which to calculate the "missing" age-specific consumer-only ingestion rates, as explained below. Food-specific intake rates (IRs) for those child age groups and food items not included in Chapter 13 of the 2011 EFH, that is $IR_{age\_group\_x}$, were derived using the following information:

- Mean or percentile-specific consumer-only intake of the farm food item, as brought into the home, for the total NFCS survey population (from EFH Chapter 13) – IRCO_total;
- Mean or percentile-specific per capita intake of the food type from all sources, as consumed, for the specific child age group, from Chapter 3 of the CSFII Analysis of Food Intake Distributions (EPA 2003c) – IRPC, age_group_x; and

- Mean or percentile-specific per capita intake of the farm food item for the total CSFII survey population (from Chapter 3 of EPA 2003c) – IRPC_total.

The ratio of $IR_{PC,\ age\_group\_x}$ to $\mathrm{IR}_{\mathrm{PC\_total}}$ from the CSFII data shows the consumption rate of a particular food type by a specific age group relative to the consumption rate for that food type for the population as a whole. The ratio of $IR_{CO,\ age\_group\_x}$ to IR_{CO_total}, that is the consumption rate of a particular food type by a specific age group (consumers only) relative to the consumption rate for that food type for the NFCS survey population as a whole (consumers only), should be approximately the same. Given the assumption that the two ratios are equal, Equation 2-56 was used to calculate the “missing” age-specific consumer-only *IRs*:

Equation 2-56. Calculation of Age-Group-Specific and Food-Specific Ingestion Rates

$$IR_{CO,\ age\_group\_x} = \frac{IR_{CO\_total} \times IR_{PC,\ age\_group\_x}}{IR_{PC\_total}}$$

where:

$IR_{CO,\ age\_group\_x}$ = Mean or percentile-specific *consumer-only* intake of the food type from all sources, as consumed, for the specific child age group X

IR_{CO_total} = Mean or percentile-specific *consumer-only* intake of the farm food item, as brought into the home, for the total NFCS survey population

$IR_{PC,\ age\_group\_x}$ = Mean or percentile-specific *per capita* intake of the food type from all sources, as consumed, for the specific child age group X from the CSFII

IR_{PC_total} = Mean or percentile-specific *per capita* intake of the farm food item for the total CSFII survey population

In this discussion, *per capita* (as opposed to *consumer-only*) indicates the intake rates are based on the entire population rather than the subset of the population that ingests the particular food category (i.e., consumers). Here, the use of *per capita* ingestion rates are recommended by the HHRAP methodology because no consumer-only percentile-specific intakes are provided for the different age groups.

The above calculation implicitly assumes that the distribution of the consumption rate for a food type for a specific age group (consumers only) has the same shape as the distribution of the consumption rate for a food type for a specific age group in the general population (*per capita*). Otherwise, the separate calculation of each percentile might yield intake estimates that decrease as the percentile increases. This calculation artifact could occur if the shapes of the two distributions differ in the upper percentiles (or “tails”) of the distributions.

In the instances where the above calculations were used to fill data gaps in the above exhibit, only the dairy child-specific age group intake estimates are not strictly increasing with increasing percentile. The distributions likely track better (and thus the above assumption of equal ratios is more reasonable) for lower percentiles, with deviations occurring due to outlier ingestion rates based on only a few respondents in the tails of the distributions. The MIRC defaults use the 90th percentile ingestion estimates, which are likely more reliable than the 95th or 99th percentile estimates in this particular calculation.

6.3.4. Local Fish Ingestion Rates

6.3.4.1. Screening Scenario

The USDA's 1987 to 1988 Nationwide Food Consumption Survey (NFCS) (USDA 1993, 1994a), as presented in Chapter 13 of the Agency's Exposure Factors Handbook (i.e., Intake Rates for Various Home Produced Food Items) (EPA 2011a), includes family-caught fish ingestion rates by age category. There are several disadvantages, however, to using that data source to estimate fish ingestion rates. First, due to inadequate sample sizes, EPA did not report fish ingestion rates for children less than 6 years of age. Second, the NFCS data were collected more than two decades ago. Third, the reported fish ingestion rates are for ages 6 to 11 and 12 to 19 and are based on 29 and 21 individuals in each age category, respectively (EPA 2011a, Table 13-20). Finally, the ingestion rates from NFCS data are based on total weight of fish as brought into the home, and do not include losses from preparation of the fish (i.e., removal of inedible parts and, possibly, the skin). Estimates of preparation losses for fish intended to apply to the NFCS fish ingestion rate data are very uncertain and are based on a wide variety of freshwater, estuarine, and marine fish, and squid (EPA 2011a, Table 13-69). Additionally, when considering the multipathway screening methodology, it is important that potential health effects to those individuals who are most likely to have the greatest PB-HAP exposure are not underestimated and, therefore, ingestion rates that are reflective of subsistence fisher ingestion rates are desired. Therefore, a more recent survey was sought that included larger sample sizes, data for children younger than six years, ingestion rates for the parts of fish actually consumed, and ingestion rates reflective of subsistence fisher ingestion rates.

Taking all of these issues into consideration, the default adult fish ingestion rate selected for use in MIRC is 373 g/day, which is the the estimated 99th percentile of fish ingestion rates for woman anglers as reported by Burger (2002). This rate is based upon ingestion of "wild-caught" fish, which includes freshwater, estuarine, and marine species, while our screening scenarios focus only on freshwater fish from lakes. This is notable because a number of studies indicate that fish ingestion rates are limited by species and habitat (i.e., lake, river, estuary, and ocean) and that the majority of the fish consumed in the United States are from river, marine and estuarine habitats versus lakes. Thus, although the fish ingestion rate for this group of subsistence fishers is not the highest fish ingestion rate available for use by EPA, we do believe it strikes the appropriate balance between being health protective and having screening scenarios so conservative that they are of limited use in the decision making process. This high-end fish ingestion rate is appropriate in the context of the conservative screening scenario used in the RTR process. This methodology is particularly applicable for national rulemakings given that it is very likely that subsistence woman fishers of child bearing age are located throughout the United States. Finally, we note that using a high-end subsistence fish ingestion rate is consistent with section 112 of the CAA, which focuses on risks associated with maximally exposed individuals.

Because Burger (2002) did not estimate fish ingestion rates for children, another data source was needed to develop ingestion rates for the child age categories that are used in MIRC. The child ingestion rates need to be consistent with the Burger adult ingestion rate, reflective of subsistence fisher ingestion rates, and based on adequate sample sizes. To satisfy these requirements, data on child ingestion rates from EPA's *Estimated Per Capita Fish Consumption in the United States* (EPA 2002) were selected for use. Specifically, the estimated 99th percentile of *as-prepared*, *consumer-only* ingestion rates for finfish and shellfish were selected (see Section 4.2.1.1 Table 5 of EPA 2002).The original data were collected as part of the 1994–96 and 1998 USDA Continuing Survey of Intakes by Individuals (CSFII; USDA 2000). Values reflect "as prepared" ingestion rates for which cooking and preparation losses (*L1* and *L2*) did not need to be considered. “Total” fish as reported in this source represents consumption of finfish plus shellfish.

Because the child age categories used in MIRC differ from the CSFII age categories presented in EPA 2002, the CSFII data were adjusted for use in MIRC. The CSFII data did not provide ingestion rates for the 1–2 year age category. To estimate ingestion rates for this age group, EPA used the ingestion rate for the 3–5 year age category scaled downward by the ratio of the mean body weight of the 1–2 year age group to the mean body weight of the 3–5 year age group. Because MIRC uses a 3–5 year age category, no adjustment was needed for CSFII data from that age category. For the 6–11 and 12–19 age categories, time-weighted average ingestion rates were calculated based on the CSFII ingestion rates. Exhibit_Add A2-18 provides the fish ingestion rates used in the screening analysis.

Exhibit_Add A2-18. Fish Ingestion Rates Used in Screening Analysis

	Ingestion Rates (g/day)					
	Infants <1 yr	**Child 1–2 yrs**	**Child 3–5 yrs**	**Child 6–11 yrs**	**Child 12–19 yrs**	**Adult 20–70 yrs**
	NA	107.7[a]	159.0[b]	268.2[c]	331.0[c]	373[d]

[a] A fish ingestion rate for ages 1-2 years was not available. The value represents the consumer-only fish ingestion rate for ages 3 to 5 from EPA (2002) (Section 4.2.1.1 Table 5 [freshwater/estuarine habitat]), scaled down by the ratio of the mean Child 1-2 body weight to the mean Child 3-5 body weight.

[b] This value represents the consumer-only fish ingestion rate for ages 3 to 5 from EPA (2002), Section 4.2.1.1 Table 5 (freshwater/estuarine habitat) rounded to the nearest full number.

[c] These values represent time-weighted average consumer-only fish ingestion rates based on ingestion rates from EPA (2002), Section 4.2.1.1 Table 5 (freshwater/estuarine habitat).

[d] This value represents the 99th percentile ingestion rate of wild caught fish for women as reported by Burger (2002).

6.3.4.2. Other values

EPA’s (2002) analysis of freshwater and estuarine fish consumption from the USDA’s Continuing Survey of Food Intake by Individuals (CSFII) for 1994-96 and 1998 was chosen to provide fish ingestion rate options by age category in MIRC. Although the fish consumption rates reported in the CSFII include all sources, commercial and self-caught, for purposes of screening level risk assessments, it was assumed that all freshwater and estuarine fish consumed are self-caught. The inclusion of commercially obtained and estuarine fish will overestimate locally caught freshwater fish ingestion rates for most populations in the United States; however, it also might underestimate locally caught fish ingestion rates for some populations (e.g., Native Americans, Asian and Pacific Island communities, rural African American communities). Because consumption of locally caught fish varies substantially from region to region in the United States and from one population or ethnic group to the next, users of MIRC are encouraged to use more locally relevant data whenever available.

For children, MIRC also includes values for the mean and the 90th, 95th, and 99th percentile fish *per-capita* ingestion rates (freshwater and estuarine fish only) based on EPA’s analysis of 1994-96 and 1998 CSFII data (EPA 2002, 2008a). Those rates include individuals who eat fish and those who do not eat fish. As shown in EPA’s 2008 CSEFH, Table 10-7, the 90th percentile *per capita* ingestion rates estimated from the two-day CSFII recall period are zero for some child age groups. Although not presented in CSEFH Table 10-7, median ingestion rates for all child age groups would be zero (considering the “consumer only” sample sizes [CSEFH Table 10-9] relative to the “*per-capita*” sample sizes in Table 10-7).

The high percentile fish ingestion rates that are zero result from the short duration of the CSFII recall period (two days) compared with the averaging time of interest (a year) and the relatively infrequent consumption of fish (e.g., on the order of once a week to once a month or less) compared with the near daily ingestion of other types of food products (e.g., dairy, produce, meat). Use of zero for fish ingestion rates, however, is not useful in MIRC. As a result, an alternative method was used to estimate fish ingestion rates for children and adults that could provide reasonable, non-zero values for all age groups and percentiles.

The alternative, age-group-specific fish ingestion rates were derived using values for each age group, *y*:

- Mean or other appropriate percentile consumer-only fish ingestion rates for age group *y*, IRCO,*y*, from EPA's Estimated Per Capita Fish Consumption in the United States (EPA 2002), Section 5.2.1.1, Table 5, for freshwater/estuarine habitat.[22]
- Fraction of the population consuming freshwater/estuarine fish, FPC,*y*, calculated as consumer-only sample size / U.S. population sample for age group *y*. The data to calculate those fractions are available in the 2008 CSEFH and EPA 2002.

Equation 2-57 was used to calculate the alternative, *per capita* fish ingestion rates by age group ($IR_{PC,y}$):

Equation 2-57. Calculation of Alternative Age-Group-Specific Fish Ingestion Rates

$$IR_{PC,y} = IR_{CO,y} \times F_{PC,y}$$

where:

$IR_{PC,y}$ = *Per capita* fish ingestion rate for age group *y* (g/day)

$IR_{CO,y}$ = *Consumer-only* fish ingestion rates for age group *y* (g/day) (EPA 2002, Section 5.2.1.1, Table 5, for freshwater/estuarine habitat)

$F_{PC,y}$ = Fraction of the population consuming freshwater/estuarine fish, calculated as consumer-only sample size / total U.S. population sample size for age group *y* (unitless) (2008 CSEFH, EPA 2002)

In the above, *per capita* (as opposed to *consumer-only*) indicates the intake rates are based on the entire population rather than the subset of the population that ingests the particular food category. Here, *per capita* ingestions are recommended by the HHRAP methodology because no consumer-only percentile-specific intakes are provided for the different age groups.

The mean and percentile consumer-only fish ingestion rates for children and adults and the fraction of the population consuming freshwater/estuarine fish used in calculating long-term *per capita* fish ingestion rates by age group are presented in Exhibit_Add A2-19 and Exhibit_Add A2-20. The mean and percentile *per capita* fish ingestion rates estimated using this methodology are summarized in Exhibit_Add A2-21 and are available in MIRC. The fish ingestion rates provided in Exhibit_Add A2-21 and included in MIRC are intended to represent the harvest and consumption of fish in surface waters in a hypothetical depositional area. For site-specific application of this tool, users should consider using more localized survey data to estimate more appropriate fish ingestion rates. The fishing season varies substantially across

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[22] Most of these data also are provided in Table 10-9 of the CSEFH; the median values, however, are not presented in the CSEFH, and values for the mean and all other percentiles are slightly different due to rounding.

the United States by latitude, and fish consumption patterns also vary by type of water body (e.g., ponds, lakes, rivers, streams, estuaries, coastal marine), cultural heritage, and general geographic area. Therefore, use of more localized information is encouraged. Note that as indicated in Exhibit_Att A-14 and Exhibit_Att A-16, in developing the screening threshold emission rates, health protective fish ingestion rates for child and adult fish consumers that more closely represent exposures of a high-end recreational fisher were used.

As noted in Section 6.4.3 of this addendum, if the user overwrites the fish IRs shown in Exhibit_Add A2-21 with fresh-weight as caught values (e.g., values obtained from a local creel survey), the user is advised to set non-zero values for the preparation and cooking loss factors L1 and L2 in Equation 2-15. Suggested values are presented in Section 6.4.3.

Exhibit_Add A2-19. Daily Mean and Percentile *Consumer-Only* Fish Ingestion Rates for Children and Adults ($IR_{CO,y}$)[a]

Lifestage (years)	Ingestion Rates, All Fish (g/day)				
	Mean	50th	90th	95th	99th
Child <1	NA	NA	NA	NA	NA
Child 1-2[b]	27.31	15.61	64.46	87.60	138.76*
Child 3-5[c]	40.31	23.04	95.16	129.31	204.84*
Child 6-11[d]	61.49	28.46	156.86*	247.69*	385.64*
Child 12-19[e]	79.07	43.18	181.40*	211.15*	423.38*
Adult[f]	81.08	47.39	199.62*	278.91	505.65*

Sources: EPA 2002, 2008a

NA = not applicable; it is assumed that children < 1 year of age do not consume fish.

*Indicates that the sample size does not meet minimum reporting requirements as described in EPA 2002. Owing to the small sample sizes, these upper percentiles values are highly uncertain.

[a] *Per capita* fish ingestion (FI) rates for children by age group are available from Chapter 10 of the CSEFH (EPA 2008a); however, all 50th and some 90th percentile ingestion rates are zero. *Per capita* FI rates were therefore estimated as described in Equation 2-57 to provide reasonable, non-zero values for all age groups and percentiles.

[b] A fish IR for ages 1-2 years was not available. The value represents the consumer-only fish ingestion rate for ages 3 to 5 from EPA (2002) (Section 5.2.1.1 Table 5 [freshwater/estuarine habitat]), scaled down by the ratio of the mean Child 1-2 body weight to the mean Child 3-5 body weight.

[c] These values represent the consumer-only fish ingestion rate for ages 3 to 5 from EPA (2002), Section 5.2.1.1 Table 5 (freshwater/estuarine habitat). Sample size = 442.

[d] These values represent the consumer-only fish ingestion rate for ages 6 to 10 from EPA (2002), Section 5.2.1.1 Table 5 (freshwater/estuarine habitat). Sample size = 147.

[e] These values represent the time-weighted average *per capita* fish ingestion rate for ages 11 to 15 and 16 to 17 years from EPA (2002), Section 5.1.1.1 Table 5 (freshwater/estuarine habitat); the value may underestimate ingestion rate for ages 12 to 19 years. Sample size = 135.

[f] These values represent the consumer-only fish ingestion rate for individuals 18 years and older from EPA (2002), Section 5.2.1.1 Table 4 (freshwater/estuarine habitat). Sample size = 1,633.

Exhibit_Add A2-20. Fraction of Population Consuming Freshwater/Estuarine Fish on a Single Day ($F_{PC,y}$)

Lifestage (years)	Fraction Consuming Fish
Child 3-5	0.0503[a]
Child 6-11	0.0440[b]
Child 12-19	0.0493[c]
Adult	0.08509[d]

Sources: EPA 2002, 2008a

[a] This value was calculated using the ages 3 to 5 sample size for consumers only divided by the sample size for the U.S. population divided by 2 to represent the proportion consuming fish on a single day (the consumers-only group includes individuals who consumed fish on at least one of two survey days) to match the one-day ingestion rate.

[b] As in footnote a, the value was calculated using the ages 6 to 10 sample size for consumers only divided by the sample size for U.S. population divided by 2.

[c] The value was calculated by summing the ages 11 to 15 and 16 to 17 sample sizes for consumers only and dividing by both by the sum of the sample sizes for U.S. population and by a factor of 2.

[d] The value was calculated using the ages 18 and older sample size for consumers only divided by the sample size for U.S. population from Section 5.1.1.1 Table 4. The result was divided by 2 to represent a one-day sampling period in order to match the one-day ingestion rate.

Exhibit_Add A2-21. Calculated Long-term Mean and Percentile *per capita* Fish Ingestion Rates for Children and Adults ($IR_{PC,y}$)

Lifestage (years)	Ingestion Rates, All Fish (g/day)				
	Mean	50th	90th	95th	99th
Child <1	NA	NA	NA	NA	NA
Child 1-2[a]	1.37	0.79	3.24	4.41	6.98
Child 3-5[b]	2.03	1.16	4.79	6.51	10.3
Child 6-11[c]	2.71	1.25	6.90	10.9	17.0
Child 12-19[d]	3.90	2.13	8.95	10.4	20.9
Adult[e]	6.90	4.03	16.99	23.73	43.02

Sources: EPA 2002, 2008a

NA = not applicable; it is assumed that children < 1 year of age do not consume fish.

[a] Values were calculated as (consumer-only IR for Child 1-2) x (fraction of population consuming fish for Child 3-5).

[b] Values were calculated as (consumer-only IR for Child 3-5) x (fraction of population consuming fish for Child 3-5).

[c] Values were calculated as (consumer-only IR for Child 6-11) x (fraction of population consuming fish for Child 6-11).

[d] Values were calculated as (consumer-only IR estimated for Child 12-19) x (fraction of population estimated to consume fish for Child 12-19).

[e] Values were calculated as (consumer-only IR for Adults) x (fraction of population consuming fish for Adults).

MIRC also includes values for the mean and the 90th percentile fish ingestion rates for recreational anglers, black and female recreational anglers, and anglers of Hispanic, Laotian, and Vietnamese descent which are shown in Exhibit_Add A2-22. These latter three populations are culturally or economically disposed to higher rates of fish ingestion than the general population. Recreational angler values are from the EFH (EPA, 2011a). Black and female recreational anglers ingestion rates are presented in Burger (2002). The fish ingestion rates for Hispanic, Laotian, and Vietnamese populations were derived from a study by Shilling *et al*. (2010) of contaminated fish consumption in California's Central Valley Delta. Shilling *et al*. (2010) reported mean and 95th percentile ingestion rates for each subpopulation. In part due to the low sample size in the Shilling study (n of 30 to 45), 95th percentile values were believed to be unrealistically high. The 90th percentile ingestion rate estimates presented in Exhibit_Add A2-22 for Hispanic, Laotian, and Vietnamese fishers were derived by EPA using information from Shilling *et al*. (2010; EPA, 2010).

Exhibit_Add A2-22. Calculated Mean and 90th Percentile Per capita Fish Ingestion Rates for Populations of Recreational Fishers ($IR_{PC,y}$)

		Subpopulation					
Percentile	**Units**	**Recreational Fisher[a]**	**Female Recreational Fisher[b]**	**Black Recreational Fisher[b]**	**Hispanic Recreational Fisher[c]**	**Laotian Recreational Fisher[c]**	**Vietnamese Recreational Fisher[c]**
Ingestion of Fish							
Mean	g/day	8	39.1	171	25.8	47.2	27.1
90th	g/day	11	123	446	98	144.8	99.1

[a] 1997 Exposure Factors Handbook (USEPA, 1997a)

[b] Burger (2002) weights are "as consumed" for locally caught fish.

[c] Shilling, F., A. White, L. Lippert, and M. Lubell. 2010. Contaminated fish consumption in California's Central Valley Delta. Environmental Research 110:334-344.

Applications to date of MIRC have used whole fish concentrations estimated by TRIM.FaTE. The proportion of lipid in TL3 and TL4 fish in TRIM.FaTE is assumed to be 5.7 percent (by weight) for the whole fish, based on information provided by Thomann (1989). The lipid content of the part(s) of the fish normally consumed is likely to be less than 5.7 percent. For example, EPA estimated a consumption-weighted mean lipid value for fillets of fish from TL3 to be 2.6 percent and from TL4 to be 3.0 percent (Table 6-9 in EPA 2003b). If a user of MIRC wishes to account for reduced chemical concentration in fillet compared with whole fish for lipophilic chemicals, the user can specify a "preparation" loss of chemical (see Section 6.4 of this addendum).

For lipophilic chemicals (e.g., log K_{ow} greater than 4), which partition primarily into the fatty tissues of fish, much of the higher concentration tissues might be stripped from the fish during preparation (e.g., belly fat, viscera which includes fat in liver, etc., fat under skin). The degree to which the concentration of chemical in a fillet is less than the average total concentration in the whole fish is chemical specific. Assuming the chemical concentration in the fillet is the same as in the whole fish may result in a health protective bias for highly lipophilic chemicals. For persons who prefer to consume fillets with the skin on and do not discard belly fat, assuming the same concentration of chemical in the fish consumed as in the whole fish also is protective.

6.3.5. Soil Ingestion Rates

Adult gardeners and farmers may incidentally ingest soils from gardening activities, and gardening and farming families might ingest soil particles that adhere to exposed fruits and exposed and belowground vegetables. Soils that are re-suspended in the air by wind can resettle on exposed fruits and vegetables. Children may incidentally ingest soils in those ways, but in addition, children playing outdoors may ingest soils directly or by hand-to-mouth activities during play. MIRC includes soil ingestion rate options by age group for these types of exposures. MIRC does not include options for children who may exhibit pica, or the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000 - 5,000 mg/day or more) (EPA 2008a).

Data on soil ingestion rates are sparse; the soil ingestion rates listed in Exhibit_Add A2-23 and included in MIRC are based on very limited data, as is evident from the values listed. The studies evaluated by EPA for children generally focused on children between the ages of 1 and 3 to 6 years and were not specific to families that garden or farm. The default ingestion rates in MIRC are the 90th percentile values, as for other ingestion rate parameters.

Exhibit_Add A2-23. Daily Mean and Percentile Soil Ingestion Rates for Children and Adults

Age Group (years)	Soil Ingestion Rate (mg/day)				
	Mean[a]	50th [a]	90th	95th	99th
Child < 1	NA				
Child 1-2	50	50	200[b]	200[b]	200[b]
Child 3-5	50	50	200[b]	200[b]	200[b]
Child 6-11	50	50	201[c]	331[d]	331[d]
Child 12-19	50	50	201[c]	331[d]	331[d]
Adult 20-70	20	20	201[c]	331[d]	331[d]

Sources: EPA 2008a, EPA 2011a

[a] For mean and 50th percentile soil ingestion rates for children, value represents a "central tendency" estimate from EPA's 2008 CSEFH, Table 5-1. For adults, value is the recommended mean value for adults from EPA's 2011 EFH, Chapter 5, Table 5-1.

[b] Values are the recommended "upper percentile" value for children from EPA's 2011 EFH, Chapter 4, Table 4-23. The 2008 CSEFH and 2011 EFH included a high-end value associated with pica only, but this value has not been used.

[c] Values are 90th percentile adult ingestion rates calculated in Stanek et al. 1997; used to represent older children and adults.

[d] Values are 95th percentile adult ingestion rates calculated in Stanek et al. 1997; used to represent older children and adults.

6.3.6. Total Food Ingestion Rates

Although not included in MIRC for deterministic screening-level exposure and risk assessments, total food ingestion rates would be included in any probabilistic module developed for MIRC. The total food ingestion rates presented in Exhibit_Add A2-24 will be used to normalize or to truncate the sum of food-specific ingestion rates to reasonable values. This procedure is particularly important when chemical intake from multiple upper-percentile food ingestion rates for different types of food are added together. Individuals representing the upper percentile ingestion rate for one food category might not be the same individuals who reported high percentile ingestion rates for one or any of the other food categories.

Exhibit_Add A2-24. Daily Mean and Percentile *Per Capita* Total Food Intake for Children and Adults

Lifestage (years)	Percent of Group Consuming Food	Mean	50th	90th	95th	99th
Total Food Intake (g/day, as consumed)						
Child < 1[a]	67.0% - 99.7% [h]	322	270	599	779	1152
Child 1-2[b]	100%	1,032	996	1537	1703	2143
Child 3-5[c]	100%	1,066	1,020	1,548	1,746	2,168
Child 6-11[d]	100%	1,118	1,052	1,642	1,825	2,218
Child 12-19[e]	100%	1,197	1,093	1,872	2,231	2,975
Adult[f]	100%	1,100	1,034	1,738	2,002	2,736
Total Food Intake (g/kg-day, as consumed)						
Child < 1[a]	67.0% - 99.7% [h]	39	34	72	95	147
Child 1-2[b]	100%	82	79	125	144	177
Child 3-5[c]	100%	61	57	91	102	132
Child 6-11[d]	100%	40	38	61	70	88
Child 12-19[e]	100%	21	19	34	40	51
Adult[g]	100%	14.8	13.9	23.7	27.6	35.5

Sources: EPA 2005e, 2008a

[a] These values represent a time-weighted average for age groups birth to <1 month (N=88), 1 to <3 months (N=245), 3 to <6 months (N=411), and 6 to <12 months (N=678) from Table 14-3 of the 2008 CSEFH.

These values represent a time-weighted average for age groups 1 to <2 years (N=1,002) and 2 to <3 years (N=994) from Table 14-3 of the 2008 CSEFH.

[c] These values were obtained from Table 14-3 of the 2008 CSEFH (age group 3 to <6 years, N=4,112).

[d] These values were obtained from Table 14-3 of the 2008 CSEFH (age group 6 to <11 years, N=1,553). These values represents a health protective (i.e., slightly low) estimate for ages 6 through 11 years since 11-year olds are not included in this CSEFH age group.

[e] These values represent a time-weighted average for age groups 11 to <16 years (N=975) and 16 to <21 (N=743) years from Table 14-3 of the 2008 CSEFH. Note that estimated values include 11-year-olds and individuals through age 20, which contributes to uncertainty in the estimates.

[f] These values represent a time-weighted average for age groups 20 to 39 years (N=2,950) and 40 to 69 years (N=4,818) from Table 5B of the 2005 EPA analysis of CSFII.

[g] These values represent a time-weighted average for age groups 20 to 39 years (N=2,950) and 40 to 69 years (N=4,818) from Table 5A of the 2005 EPA analysis of CSFII.

[h] Percents consuming foods from Table 14-3 of the 2008 CSEFH include: 67.0% (birth to <1 month); 74.7% (1 to <3 months); 93.7% (3 to <6 months); and 99.7% (6 to <12 months). Infants under the age of 1 that consume breast milk are classified as “non-consumers” of food.

6.4. Other Exposure Factor Values

The other exposure parameters included in the MIRC algorithms are exposure frequency (Section 6.4.1), fraction of the food type obtained from the contaminated area (Section 6.4.2), and reduction in the weight of the food types during preparation and cooking (Section 6.4.3). For the breast milk ingestion pathway, additional exposure parameters are included in the FFC algorithms (Section 6.5).

6.4.1. Exposure Frequency

The exposure frequency (EF) represents the number of days per year that an individual consumes home-produced food items that are contaminated with the chemical being evaluated. In MIRC, the default value for EF is 365 days/year for all exposure sources and all potential receptors. This assumption is consistent with the food ingestion rates used in MIRC (i.e., daily intake rates equivalent to annual totals divided by 365 days) and does not imply that residents necessarily consume home-produced food products every day of the year.

If the user wishes to evaluate daily intake rates based on shorter averaging times, the user can overwrite both the food-specific ingestion rates and the EF for each home-grown food product. Users of MIRC might want to specify a lower EF values for various food types where residents obtain some of their diet from commercial sources and where consumption of home grown produce is seasonal.

6.4.2. Fraction Contaminated

The fraction contaminated (FC) represents the fraction of each food product consumed that is contaminated by the chemical at a level consistent with environmental concentrations in the area of concern (e.g., area with maximum deposition rates). Obviously, the most health protective assumption is that all food products consumed (i.e., 100 percent) are from the location represented by the chemical concentrations input into MIRC.

For non-infant children and the adult age cohorts, MIRC includes the default FC of 1, assuming that 100 percent of the food product consumed is produced by households that farm, garden, or raise animals. The user can vary this default FC value for individual food products to tailor the assessment to a particular exposure scenario.

6.4.3. Preparation and Cooking Losses

Food preparation and cooking losses are included in the FFC exposure calculations to account for the amount of a food product as brought into the home that is not ingested due to loss during preparation, cooking, or post-cooking. These losses need to be accounted for in the ADD equations because the food ingestion rates calculated from the USDA 1987 to 1988 NFCS are based on the weight of home grown produce and animal products brought from the field into the house prior to any type of preparation. Not all of the produce or products were eventually ingested. In general, some parts of the produce and products are discarded during preparation while other parts might not be consumed even after cooking (e.g., bones). Thus, the actual food ingested is generally less than the amount brought into the home.

Three distinct types of preparation and cooking losses are included in the ingestion exposure algorithms in MIRC: (1) loss of parts of the food type from paring (i.e., removing the skin from vegetables and fruits) or other types of preparation (e.g., removing pits, coring, deboning), (2) additional loss of weight for the food type during cooking (e.g., evaporation of water), and (3) post-cooking losses (e.g., non-consumption of bones, draining cooking liquid [e.g., spinach]). MIRC includes mean values for these three types of preparation and cooking losses for exposed fruit, protected fruit, exposed vegetables, protected vegetables, root vegetables, beef, pork, poultry, and fish. Different types of losses apply to different types of foods. Therefore, the losses can be represented by only two parameters, *L1* and *L2*, the definitions of which vary according to the food type as explained in the endnotes in Exhibit_Add A2-25. All preparation and cooking loss parameter values were estimated as specified in the exhibit's endnotes from data presented in Chapter 13 of the EPA's 1997 and 2011 EFH (EPA 1997a and 2011a).

Exhibit_Add A2-25. Fraction Weight Losses from Preparation of Various Foods

Product	Mean Cooking, Paring, or Preparation Loss (Cooking Loss Type 1 [L1]) (unitless)[a]	Mean Net Post Cooking (Cooking Loss Type 2 [L2]) (unitless)[b]
Exposed Fruit[c]	0.244	0.305
Exposed Vegetable	0.162[d]	NA
Protected Fruit	0.29[e]	NA
Protected Vegetable	0.088[f]	NA
Root Vegetable[g]	0.075	0.22
Beef	0.27	0.24
Pork	0.28	0.36
Poultry	0.32	0.295[h]
Fish[i]	0.0	0.0

Source: EPA 1997a and 2011a

NA = Not Available

[a] For *fruits*, includes losses from draining cooked forms. For *vegetables*, includes losses due to paring, trimming, flowering the stalk, thawing, draining, scraping, shelling, slicing, husking, chopping, and dicing and gains from the addition of water, fat, or other ingredients. For *meats*, includes dripping and volatile losses during cooking.

[b] For *fruits*, includes losses from removal of skin or peel, core or pit, stems or caps, seeds and defects; may also include losses from removal of drained liquids from canned or frozen forms. For *vegetables*, includes losses from draining or removal of skin. For *meats*, includes losses from cutting, shrinkage, excess fat, bones, scraps, and juices.

[c] These values represent averages of means for all fruits with available data (except oranges) (Table 13-6).

[d] This value represents an average of means for all exposed vegetables with available data (Table 13-7). Exposed vegetables include asparagus, broccoli, cabbage, cucumber, lettuce, okra, peppers, snap beans, and tomatoes.

[e] This value was set equal to the value for oranges (Table 13-6).

[f] This value represents an average of means for all protected vegetables with available data (Table 13-7). Protected vegetables include pumpkin, corn, peas, and lima beans.

[g] These values represent averages of means for all root vegetables with available data (Table 13-7). Root vegetables include beets, carrots, onions, and potatoes.

[h] This value represents an average of means for chicken and turkey (Table 13-5).

[i] If the user changes fish ingestion rates to match a survey of the whole weight of fish brought into the home from the field (divided by the consumers of the fish), an appropriate value for L1 would be 0.31 and an appropriate L2 would be 0.11 (EPA 2011a).

There are substantial uncertainties associated with the L1 and L2 parameters, including the wide variation in values across produce types that were averaged together to recommend a central tendency value for each. For example, the L2 factor does not distinguish between weight loss during cooking by water evaporation, which might leave the chemical in the food (chemical not lost), and pouring the cooking liquid down the drain (chemical lost) or using the liquid to create a sauce (chemical not lost). In addition, the concentration of chemical might be highest in the skin, which often is discarded, and lower in the consumed portion of many bulky fruits and vegetables. Finally, the data EPA used to evaluate L1 included negative losses (i.e., weight gains) due to hydration of dried vegetables (e.g., peas and lima beans), which increases the range of L1 values across different vegetables.

Note that the default L1 and L2 values for fish are set to zero. That is because the data source for the fish ingestion rates is not the USDA's 1987 to 1988 NFCS (USDA 1993, 1994a) as reported in EPA's EFH, which reported food as brought into the home, as is the case for the other food categories. Instead, the fish IR data included in MIRC are based on parts actually consumed, and so no loss processes for preparation are needed.

If the user manually changes fish ingestion rates to match a local survey of the whole weight of fish brought into the home from the field (divided by number of persons consuming the fish), the user should also set the L1 and L2 parameter to non-zero values.

6.4.4. Food Preparation/Cooking Adjustment Factor (FPCAF) for Fish

In addition to estimating the weight of the food that is lost to preparation and cooking, there also can be changes in the chemical concentrations due to cooking. Because the fish consumption rates are “as consumed” and the fish concentration is based on uncooked fish, adjustments should be made to reflect the chemical concentrations in fish after cooking. In order to account for this phenomenon, an FPCAF can be applied to the uncooked fish concentration to estimate a concentration in cooked fish. The following sections discuss FPCAFs for each of the 4 PB-HAPs.

6.4.4.1. Mercury

In the U.S. EPA Revised Technical Support Document: National-Scale Assessment of Mercury Risk to Populations with High Consumption of Self-caught Freshwater Fish (EPA 2011b), a food preparation/cooking adjustment factor (FPCAF) of 1.5 was used to adjust methyl-mercury (MeHg) concentrations in consumed fish (i.e., a 50% increase in MeHg concentration due to cooking). Cooking fish typically increases MeHg levels per unit fish (as consumed) because MeHg concentrates in the muscle, while preparation involves removal primarily of non-muscle elements of the fish. The value is based on a study by Morgan et al. (1997).

6.4.4.2. Cadmium

Similar to mercury, cadmium will bind to muscle and will be retained during the cooking process. As such, the same FPCAF of 1.5 that is used for mercury is assumed for cadmium.

6.4.4.3. Dioxin

Dioxins are lipophilic and have been demonstrated to be lost during cooking. Based on a literature review, an FPCAF of 0.7 to is applied to account for these losses during the cooking process. A brief summary of supporting literature follows.

- Schecter et al. (1998) found that the mass of PCDD and PCDF in fresh catfish fillet (skin on) decreased by about 50 percent per serving portion during cooking. Given the simultaneous losses of moisture/fats during broiling of the catfish, the PCDDs and PCDFs concentrations decreased by 33 percent (i.e., multiply uncooked concentration in fresh fish by a factor of 0.66 = 0.70 to one significant digit).
- Reinert et al. (1972) reported higher losses of another highly lipophilic chemical, DDT, from cooking fish fillets of bloaters, yellow perch, lake trout, and coho salmon. Concentrations of DDT in fish fillet portions for lake trout and coho salmon, top predators, were reduced by 64 to 72 percent by frying or broiling, primarily through preferential loss of fat (and lipophilic DDT) during cooking. The investigators did not report skin on or off; however, they used steak cuts instead of flat fillets, which provide a smaller ratio of skin to muscle than is the case for fillets that constitute one side of the fish.
- Zabik and Zabik (1995) quantified the reduction in TCDD concentration of cooked, with the skin off, fillets compared with uncooked fillet with skin for fish harvested from the Great Lakes. Concentrations in the cooked fish with the skin off were reduced relative to the raw fillet with the skin on by approximately 44 percent for walleye, 80 percent for white bass, and 61 percent for lake trout. Comparing losses of TCDD for fillets cooked with the skin on versus fillets that were both skinned and cooked, Zabik and Zabik (1995) found reductions in TCDD concentrations of approximately 43 percent for Chinook Salmon cooked with the skin on and 57 percent for chinook salmon cooked with

the skin off. They found a 37 percent reduction of TCDD concentration for carp fillets cooked with the skin on and 54 percent reduction if the skin was removed.

The three studies listed above indicate that the 0.7 factor is not likely to overestimate loss of PCDD/PCDFs from fish during cooking (pan frying, broiling, grilling). Reductions in TCDD concentrations could be much higher with skin removal and trimming of fat.

6.4.4.4. PAHs

While it is reasonable to assume that there might be losses of lipophilic PAHs during the cooking process, there is insufficient information to distinguish what the net loss (or gain) during cooking might be because cooking can create PAHs from proteins in the tissue. The literature acknowledges these competing forces, but does not provide information to disentangle the gain and loss mechanisms. As such, a neutral approach was taken, which is to assume an adjustment factor of 1.0 (i.e., no adjustment) for PAHs.

6.5. Breast-Milk Infant Exposure Pathway Parameter Values

Values used for parameters in the breast-milk exposure pathway algorithms (see Section 3.4 of this addendum) can be scenario-specific, receptor-specific, and/or chemical-specific and might be empirically derived or estimated by an appropriate model. For parameters that are scenario-specific or for which empirical values are required, the default values provided in MIRC are listed. For parameters for which MIRC calculates values, the appropriate equation is listed. Scenario- and receptor-specific parameters are discussed in Section 6.5.1 and chemical-specific parameters are discussed in Section 6.5.2.

6.5.1. Receptor-specific Parameters

Receptor-specific values are needed for parameters that describe the characteristics or activities of the exposed individual. In this context, there are two relevant receptors: the mother and the infant. Exhibit_Add A2-26 lists the parameters and their default values. The text that follows describes the input value or value options for each exposure parameter required by MIRC to calculate the infant absorbed chemical intake rate, or DAI_{inf}. For parameter values that can be estimated when empirical values are not available, see the equation description in Section 3.4 of this addendum.

Exhibit_Add A2-26. Scenario- and Receptor-Specific Input Parameter Values Used to Estimate Infant Exposures via Breast Milk

Parameter	Description	Default Value
AT	Averaging time for infant's exposure via breast milk, i.e., duration of nursing (days)	=ED
BW_{inf}	Body weight of infant (kg) averaged over duration of nursing exposure	7.8
BW_{mat}	Body weight of mother (kg) averaged over duration of mother's exposure	66
DAI_{mat}	Daily absorbed intake of chemical by mother (mg/kg-day)	Equation 2-36
ED	Exposure duration for infant, i.e., duration of breast feeding (days)	=AT
AT/ED	Averaging time divided by exposure duration	1.0
f_{bp}	Fraction of mother's whole blood that is plasma (unitless)	0.65
f_{fm}	Fraction of mother's body weight that is fat (unitless)	0.30
f_{mbm}	Fraction of fat in mother's breast milk (unitless)	0.04
f_{pm}	Fraction of mother's body weight that is plasma (unitless)	0.046
IR_{milk}	Mean infant milk ingestion rate over duration of nursing (kg/day)	0.709
t_{bf}	Duration of breast feeding (days)	365
t_{pn}	Duration of maternal chemical exposure prior to nursing (days)	3285

Averaging time (*AT*) and exposure duration (*ED*). AT refers to the time over which the infant's exposure to the chemical of concern is averaged. *ED* refers to the duration of the infant's exposure. For the exposure scenario considered for this age group, both *AT* and *ED* equal the duration of the nursing period, and they therefore cancel each other out in the infant average daily dose equation.

Infant body weight (BW_{inf}). The user selects a value for BW_{inf}, the time-weighted average body weight of the infant over the entire duration of breast feeding, based on the age at which the infant stops breast feeding. For example, if the infant breast feeds for one year, the user should select the body weight for an infant that is averaged from birth to the first birthday. Similarly, if an infant breast feeds for 6 months, the user should select the body weight for an infant that is averaged from birth to six months. Because the default breast feeding duration (t_{bf}) is one year (i.e., 365 days), the default infant body weight is 7.8 kg, which is the time-weighted average for the mean infant body weight between birth and the first birthday from EPA's 2008 *Child Specific Exposure Factors Handbook* (CSEFH; EPA 2008a). Exhibit_Add A2-27 presents additional values for the infant body weight parameter that the user can select instead of the MIRC default.

Exhibit_Add A2-27. Average Body Weight for Infants

Statistic	0 to < 6 months (kg)	0 to < 12 months (kg)	0 to < 18 months (kg)	0 to < 24 months (kg)
Mean	6.5	7.8[a]	9.0	9.6
5th percentile	5.0	6.0	7.0	7.5
10th percentile	5.3	6.4	7.4	7.8
15th percentile	5.5	6.7	7.7	8.2
25th percentile	5.8	7.0	8.1	8.7
50th percentile	6.4	7.8	8.9	9.5
75th percentile	7.1	8.6	9.9	10.5
85th percentile	7.4	9.0	10.3	11.0

Exhibit_Add A2-27. Average Body Weight for Infants

Statistic	0 to < 6 months (kg)	0 to < 12 months (kg)	0 to < 18 months (kg)	0 to < 24 months (kg)
Mean	6.5	7.8[a]	9.0	9.6
90th percentile	7.7	9.2	10.6	11.3
95th percentile	8.0	9.7	11.1	11.8

Source: EPA (2008a); each value is the time-weighted average from the data summaries presented in the CSEFH, Table 8-3.

[a] MIRC default

Maternal body weight (BW_{mat}). This parameter represents the body weight of the mother averaged over the entire duration of the mother's exposure to the chemical of concern. The maternal body weight is needed to calculate the biological elimination constant for the lipophilic chemical in lactating women (k_{fat_elac}). MIRC assumes that the mother will be pregnant for 9 months (i.e., 0.75 year) and will be lactating for 1 year. The MIRC default maternal body weight also assumes that the mother has been exposed for 10 years total. For 8.25 years, she is not pregnant or lactating, for 0.75 year she is pregnant, and for 1 year she is lactating. The MIRC default BW_{mat} of 66 kg is based on CSFII data compiled by EPA for non-lactating and non-pregnant women between the ages of 15 and 44 (i.e., women of child-bearing age), lactating women, and pregnant women (EPA 2004). Exhibit_Add A2-28 presents additional values for the maternal body weight parameter which the user may choose to use instead of the MIRC default. The BW_{mat} value is *not* the value that MIRC uses to estimate the mother's absorbed daily intake (DAI_{mat}). The daily ingestion rates for home-grown/raised food products in MIRC are for men and women combined, with the rates normalized to body weight. The ingestion rates for soil, water, and fish included in MIRC are not normalized to body weight but are based on both men and women. For those ingestion rates, MIRC uses an average body weight value for males and females to estimate the average daily dose (intake) of the chemical in mg/kg-day. These values are subject to the assumption that the body-weight normalized ingestion rates and resulting ADD values are applicable to nursing mothers.

Exhibit_Add A2-28. Time-weighted Average Body Weight for Mothers

Statistic	Weight (kg)
Mean	66.0[a]
5th	47.1
10th	50.2
25th	54.3
50th	62.0
75th	72.0
90th	85.7
95th	97.0

Source: EPA 2004

[a] MIRC default value

Exposure duration (*ED*). See discussion of *AT* and *ED* above.

Fraction of mother's whole blood that is plasma (f_{bp}). Steinbeck (1954) reported that plasma volume accounts for approximately 60 percent of the total blood volume in non-lactating human females (EPA 1998). Harrison (1967) and Ueland (1976) reported plasma volumes between 63 to 70 percent in postpartum women (EPA 1998). The default value in MIRC of 65 percent (0.65) is the value recommended by EPA in its *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* (MPE, EPA 1998).

Fraction of mother's body weight that is fat (f_{fm}). A limitation of using a steady-state, instead of a dynamic partitioning, model for lactational transfer of chemicals is that several key parameters change over the course of exposure. For example, Equation 2-38, used to estimate the concentration of a lipophilic chemical in breast milk fat, assumes that the mother's body fat will remain constant over the entire duration of breast feeding (t_{bf}), which is unlikely to be true (EPA 2001a). Another limitation of the single analytic model is that chemical transfer rates from blood to milk are unlikely to be the same as the rate of mobilization of the chemical from fat stores to the blood (EPA 2001a). Studies cited in ATSDR's toxicological profile for chlorinated dibenzo-p-dioxins show a correlation between percent body fat and the elimination rate of dioxins, with longer half-lives for dioxins in individuals with a higher proportion of fat in their bodies (ATSDR 1998). In the context of a screening model, however, EPA recommends a default value for the fraction of a mother's body comprised of fat of 0.3 based on data and discussions presented by Smith (1987) and Sullivan *et al*. (1991) (EPA 1998). A fraction of 0.3 indicates that 30 percent of the mother's body weight is fat, which is a health protective value (EPA 2001a). To establish a health protective screening scenario, the MIRC default value for f_{fm} is 0.30**.**

Fraction of fat in mother's breast milk (f_{mbm}). The $C_{milkfat}$ model (Equation 2-38) assumes that a constant fraction of breast milk is fat, even though there is evidence that indicates variation in the fat content of breast milk throughout lactation (Sim and McNeil 1992). Different studies suggest a fat content of breast milk in humans of between 1 and 5 percent (Jensen 1987, Schecter *et al*. 1994, Hong *et al*. 1994, McLachlan 1993, Bates *et al*. 1994, NAS 1991, Butte *et al*. 1984, Maxwell and Burmaster 1993, EPA 2011a, Smith 1987, Sullivan *et al*. 1991). The MIRC default value for f_{mbm} of 0.04 (i.e., 4 percent) is the value EPA recommended for MPE (EPA 1998).

Fraction of maternal weight that is plasma (f_{pm}). Altmann and Dittmer (1964) estimated that plasma volume for adult women ranged from 37 to 60 mL/kg of body weight and averaged about 45 mL/kg. Ueland (1976) observed that the average plasma volume of women 6 weeks postpartum was 45 mL/kg of body weight. Using a value of 1.026 for the specific gravity of plasma from Conley (1974), EPA estimated a value of 0.046 for the fraction of maternal weight that is plasma (EPA 1998). The MIRC default for f_{pm} therefore is 0.046.

Infant breast milk ingestion rate (IR_{milk}). Milk ingestion rates vary with several factors, including the age and size of the infant and use of other foods such as formula. Based on its review of a several studies, EPA recommended time-weighted average and upper percentile milk ingestion rates for infants that nurse for six and for twelve months (EPA 2011a, Table 15-3). To estimate an "average" value, EPA first estimated study-sample-size weighted average values for 1 through 12 months of age and then developed time-weighted average milk ingestion rates from those (EPA 2011a). EPA estimated an upper percentile (upper bound) value as the mean plus two standard deviations. MIRC converts the ingestion rates measured volumetrically (mL/day) to mass-based estimates (kg/day) assuming the density of human milk to be 1.03 g/mL (reported by NAS 1991 and recommended by EPA 2011a). The resulting values are shown in the first two rows of Exhibit_Add A2-29. The MIRC screening-level default of 980 mL/day is an upper-bound estimate based on a one-year nursing period.

Exhibit_Add A2-29 also includes the recommended values for four non-overlapping age categories from the CSEFH (EPA 2008a, Table 15-1). The values demonstrate that although infants grow substantially from birth to one year of age, the "upper bound" estimates of their milk ingestion rates are very close to 1 liter per day at all stages of development in the first year.

Exhibit_Add A2-29. Infant Breast Milk Intake Rates

Age Category	Average (mL/d)	Average (kg/d)	"Upper Bound" (mL/d)	"Upper Bound" (kg/d)	Reference
1 to 6 months	742	0.764	1,033	1.064	EPA 2011a†
0 to < 12 months	688	0.709	980[a]	1.01[a]	EPA 2011a†
0 to < 1 month	510	0.525	950	0.979	EPA 2008a††
1 to < 3 months	690	0.711	980	1.01	EPA 2008a†
3 to < 6 months	770	0.793	1,000	1.03	EPA 2008a†
6 to < 12 months	620	0.639	1,000	1.03	EPA 2008a†

[a]MIRC default; † Based on review of multiple studies; †† Based on a single study

<u>Duration of breast feeding (t_{bf}).</u> This parameter is equal to the infant's exposure duration (*ED*) and the infant's averaging time (*AT*). In its MPE Methodology, EPA asserts a health protective value for the duration of breast feeding of 1 year (i.e., 365 days) and a central tendency estimate of 6 months (180 days) (EPA 1998). Reviewers of MPE noted that 365 days may be overly health protective, given that only 20 percent of infants are breast fed for 6 months, at which point alternative foods are introduced, at least in addition to breast milk (EPA 2001a). Nonetheless, to establish a health protective screening scenario, the MIRC default for t_{bf} is 365 days.

<u>Duration of the mother's exposure to the chemical of concern prior to nursing (t_{pn}).</u> The model shown as Equation 2-38 includes this parameter to reduce the over-estimate of chemical concentration in milk fat that occurs if the model is applied to a chemical with a long biological half-life (e.g., many years). The factor is needed for applications of the model to scenarios with a brief exposure duration (e.g., beginning a few months prior to the start of nursing) relative to the chemical half-life. As the duration of an exposure scenario increases to meet and exceed the chemical half-life, however, the overestimate that occurs without this parameter is reduced. For example, assume a chemical biological half-life of 8 years and a nursing period of 1 year. If exposure of the mother starts at the beginning of nursing, using Equation 2-38 without the t_{pn} term results in an over-estimate of the concentration of the chemical in breast milk by a factor of 28.1 compared with the prediction using Equation 2-38 with the t_{pn} term (EPA 1998, Table 9-6). However, at longer pre-natal exposures of the mother, the magnitude of the over-estimate is reduced: for a 10-year exposure, the magnitude of the overestimate without the t_{pn} term is 2.28, and for a 30-year exposure, the overestimate is reduced to 1.39.

For purposes of the screening-level assessment, we assume an exposure duration equal to the MIRC default half-life for dioxins, or 10 years. Only 3,285 days of that period are pre-natal (i.e., 3650 minus 365 days, assuming 1 year lactation period). Although longer exposure periods are possible for the screening scenario, there is sufficient uncertainty in the model to merit accepting a health protective bias for this parameter value.

6.5.2. Chemical-Specific Parameter Values

The chemical-specific parameters in the breast-milk pathway in MIRC are listed in Exhibit_Add A2-30. Note that the parameters for which values are needed are different for the lipophilic chemicals (i.e., dioxins), for which lactational transfer is assumed to occur via milk fat, and inorganic chemicals, for which the transfer is assumed to occur via the aqueous phase of breast milk (i.e., mercury). All dioxin congeners were assumed to manifest identical values as TCDD in regard to breast milk-related parameters.

Exhibit_Add A2-30. Chemical-specific Input Parameter Values for Breast Milk Exposure Pathway

Parameter and Description		2,3,7,8-TCDD	MeHg
AE_{inf}	Infant absorption efficiency of the chemical by the oral route of exposure (i.e., fraction of ingested chemical that is absorbed by the infant; unitless)	1.0 (default)	1.0 (default)
AE_{mat}	Maternal absorption efficiency of the chemical by the oral route of exposure (i.e., fraction of ingested chemical that is absorbed by the mother; unitless)	1.0 (default)	1.0 (default)
f_{bl}	Fraction of steady-state total body burden of hydrophilic chemical in mother that is in the mother's whole blood compartment (unitless)	NA	0.059 (Kershaw *et al*. 1980)[a]
f_f	Fraction of steady-state lipophilic chemical body burden in mother that is stored in body fat (unitless)	≥0.90 (ATSDR 1992)	NA
$f_{\mathbf{pl}}$	Fraction of steady-state total hydrophilic chemical body burden in mother that is in the blood plasma compartment (unitless)	NA	Not yet identified[b]
h	Biological half-life for chemical in non-lactating women (days)	3650 (EPA 1994c)	50 (Sherlock *et al*. 1984)
k_{aq_elac}	Rate constant for total elimination of hydrophilic chemicals by lactating women (per day)	NA	$= k_{elim}$
k_{elim}	Rate constant for elimination of chemical for non-lactating women (per day; related to chemical half-life)	1.9E-04[b]	1.4E-02 [c]
k_{fat_elac}	Rate constant for total elimination of lipophilic chemicals by lactating women (per day)	Est. using Equation 2-41	NA
Pc_{bm}	Partition coefficient for hydrophilic chemical between maternal *blood plasma* and aqueous phase of breast milk (g milk/g plasma; model assumption)	NA	1.0 (model assumption)
Pc_{RBC}	Partition coefficient for hydrophilic or protein-bound chemical between *red blood cells* (RBC) and *plasma* in maternal blood (mL whole blood/mL RBC)	NA	40 (Hollins *et al*. 1975)

NA = not applicable. ND = not yet determined from literature.

[a] This value is based on a single-dose study and may not be appropriate for a chronic exposure model.

[b] An empirical value for this variable is currently missing for application of model.

[c] This value was calculated from biological half-life (*h*) using Equation 2-40.

Absorption efficiency of the chemical by the oral route of exposure for the infant (AE_{inf}). The models included in MIRC assume that the AE_{inf} from the lipid phase of breast milk is equal to the AE_{inf} from the aqueous phase of the milk. Reviewers of the model stated that this assumption may not be valid and that ideally, the equation DAI_{inf} would include variables for the AE_{inf} from the breast milk fat and the AE_{inf} from the aqueous phase of breast milk (EPA 2001a). However, since the MIRC assumption is that chemicals will partition to either the lipid or aqueous phase of milk, it is not necessary at this time to have multiple AE_{inf} values for a given chemical. If data on the AE from the mother or an adult but not for the infant are available, data for the adult may be used for AE_{inf}. Reviewers also recommended that chemical-specific values come from studies that account for absorption of the chemical from milk, because absorption from other matrices (e.g., solid foods) may not be relevant (EPA 2001a). If chemical-specific data are not available for adults or infants, a health protective default value for AE_{inf} for a screening level assessment is 1.0, which assumes 100 percent absorption (EPA 1998).

The default value for AE_{inf} in MIRC for both MeHg and dioxin is 1.0. For ingested lipophilic chemicals, it is reasonable to assume that absorption will be high (EPA 2004c). ATSDR (1998) reported that dioxins are well absorbed by the oral route of exposure, with one human experiment indicating more than 86 percent absorption. It is EPA policy to assume 100 percent absorption for chemicals with reported *AEs* of 50 percent or higher (EPA 2004c). MeHg also is well absorbed, with measured values as high as 95 percent, and so a value of 100 percent is used in MIRC (EPA 2001b).

Absorption efficiency of the chemical by the oral route of exposure for the mother (AE_{mat}). The default value for both dioxins and MeHg is 1.0, as described in the previous paragraph.

Fraction of total maternal chemical body burden that is in the whole blood (f_{bl}). The default value for MeHg in MIRC, 0.059, is from Kershaw *et al*. (1980), which reported kinetics of blood deposition and clearance of MeHg in humans. Individuals consumed one meal of fish that contained between 18 and 22 µg Hg/kg body weight. The fraction of the dose deposited in the blood volume after mercury was fully distributed in tissues was 5.9 percent or 0.059. This study used a single-dose and thus may not be appropriate for a chronic exposure analysis.

Fraction of total maternal chemical body burden that is in body fat (f_f). Based on ATSDR's *Toxicological Profile for Selected PCBs* (ATSDR 1992) and Sullivan *et al*. (1991), EPA concluded that the "fraction of ingested contaminant stored in fat may be >90%" for lipophilic chemicals such as PCBs and dioxins (EPA 1998). This statement was interpreted to mean that 90 percent of the maternal body burden of chemical at "steady state" is located in body fat for dioxins at steady state.

Fraction of total maternal chemical body burden that is in blood plasma (f_{pl}). For hydrophilic chemicals, this parameter represents the steady-state fraction of the total chemical in the body that is circulating in the blood plasma. Values for f_{pl} may be available for some chemicals in the scientific literature. No value for this parameter for methyl mercury has been identified from the literature at this time. A value can be calculated using Equation 2-43. However, this equation requires a reliable value for f_{bl}, and the value found for mercury may not be appropriate for a chronic exposure analysis (see above).

Chemical half-life in non-lactating women (*h*). In general, highly lipophilic chemicals tend to have relatively long biological half-lives. EPA estimates that the half-life for dioxins is between 7 and 10 years (EPA 1994a). ATSDR estimates that the half-life for 2,3,7,8-TCDD in particular may be as long as 12 years (ATSDR 1998). To establish a health protective screening scenario, the MIRC default half-life for dioxins is set to 10 years or 3650 days.

The half-life for methylmercury is on the order of weeks, not years. Greenwood *et al*. (1978) measured blood clearance rates for MeHg in lactating Iraqi women exposed accidentally to MeHg via bread prepared from wheat treated with a fungicide that contained MeHg. The data indicated a mean half-life for MeHg of approximately 42 days. Sherlock *et al*. (1984) reported an average measured half-life for MeHg of 50 days with a range of 42-70 days. The MIRC default for MeHg is set to the longer average half-life of 50 days.

Chemical elimination rate constant for lactating women – aqueous (k_{aq_elac}). The parameter k_{aq_elac} is equal to k_{elim} plus the loss rate for the chemical in the aqueous phase of breast-milk during lactation. EPA has yet to propose a term for the additional elimination of a chemical in the aqueous phase of milk from breast feeding. In the absence of empirical values, a reasonable assumption for water soluble chemicals is that k_{aq_elac} is equal to k_{elim} as discussed for Equation 2-43. The extent to which k_{elim} is an underestimate of k_{aq_elac} for a given chemical will determine the extent of health protective bias in k_{aq_elac}.

Chemical elimination rate constant for non-lactating women (k_{elim}). Although values for this parameter often are reported directly in the literature, MIRC estimates k_{elim} from chemical half-life assuming first-order kinetics as shown in Equation 2-40. For example, for a biological half-life of 3,650 days for dioxins, k_{elim} is estimated to be 1.9E-04 per day. Assuming a biological half-life of 50 days for MeHg, the value for k_{elim} is estimated to be 0.014 per day.

Rate constant for total elimination of lipophilic chemicals by lactating women (k_{fat_elac}). Although values for this parameter might be found in the scientific literature for some chemicals, in MIRC, k_{fat_elac} for dioxins is calculated from Equation 2-41. When the parameters in that equation are set to the default values in MIRC for dioxins, MIRC estimates a value of 0.0015 per day for k_{fat_elac}.

Partition coefficient for chemical between maternal blood plasma and aqueous phase of breast milk (Pc_{bm}). The aqueous model, presented in Equation 2-42, assumes that the concentrations in the plasma and aqueous phase of breast milk are directly proportional (EPA 1998). Therefore, the default value for this parameter for MeHg in MIRC is 1.0.

Partition coefficient for chemical between red blood cells and plasma in maternal blood (Pc_{RBC}). Chemical-specific values for this parameter should be located in the scientific literature. If chemical-specific values are unavailable and it is assumed that there is equal distribution of the chemical in the plasma and red blood cells, EPA suggests a default value of 1.0 (EPA 1998). For MeHg, MIRC includes a value of 40 based on Hollins *et al*. (1975) study of cats exposed to MeHg, which reported a ratio of radio-labeled mercury in red blood cells to plasma of 97.7 to 2.3 (i.e., ratio of 42.5).

7. Summary of MIRC Default Exposure Parameter Settings

The default settings included in MIRC are intended to be characteristic of a health protective (but plausible) exposure scenario that results in a negligible or extremely low chance of underestimating risk. These default parameter values were used to derive the screening threshold emission rates used for screening emissions of PB-HAPs from sources included in RTR risk assessments. These values are the default, or initial setting, for parameter values in MIRC as described in Section 6 of this addendum. This section summarizes the default parameter values used to calculate screening thresholds.

This chapter is organized to present the chemical- and scenario-specific inputs to MIRC by data type. The screening-level analysis uses 90th percentile ingestion rates for soil, breast milk, and farm food items and 99th percentile ingestion rates for fish (presented in Section 7.1) and population-specific characteristic assumptions (presented in Section 7.2), that are generally health protective in nature. Screening thresholds were derived for five RTR chemical species: benzo(a)pyrene, cadmium, mercuric chloride, methyl mercury, and 2,3,7,8-TCDD; Section 7.3 presents chemical-specific parameter inputs for these five chemicals. Finally, Section 7.4 presents default parameter values for the nursing infant exposure scenario, which applied only to dioxin and methyl mercury as discussed in Section 3.4.

7.1. Default Ingestion Rates

The screening-level (or default) values for ingestion rates for soil, breast milk, and for each farm food item are equal to the 90th percentile of the distribution of national data for that ingestion medium. In general, these values were obtained from the 2011 Exposure Factors Handbook or the 2008 Child-Specific Exposure Factors Handbook (see Exhibit_Add A2-31). Fish ingestion rates are also available from these sources; however, as described in Section 6.3.4, these sources were not used to obtain fish ingestion rates.

7.1.1. Fish Ingestion Rates

The adult fish ingestion rate was obtained from Burger (2002), a study that examined daily consumption of wild-caught fish for high-end recreationalists (white, black and female) in South Carolina. For female high-end consumers of wild-caught fish, Burger identified average and higher-percentile consumption rates as follows: 39.1 g/day (mean), 123 g/day (90th percentile), 172 g/day (95th percentile), and 373 g/day (99th percentile). As shown in Exhibit_Add A2-31 and discussed in Section 6.3.4, for adults, the rate of fish ingestion assumed in the screening scenario is 373 g/day, which corresponds to the 99th percentile value estimated by Burger for adult females. This value was selected to be representative of subsistence fishers.

For the child age groups, as discussed in Section 6.3.4, the baseline fish ingestion rates for the screening scenario are based on “as prepared” total freshwater/estuarine fish ingestion rates at the 99th percentile of the distribution for the *consumer-only* population (i.e., inclusive only of people who consume fish, rather than per-captita rates, which include both consumers and non-consumers), as estimated in EPA (2002), Section 4.2.1.1. Some adjustments were necessary because the age groups evaluated for RTR (which correspond to the age groups for which farm food ingestion rates are available) do not all directly correspond to the age groups in the EPA (2002) report. As described in Section 6.3.4, these adjustments convert the available age-specific data on fish ingestion rates to the age-specific values needed for MIRC.

For the screening-level fish ingestion exposure scenario, the consumer evaluated is an individual who regularly consumes a large amount of fish that he or she has caught locally over the course of a 70-year lifetime. Modeled exposures are intended to encompass those of a subsistance fisher whose diet comprises a substantial proportion of fish. The scenario is not, however, intended to represent the maximum possible exposure an individual subsistence fisher might experience.

Although the fish ingestion rates presented here are representative of the 99th percentile of the evaluated data set, the use of these inputs (compared with 90th percentile values used for other food types) is not considered to be inconsistent. This is due to the idiosyncrasies of the survey data on fish consumption, the fact that the data sets for homegrown foods and fish are not parallel, and the consideration of rates appropriate for subsistence fishers, as described above.

As discussed above, EPA believes that use of these fish ingestion rates strikes the appropriate balance between being health protective and having screening scenarios so conservative that they are of limited use in the decision making process. This high-end fish ingestion rate is appropriate in the context of the conservative screening scenario used in the RTR process and is applicable for national rulemakings given that it is very likely that subsistence woman anglers of child bearing age are located throughout the United States. Using a high-end subsistence fish ingestion rate also is consistent with section 112 of the CAA, which focuses on risks associated with maximally exposed individuals.

7.1.2. Farm Food Chain Ingestion

The default settings assume that all food types are obtained from the area of chemical deposition specified by the user (i.e., fraction of food from contaminated area = 1.0).

For estimates of screening threshold emission rates for PB-HAPS, environmental concentrations and air deposition rates were estimated using TRIM.FaTE for the area of maximal deposition in the vicinity of a hypothetical facility, and thus represent risks estimated for a maximally exposed individual/farm/family.

Exhibit_Add A2-31 also includes a sum of the 90th percentile ingestion rates for homegrown food categories and 99th percentile fish ingestion to show the implied total food ingestion rate associated with setting multiple food-type-specific ingestion rates at upper percentiles. Because these upper percentile values for each farm food category are likely to reflect different individuals, it is likely that addition of multiple upper percentile intake values will exceed the total food ingestion rates expected for the general population. This sum is shown on the third row from the bottom (Total Food: Homegrown Only).

The second row from the bottom presents the 90th percentile of the distribution of *individual total food ingestion rates* from the USDA's 1994-96 and 1998 *Continuing Survey of Food Intakes by Individuals* (CSFII) (USDA 2000) data sets, as analyzed by EPA (EPA 2005e). The total ingestion rate for the farming households (third row from bottom) takes into account the cooking losses typical of each food category to provide a better comparison with the 90th percentile individual total food ingestion rates from CSFII (which are based on consumption of prepared foods). The final row of Exhibit_Add A2-31 shows the likely magnitude of the overestimates by age category by presenting the ratio of the two preceding rows. The values in this row demonstrate the potential for overestimating intake by using upper percentile values for all food groups. This bias may be considered when evaluating the results estimated by MIRC.

Exhibit_Add A2-31. Farm Food Category Ingestion Rates for Health Protective Screening Scenario for Farming Households

Product	Screening-Level Consumer Ingestion Rate						Units
	Infants <1 yr	Child 1–2 yrs	Child 3–5 yrs	Child 6–11 yrs	Child 12–19 yrs	Adult 20–70 yrs	
Farm Food Item							
Beef[a]	NA	9.49	8.83	11.4	3.53	4.41	g/kg-day
Dairy[b]	NA	185	92.5	57.4	30.9	6.16	g/kg-day
Eggs[a]	NA	4.90	3.06	1.90	1.30	1.31	g/kg-day
Exposed Fruit[a]	NA	12.7	5.41	6.98	3.41	2.37	g/kg-day
Exposed Vegetable[a]	NA	10.7	3.47	3.22	2.35	3.09	g/kg-day
Pork[a]	NA	4.90	4.83	3.72	3.69	2.23	g/kg-day
Poultry[a]	NA	7.17	6.52	4.51	3.13	2.69	g/kg-day
Protected Fruit[a]	NA	44.8	32.0	23.3	7.44	15.1	g/kg-day
Protected Vegetable[a]	NA	3.88	2.51	2.14	1.85	1.81	g/kg-day
Root Vegetable[a]	NA	7.25	4.26	3.83	2.26	2.49	g/kg-day
Other							
Breast milk[c]	1.01	NA	NA	NA	NA	NA	kg/day
Soil (dry)	NA	200[d]	200[d]	201[e]	201[e]	201[e]	mg/day
Fish (per individual)[f]	NA	107.7[g]	159.0[g]	268.2[h]	331.0[h]	373	g/day

Exhibit_Add A2-31. Farm Food Category Ingestion Rates for Health Protective Screening Scenario for Farming Households

Product	Screening-Level Consumer Ingestion Rate						Units
	Infants <1 yr	Child 1–2 yrs	Child 3–5 yrs	Child 6–11 yrs	Child 12–19 yrs	Adult 20–70 yrs	
Total Food Ingestion Rates for Comparison Only (not in MIRC; excludes soil and water)							
Total Food: Homegrown only[i]	NA	259	142	99	51	35.5	g/kg-day
Total Food: All Sources[j]	NA	125	91	61	34	23.7	g/kg-day
Overestimate (ratio of Homegrown/Total)	NA	2.1	1.6	1.6	1.5	1.3	(unitless)

Sources: EPA 2011a, EPA 2008a, unless otherwise noted.

NA = not applicable

[a] Primary source for values was the 1987–1988 NFCS survey; compiled results are presented in Chapter 13 of the 2011 Exposure Factors Handbook (EPA, 2011a). When data were unavailable for a particular age group, the intake rate for all age groups was multiplied by the age-specific ratio of intake based on national population intake rates from CSFII.

[b] Primary source for values was 1987–1988 NFCS survey, compiled results are presented in Chapter 13 of the 2011 Exposure Factors Handbook (EPA, 2011a). When data were unavailable for a particular age group, the intake rate for all age groups was multiplied by the age-specific ratio of intake based on national population intake rates from an NHANES 2003–2006 analysis in Chapter 11 of the Exposure Factors Handbook.

[c] Infants are assumed to consume only breast milk for one year.

[d] These values are the recommended "upper percentile" value for children from EPA's 2011 EFH, Chapter 4, Table 4-23. The 2008 CSEFH and 2011 EFH included a high-end value associated with pica only, but this value has not been used.

[e] These values are 90th percentile adult ingestion rates calculated in Stanek et al. 1997, and they are used to represent older children and adults.

[f] The ingestion rate for adults was obtained from Burger (2002) and is the 99th percentile value for adult females considered high-end recreationists; this value is believed to be representative of subsistence fishers. The 99th percentile values for children were derived based on EPA's Estimated Per Capita Fish Consumption in the United States (2002)—Section 4.2.1.1 Table 5 (for child age categories) adjusted and scaled. Values reflect "as prepared" ingestion rates.

[g] The fish ingestion rate for children aged 3–5 years was obtained directly from Section 4.2.1.1, Table 5 in the EPA (2002) report (value presented is rounded); for these children, the RTR age-group range matches the EPA (2002) age category. Fish ingestion rates for children less than 3 years old, however, were not provided. Therefore, for children aged 1–2 years, the fish ingestion rate was calculated using the ingestion rate for children aged 3–5 years scaled downward by the ratio of the mean body weight of children aged 1–2 years to the mean body weight of children aged 3–5-years.

[h] Time-weighted average ingestion rates were calculated using the EPA (2002) fish ingestion estimates in order to adjust for the differences between the age group ranges used for the RTR screening and those presented in the 2002 EPA report.

[i] Sum of post-cooking food ingestion rates. This estimate is calculated by multiplying the food ingestion rates on previous rows (excluding soil and water) by $(1-L_1)x(1-L_2)$, where L_1 and L_2 are the loss rates from Exhibit_Add A2-25. The rows are then summed to get the total post-cooking ingestion rate.

[j] 90th percentile total food intake rates from EPA 2008a and 2005e based on CSFII data 1994-96 and 1998; see Section 6.3.6 of this document.

7.2. Default Screening-Level Population-Specific Parameter Values

The screening-level values for body weights (BWs) for the RTR screening threshold analysis, which serve as the default values in MIRC, are mean values and are presented in Exhibit_Add A2-32. As stated in Section 6 of this addendum, EPA recommends using the mean BW for each age group when using upper percentile values for medium ingestion rates. Use of the mean body weights introduces no bias toward over- or underestimating risk.

Exhibit_Add A2-32. Mean Body Weight Estimates for Adults and Children[a]

Lifestage (years)	Duration (years)	Mean Body Weight (kg)
Adult[b] (20-70)	50	80.0
Child < 1[c]	1	7.83
Child 1-2[c]	2	12.6
Child 3-5[d]	3	18.6

Exhibit_Add A2-32. Mean Body Weight Estimates for Adults and Children[a]

Lifestage (years)	Duration (years)	Mean Body Weight (kg)
Child 6-11[e]	6	36.0
Child 12-19[f]	8	64.2

[a] Sources: EPA 1997, 2008a

[b] EPA-recommended value (EPA 2011a).

[d] These values were obtained directly from Table 8-3 of the 2008 CSEFH.

[e] Each BW represents a time-weighted average of BWs for age groups 6 to <11 years and 11 to <16 years from Table 8-3 of the 2008 CSEFH. Original sample sizes for each of these age groups can also be found in Table 8-3.

[f] These values were calculated as time-weighted average BW for age groups 11 to <16 years and 16 to <21 years from Table 8-3 of the 2008 CSEFH. The direction of the possible bias is unknown. The values match the estimate based on Table 8-22 of the NHANES IV data as presented by Portier et al. (2007).

7.3. Default Chemical-Specific Parameter Values for Screening Analysis

Exhibit_Add A2-33 presents chemical-specific parameter values for input to MIRC for the screening-level analysis. Values for bioavailability when ingested in soil (*Bs*), mammalian metabolism factors (*MF*), correction factors for belowground produce ($VG_{rootveg}$), wet deposition fractions (*Fw*), air to plant transfer factors (Bv_{AG}), root concentration factors (*RCF*), and soil-water partition coefficient (*Kds*) are presented in Exhibit_Add A2-33.

Exhibit_Add A2-33. Chemical-Specific Parameter Values for Input to MIRC[a]

Parameter	Description	Benzo(a)-pyrene	Cadmium	Mercuric chloride	Methyl mercury	2,3,7,8-TCDD	Units
Bs	Soil bioavailability factor for livestock	1	1	1	1	1	unitless
MF	Mammalian metabolism factor	0.01	1	1	1	1	unitless
VGrootveg	Empirical correction factor for belowground produce, i.e., tuber or root vegetable, to account for possible overestimate of the transfer of chemicals from the outside to the inside of bulky tubers or roots (based on carrots and potatoes)	0.01	1	1	0.01	0.01	unitless
Fw	Fraction of wet deposition that adheres to plant surfaces; 0.2 for anions, 0.6 for cations and most organics	0.6	0.6	0.6	0.6	0.6	unitless

Exhibit_Add A2-33. Chemical-Specific Parameter Values for Input to MIRC[a]

Parameter	Description	Benzo(a)-pyrene	Cadmium	Mercuric chloride	Methyl mercury	2,3,7,8-TCDD	Units
BvAG	Air-to-plant biotransfer factor for aboveground produce for vapor-phase chemical in air	124,742	0	1,800	0	65,500	[mg/g produce DW]/[mg/g air]
RCF	Chemical-specific root concentration factor for tubers and root produce	9,684	0	0	0	39,999	L soil pore water/kg root WW
Kds	Chemical-specific soil/water partition coefficient	160,000	75	58,000	7,000	38,904.51	L soil pore water/kg soil DW

[a] Values presented in this exhibit are also presented in previous exhibits; however exact values used in the analysis are presented here, rather than values restricted by significant figures. In addition, only values for those chemicals that are specifically used in the screening analysis are provided here.

Only single estimates were developed for each of these parameters for HHRAP (EPA 2005a), and the potential direction and magnitude of bias toward over- or underestimating risks were not investigated in this analysis. The inputs that are both chemical-specific and plant-type-specific, as presented in Exhibit_Add A2-11, are *not* repeated here. Again, only single estimates were developed for these parameters and the potential direction and magnitude of bias toward over- or underestimating risks were not investigated. Finally, Exhibit_Add A2-34 presents biotransfer factors for each of the chemicals and animal types for which screening threshold emissions were calculated.

Exhibit_Add A2-34. Chemical and Animal-Type Specific Biotransfer Factor (Ba) Values for Input to MIRC

([mg chemical/kg WW tissue or dairy] / [mg chemical intake/day] = day/kg WW tissue or dairy)

Chemical	Beef	Dairy	Pork	Eggs	Poultry
Benzo(a)pyrene	3.8E-02	8.0E-03	4.6E-02	1.6E-02	2.8E-02
Cadmium	1.2E-04	6.5E-06	1.9E-04	2.5E-03	1.1E-01
Mercuric chloride	1.1E-04	1.4E-06	3.4E-05	2.4E-02	2.4E-02
Methyl mercury	1.2E-03	1.7E-05	5.1E-06	3.6E-03	3.6E-03
2,3,7,8-TCDD	3.6E-02	7.7E-03	4.4E-02	1.5E-02	2.7E-02

7.4. Screening-Level Parameter Values for Nursing Infant Exposure

MIRC is configured to evaluate risk to nursing infants exposed to dioxins and to methylmercury (MeHg) in their mother's milk for a family farming and catching fish in the area of maximal air deposition of chemical. Input values were summarized in Section 6.5 of this addendum.

7.4.1. Dioxins

For dioxins, chemical intake via breast milk by nursing infants was estimated using the model presented in EPA's *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* (MPE, EPA 1998). The assumption that lactational transfer of dioxins to the infant occurs via the lipid-phase of milk appears reasonable. The following screening-level assumptions used in that model should bias the results toward health-protective estimates of risks.

- Duration of nursing is a full year and no other foods or liquids are consumed by the infant; a more “typical” value would be six months.
- Absorption efficiency of dioxin in food or milk by mother and infant are 100 percent; this assumption might overestimate absorption but probably by no more than 15 percent (see Section 6.5.2).
- The fat content of human milk is assumed to be 4 percent, a value toward the high end of the reported range of values (1 to 5 percent).
- The maternal chemical intake is estimated using upper percentile ingestion rates for the different homegrown foods (see discussion for Exhibit_Add A2-31); this assumption might overestimate total ingestion of homegrown foods by a factor of more than 2 (see Exhibit_Add A2-31).
- If the fraction of the maternal body burden of dioxin that is in the body fat compartment is greater than 90 percent, as suggested by ATSDR (1998), then actual exposures of the infant may be less than estimated.

There also are parameter values and model assumptions for the lipid-phase breast-milk pathway for which possible bias is unknown.

- The accuracy of the model is unknown; it has not been verified or validated with empirical data.
- Using a half-life of 10 years for dioxins may over- or under-estimate risks.

Finally, there is one assumption that might possibly introduce some bias toward underestimating risks. The model results are sensitive to the biological half-life of the chemical in the mother relative to the length of her exposure prior to the lactation period. Using an exposure duration for the mother equal to the assumed half-life for dioxins, 10 years, may underestimate the duration of exposure of the mother.

7.4.2. Methyl Mercury

For MeHg, empirical data from a single human study (Fujita and Takabatake 1977) was used in conjunction with a physiologically based pharmacokinetic (PBPK) model of lactational transfer of MeHg developed and partially validated by Byczkowski and Lipscomb (2001) to support a very simple predictive model. Both the human data and the PBPK model indicated that for relatively low MeHg exposures, the concentration of MeHg in the nursing infant’s blood is similar to its concentration in the mother’s blood. The PBPK model suggested in addition that the average daily dose of MeHg absorbed from milk by the nursing infant (DAI_{inf}) is indistinguishable from the dose of MeHg absorbed by its mother from her food (DAI_{mat}). The data are limited, and the model includes various assumptions; however, there is no known directional bias in the estimates.

8. References

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Addendum 3. Dermal Risk Screening

CONTENTS, ADDENDUM 3

Exhibits, Addendum 3

Non-inhalation exposure to PB-HAPs can occur by way of the dermal pathway through contact with PB-HAP-contaminated soil and water. However, dermal absorption of chemicals that are originally airborne is generally a relatively minor pathway of exposure compared to other exposure pathways (EPA 2006, Cal/EPA 2000). This section demonstrates that for the conservative tierd screening scenario developed for RTR multipathway evaluation, the dermal exposure route is not a significant risk pathway when compared to the ingestion pathway. In general, the RTR multipathway assessment followed the protocol for evaluating a reasonable maximum exposure as described in EPA's *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Model, Part E, Supplemental Guidance for Dermal Risk Assessment* (EPA 2004).

1. Hazard Identification and Dose Response Assessment

To assess the potential contribution of dermal exposure to non-inhalation exposure, we evaluated the potential for cancer and chronic non-cancer effects for the four PB-HAPs currently assessed in the multipathway screening evaluation for RTR: cadmium, divalent mercury, 2,3,7,8-TCDD, and benzo(a)pyrene. EPA has not developed carcinogenic potency slope factors (CSFs) and non-cancer reference doses (RfDs) specifically for evaluating potential human health concerns associated with dermal exposure to PB-HAPs. Instead, dermal toxicity values can be derived from oral toxicity values via route-to-route extrapolation by adjusting for gastrointestinal (GI) absorption. EPA recommends making this adjustment only when GI absorption of the chemical is significantly less than 100% (i.e., less than 50 percent). Otherwise, a default value of complete (100 percent) oral absorption is assumed, and no adjustment is made (EPA 2004).

The absorbed cancer slope factor (CSF_{ABS}) is based on the oral cancer slope factor (CSF_O) and the fraction of the contaminant absorbed in the gastrointestinal track (ABS_{GI}), as follows:

$$CSF_{ABS} = \frac{CSF_o}{ABS_{GI}}$$

where:

CSF_{ABS} = Absorbed slope factor $(mg/kg\text{-}day)^{-1}$
CSF_o = Oral slope factor $(mg/kg\text{-}day)^{-1}$
ABS_{GI} = Fraction of chemical absorbed in gastrointestinal tract (unitless)

The absorbed reference dose (RfD_{ABS}) is based on the oral reference dose (RFD_O) and the fraction of the contaminant absorbed in the gastrointestinal tract (ABS_{GI}), as shown below.

$$RfD_{ABS} = RfD_o \times ABS_{GI}$$

where:

RfD_{ABS} = Absorbed reference dose (mg/kg-day)
RfD_o = Oral reference dose (mg/kg-day)
ABS_{GI} = Fraction of chemical absorbed in gastrointestinal tract (unitless)

The GI absorptions for 2,3,7,8-TCDD and all polycyclic aromatic hydrocarbons (PAHs) (which includes benzo[a]pyrene) were estimated to be greater than 50 percent. Therefore, as shown in Exhibit_Add A3-1, no adjustments to the available oral CSFs were required. For cadmium and divalent mercury, adjustments were made based on absorption data provided in RAGS Part E, Exhibit 4-1. The RfDs for dermal exposure to cadmium and divalent mercury are also shown in Exhibit_Add A3-1.

Exhibit_Add A3-1. Cancer Slope Factors and Reference Doses Based on Absorbed Dose

PB-HAP	Fraction of Contaminant Absorbed in GI Tract (ABS_{GI}) (unitless)	Absorbed Cancer Slope Factor (CSF_{ABS})[a] $(mg/kg\text{-}day)^{-1}$	Absorbed Reference Dose (RfD_{ABS})[a] (mg/kg-day)
Cadmium Compounds	0.05	NA	2.5E-05
Divalent Mercury	0.07	NA	2.1E-05
2,3,7,8-TCDD	No adjustment required [b]	1.5E+05	1.0E-09
Benzo[a]pyrene	No adjustment required [b]	1.0E+01	NA

NA = Not applicable

[a] Oral dose response values are presented in Appendix 2. Only the resulting adjusted dose response values are presented in this table.

[b] According to RAGS Part E, Exhibit 4-1, GI absorption is expected to be greater than 50%.

2. Dermal Exposure Estimation

Dermal exposures and risks resulting from absorption of the chemical through the skin from contact with contaminated water and soil were evaluated for the RTR screening scenario. Individuals were assumed to be exposed on a fraction of their bodies (i.e., their head, forearms, hands, lower legs, and feet) to contaminated soil from the TRIM.FaTE surface soil parcel with the highest concentration (N1) on a daily basis. For the water evaluation, individuals were assumed to be exposed to contaminated surface water with the same PB-HAP concentration as the TRIM.FaTE screening scenario lake over their entire bodies on a daily basis.

2.1. Equations for Estimating Dermal Exposure

The general equation used to estimate dermal absorbed dose (DAD) for water or soil is shown below, and is expressed in milligrams of PB-HAP per kilogram of receptor body weight per day (mg/kg-day). DADs are calculated separately for the water and soil pathways and then added together for each age group.

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$$

where:

DA_{event} = Absorbed dose per event; chemical-specific; equation for DA_{event} also differs depending on water or soil contact (mg/cm^2-event)

EV = Event frequency (events/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

SA = Skin surface area available for contact (cm^2)

BW = Body weight (kg)

AT = Averaging time; for non-cancer effects, equals ED x 365 days/year; for cancer effects, equals 70 years x 365 days/year (days)

DA_{event} is estimated to be the total dose absorbed through the skin at the end of exposure and the equation for calculation is different for organic and inorganic chemicals in water and for soil. The equations for calculating these chemical-specific DA_{event} values for water contact are provided in RAGS Part E, Chapter 3 (see Equations 3.2 – 3.4). For soil, the equation for calculating these chemical-specific DA_{event} values is provided in RAGS Part E, Chapter 3 (see Equation 3.12).

$$\textit{Water – Organic Chemicals:}\quad DA_{event} = C_w \times 2 \times FA \times K_p \sqrt{\frac{6 \times \tau_{event} \times t_{event}}{\pi}}$$

$$\textit{Water – Inorganic Chemicals:}\quad DA_{event} = C_w \times K_p \times t_{event}$$

$$\textit{Soil – All Chemicals:}\quad DA_{event} = C_s \times AF \times ABS \times CF$$

where:

DA_{event} = Absorbed dose per event (mg/cm^2-event)

C_w C_s = Chemical concentration in water (mg/cm^3) or soil (mg/kg)

K_p = Chemical-specific dermal permeability coefficient of compound in water (cm/hr)

FA = Chemical-specific fraction absorbed; accounts for loss due to the regular shedding of skin cells of some chemical originally dissolved into skin (unitless)

τ_{event} = Chemical-specific lag time per event (hr/event)

t_{event} = Receptor-specific event duration (hr/event)

AF = Receptor- and activity-specific adherence factor of soil to skin (mg/cm^2-event)

ABS = Chemical-specific dermal absorption fraction (unitless)

CF = Conversion factor (10^{-6} kg/mg)

2.2. Exposure Factors and Assumptions

The exposure parameters included in this assessment and their default and other value options are summarized in this subsection. Default values were selected to result in a highly conservative estimate of exposure (i.e., exposures are likely overestimated). Parameter values were primarily obtained or estimated from RAGS Part E (EPA 2004) and the Child-Specific Exposure Factors Handbook (CSEFH, EPA 2008). Receptor-and scenario-specific exposure assumptions are discussed first, and a discussion of chemical-specific parameters values follows. Estimated water and soil exposure concentrations are presented at the end of this subsection.

2.3. Receptor-Specific Parameters

Dermal exposures and risks were estimated for the same age groups used in the ingestion exposure assessment: adults (ages 20 to 70 years) and five child age groups: <1 year; 1 to 2 years; 3 to 5 years; 6 to 11 years; and 12 to 19 years. The body weight values used in the ingestion exposure assessment were used in the dermal exposure assessment.

Body surface areas (SAs) for water and soil exposures for adults were calculated using Appendix C, Exhibit C-1, of RAGS Part E. For children, SAs for water and soil exposures for the five children's age groups were estimated using Tables 7-1 and 7-2 of the CSEFH, respectively. For SA (water), individuals were assumed to shower or bathe in the water with 100 percent of their body exposed. For SA (soil), it was assumed that individuals were exposed on a fraction of their total body, specifically their head, forearms, hands, lower legs, and feet. Based on information provided in RAGS Part E, the SA for forearms was calculated using the SA for arms and assuming a forearm-to-arm ratio of 0.45, and the SA for lower legs was estimated using the SA for legs and assuming a lower leg-to-leg ratio of 0.4.

Values for body SA by age group are summarized in Exhibit_Add A3-2.

Exhibit_Add A3-2. Receptor-Specific Body Surface Area Assumed to be Exposed to Chemicals

Age Group[a] (years)	Surface Area for Water Exposure (cm^2)	Surface Area for Soil Exposure (cm^2)
Adult 20-70	18,150[g]	6,878[h]
Child <1[b]	3,992	1,772
Child 1-2[c]	5,700	2,405
Child 3-5[d]	7,600	3,354
Child 6-11[e]	10,800	4,501
Child 12-19[f]	17,150	6,906

[a] Sources for the child groups included Table 7-1 (total body surface area for SA-Water), and Table 7-2 (fraction of total body surface area for SA-Soil) of the 2008 CSEFH.

[b] Represents a time-weighted average for age groups birth to <1 month, 1 to <3 months, 3 to <6 months, and 6 to <12 months.

[c] Represents a time-weighted average for age groups 1 to <2 years and 2 to <3 years.

[d] Values for age group 3 to <6 years in the 2008 CSEFH.

[e] Values for age group 6 to <11 years in the 2008 CSEFH. Represents a conservative (i.e., slightly low) estimate for ages 6 through 11 years since 11-year olds are not included in this CSEFH age group.

[f] Represents a time-weighted average for age groups 11 to <16 years and 16 to <21 years. Note that estimated values include 11-year-olds and individuals through age 20, which contributes to uncertainty in the estimates for 12 to 19 years.

[g] Represents the average total surface area of adults from Table C-1 of RAGS Part E.

[h] Represents the average surface area of adults for head, forearms, hands, lower legs, and feet from Table C-1 of RAGS Part E.

2.4. Scenario-Specific Parameters

Exhibit_Add A3-3 summarizes the exposure values related to frequency and duration of contact. In general, these are the recommended defaults for calculating a reasonable maximum exposure (RME) for a residential scenario as proposed by EPA in RAGS Part E, Chapter 3.

Exhibit_Add A3-3. Scenario-Specific Exposure Values for Water and Soil Contact

Exposure Parameter	Receptor	Value	Source
Water Contact			
Event Duration (t_{event}) (hr/event)	Child	1	Reasonable maximum exposure scenario for showering/bathing from RAGS Part E, Exhibit 3-2
	Adult	0.58	
Soil Contact			
Soil Adherence Factor (AF) (mg/cm^2)	Child	0.2	For children, value is geometric mean value for children playing (wet soil) and for adults, value is geometric mean value for an adult farmer from RAGS Part E, Exhibit 3-3
	Adult	0.1	
Both Media			
Event Frequency (EV) (events/day)	All	1	Reasonable maximum exposure scenario from RAGS Part E, Exhibits 3-2 and 3-5.
Exposure Frequency (EF) (days/year)	All	350	
Exposure Duration (ED) (years)	Child <1	1	Represents the number of years included in the age group; also used in ingestion exposure calculations.
	Child 1-2	2	
	Child 3-5	3	
	Child 6-11	6	
	Child 12-19	8	
	Adult 20-70	50	
Averaging Time (AT) (days)	For cancer assessment, an AT equal to a lifetime (70 years) × 365 days/year is used. Same value used in ingestion exposure calculations. For non-cancer assessment, an AT equal to the exposure duration (ED) × 365 days/year is used, so AT will vary by receptor group. Same value used in ingestion exposure calculations.		

2.5. Chemical-Specific Parameters

The chemical-specific parameters required to quantitatively evaluate dermal pathway exposures are listed in Exhibit_Add A3-4. For the water concentration in the dermal analysis, the modeled TRIM.FaTE chemical concentration in the screening scenario pond at the screening threshold emission rate was used. For the soil concentration, the modeled TRIM.FaTE chemical concentration in surface soil in parcel N1 (untilled soil, closest to facility) of the screening scenario at threshold emission rate was used. This same soil concentration was also used in ingestion exposure calculations for soil ingestion.

Dermal absorption of chemicals in water is based on the use of a dermal permeability coefficient (K_p), which measures the rate that a chemical penetrates the skin. Dermal absorption of soil-bound chemicals is based on the use of a dermal absorption fraction (ABS), which is a measure of how much of a chemical the skin absorbs through contact with soil.

Exhibit_Add A3-4. Chemical-Specific Dermal Exposure Values for Water and Soil Contact

PB-HAP	Cadmium	Divalent Mercury	2,3,7,8-TCDD	Benzo[a] pyrene	Source
Chemical concentration in Water (Cw) (mg/cm^3)	2.4E-08	1.9E-09	2.6E-18	2.1E-13	TRIM.FaTE modeled concentration in screening scenario pond
Chemical concentration in Soil (Cs) (mg/kg)	6.9E-02	6.3E-02	2.2E-10	1.4E-04	TRIM.FaTE modeled concentration in surface soil in parcel N1 in screening scenario
Permeability coefficient in water (Kp) (cm/hour)	0.001	0.001	0.81	0.7	Values from RAGS Part E, Exhibits B-3 (organics) and B-4 (inorganics)
Fraction absorbed water (FA) (unitless)	NA	NA	0.5	1.00	Values from RAGS Part E, Exhibits B-3; only used for organic chemicals
Lag time per event (event) (hr/event)	NA	NA	6.82	2.69	Values from RAGS Part E, Exhibits B-3; only used for organic chemicals
Dermal absorption fraction (ABS) from soil (unitless)	0.001	0.045[a]	0.03	0.13	Values from RAGS Part E, Exhibit 3-4, unless otherwise noted

[a] Value obtained from Bioavailability in Environmental Risk Assessment (Hrudey et al. 1996).

3. Screening-Level Cancer Risks and Non-Cancer Hazard Quotients

Toxicity values were used in conjunction with exposure information to evaluate the potential for cancer risks and non-cancer health hazards. Risk estimation methods are presented below.

3.1. Dermal Cancer Risk

Cancer risk for the dermal route was calculated as the product of the age-specific *DAD*s and the absorbed CSF for each chemical, as follows:

$$\text{Dermal Cancer Risk} = DAD \times CSF_{ABS}$$

where:

DAD = Dermal Absorbed Dose (mg/kg-day)

CSF_{ABS} = Absorbed cancer slope factor $(\text{mg/kg-day})^{-1}$

Lifetime dermal cancer risks were calculated for 2,3,7,8-TCDD and benzo[a]pyrene. The total risk accounts for dermal exposures that an individual might receive from these PB-HAPs in water plus soil over his or her lifetime (70 years).

3.2. Dermal Hazard Quotient

Dermal hazard quotient (HQ) was estimated as the ratio of age-specific *DAD*s to the absorbed RfD for each chemical, as shown below:

$$Dermal\ HQ = DAD / RfD_{ABS}$$

where:

DAD = Dermal Absorbed Dose (mg/kg-day)

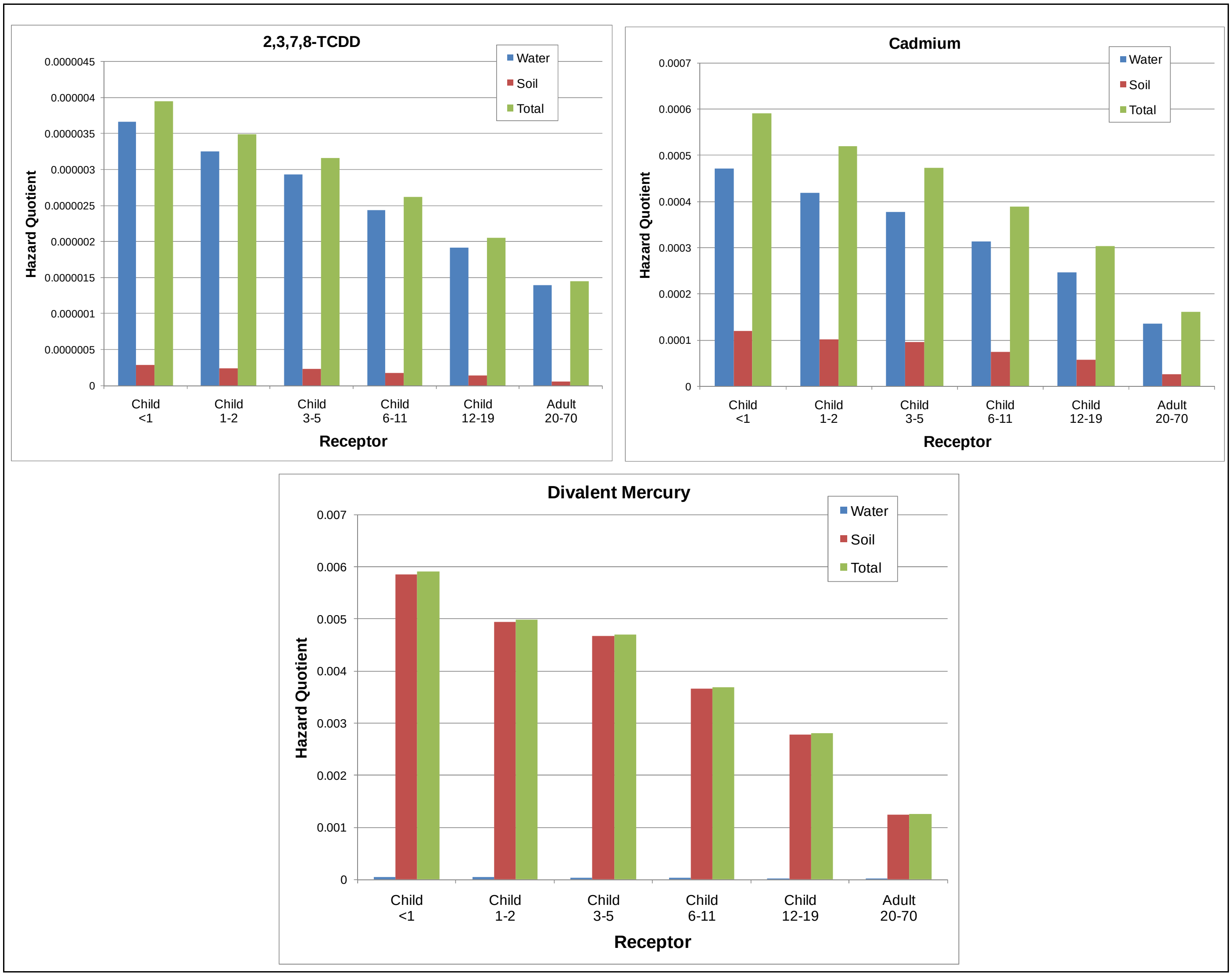
RfD_{ABS} = Absorbed reference dose (mg/kg-day)

The aggregate HQ accounts for exposures that an individual in a receptor group may receive from the PB-HAP in water and soil over the exposure duration. Non-cancer hazard is not additive *across* the age groups evaluated here.

4. Dermal Screening Results

Exhibit_Add A3-5 presents a summary of estimated dermal non-cancer hazards by age group. A summary of estimated lifetime dermal cancer risks is provided in Exhibit_Add A3-6. The highest HQ value was 0.006 (representing divalent mercury exposure for children less than 1 year of age) or less. This is approximately 170 times less than the potential ingestion hazard quotients associated with the screening scenario (i.e. emissions of divalent mercury in the screening scenario resulted in an ingestion hazard quotient of 1). The highest estimated individual lifetime cancer risk associated with potential dermal exposures was 4.1E-09 for benzo[a]pyrene; this value is approximately 240 times smaller than the ingestion risk (i.e., 1E-06) estimated for the same screening threshold emission rate.

Exhibit_Add A3-5. Summary of Dermal Non-Cancer Hazards



Exhibit_Add A3-6. Summary of Dermal Cancer Risks

PB-HAP	Dermal Lifetime Cancer Risk	Magnitude of Difference[a]
2,3,7,8-TCDD		
Water	2.64E-10	>3,700
Soil	1.49E-11	>67,300
Total	2.79E-10	>3,500
Benzo[a]pyrene		
Water	1.50E-09	>600
Soil	2.63E-09	>300
Total	4.12E-09	>200

[a] Represents the magnitude of difference between the estimated dermal risk and the potential ingestion risk associated with the screening scenario.

Based on these results and taking into consideration the extremely conservative nature of the dermal exposure calculations, it was assumed that it is not necessary to incorporate dermal exposures in calculating multipathway screening threshold levels. Specifically, the daily exposure durations of 0.58 hour for adults and 1 hour for children used to calculate dermal exposure from water are highly conservative and assume that the individual is bathing in surface water taken directly from a contaminated lake or is swimming in the lake for 350 days of the year. The exposure frequency of 350 days and corresponding skin surface area available for contact with contaminated soils (i.e., head, hands, arms, legs, and feet) likely also grossly overestimates dermal exposure to soil.

5. References

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Attachment B. Tier 2 Screening Methodology

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CONTENTS, ATTACHMENT B

EXHIBITS, ATTACHMENT B

B.1 Overview of Approach

The Tier 1 screening scenario is, by design, generic and health-protective. It was constructed to allow for quick application to a large number of facilities in a source category with a minimal chance of returning false negatives for risk. Based on screening analyses conducted for RTR to date, many facilities can "fail" the Tier 1 screen. Because the Tier 1 screen uses "worst case" assumptions, the analysis must be refined to determine whether the failing facility is actually expected to pose a risk.

One way to refine the risk estimates is to conduct a site-specific assessment where the Tier 1 model values and layout are replaced with site-specific values wherever possible. However, this approach would not be feasible given the resource intensive nature of a site-specific assessment and the number of facilities that tend to fail the Tier 1 screen in the different source categories.

As an intermediate approach, we instead refine our Tier 1 screening estimates to Tier 2 screening estimates. This is done by replacing some of the worst-case assumptions in a Tier 1 screen with more site-appropriate values. Specifically, for Tier 2, the following variable values are varied from their Tier 1 values:

- Meteorological characteristics, including the fraction of time the wind blows in the direction of the farm and lake (using wind direction), the wind speed, the precipitation rate, and the mixing height; and
- Location of the nearest fishable lake(s) relative to the facility.[23]

In selecting the fate and transport variables listed above to include in Tier 2 adjustments, a balance was struck between: 1) the degree of impact on the potential risk estimate; 2) the ease of implementation in TRIM.FaTE; and 3) the ease of obtaining site-specific values on a facility-by-facility basis. Because of the expected variability in exposure parameters (such as fish or food ingestion rates) amongst any population living around a given facility, only the fate and transport parameters were candidates to be varied in the Tier 2 analysis, and the exposure parameters remain at their health-protective Tier 1 values.

Tier 2 screening assessments are performed for those facilities that fail the Tier 1 screening assessment. The overall implementation of Tier 2 is shown in Exhibit_Att B-1. The starting point (shown in green) is the ratio of the facility emission rate for the PB-HAP of concern to the Tier 1 threshold for that PB-HAP. Next, the facility-specific estimates of the Tier 2 meteorological and lake-location parameters listed above must be gathered for each facility (shown in red). Then, the associated TRIM.FaTE and MIRC estimates of risk must be estimated (shown in orange). Because of the volume of facilities that need to be evaluated in Tier 2, the implementation focuses on estimating refined risk using pre-calculated databases (discussed below) rather than gathering the input data and performing TRIM.FaTE and MIRC modeling speartely for each facility.

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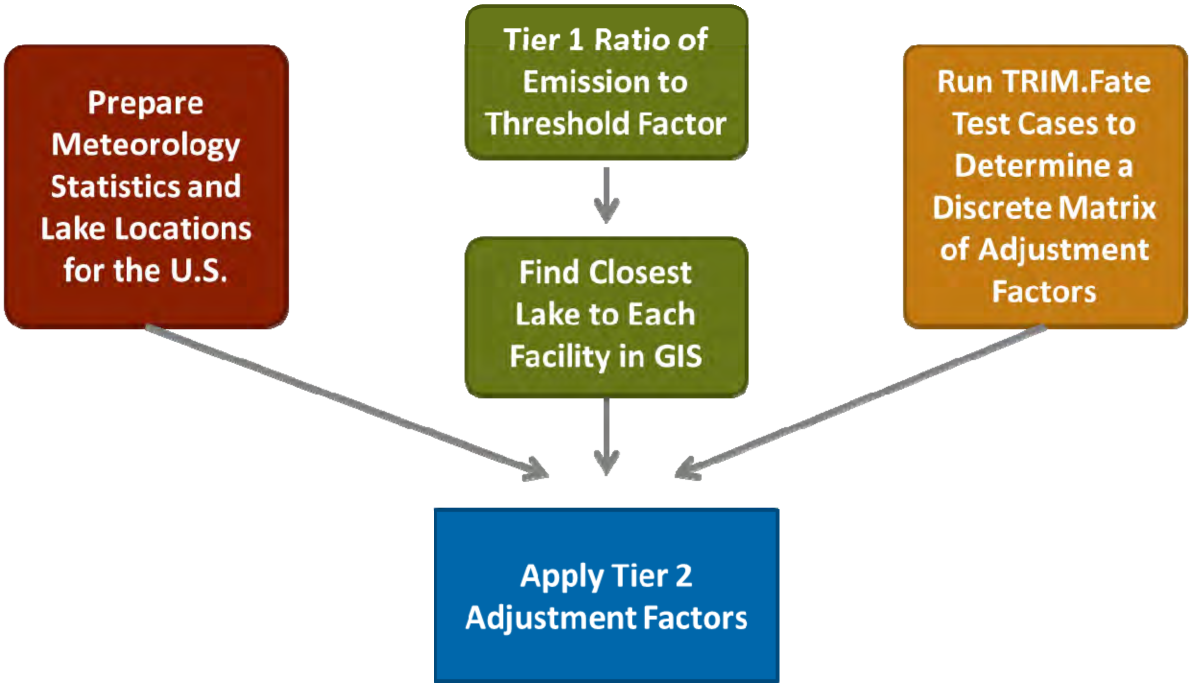
[23] The lake size was also changed for each new facility lake distance. This change allowed the simulations to maintain a constant ratio between watershed and erosion area compared with the lake area.

Exhibit_Att B-1. Basic Implementation Process for Implementing Tier 2



First, databases of the relevant U.S. meteorological and lake data were created that can be accessed during a Tier 2 evaluation (shown in red in the figure). These meteorological and lake data are discussed in more detail in Section B.4. The meteorological database includes annual-average summary statistics on wind direction, wind speed, and precipitation for more than 800 surface stations paired with their closest upper-air stations located throughout the United States. These surface data cover year 2011 and are the sameAERMOD-ready data used by EPA OAQPS for RTR inhalation modeling. As discussed below, in most cases the 2011 precipitation data were not used, and instead, the 30-year average annual precipitation data for each station were used. The database of lakes, available from ESRI® and based on U.S. Geological Survey data, includes information on the location, size, use or type designation, and name (if available) of all lakes in the United States. To focus on lakes that can support angling of upper trophic level fish, lakes used for disposal, evaporation, or treatment were excluded, and only lakes greater than 100 acres in area are included. Lakes larger than 100,000 acres in area are not included because the sizes of their watersheds and the complexity of their lake dynamics are not feasible to model with the TRIM.FaTE modeling system.

In parallel to the meterological and lake data collection, a series of TRIM.FaTE simulations was performed that systematically varied the values for four of the five selected fate and transport variables (shown in orange in the figure, consisting of lake location, wind speed, precipitation rate, and mixing height). Wind direction affects only whether the chemical mass advects toward the farm and lake, so the effect of site-specific wind directions can be evaluated outside TRIM.FaTE simulations. These simulations do not simulate specific facilities; instead, four or five alternative values for each of the four variables were selected using statistics on U.S. meteorological data or professional judgment to capture the expected range in the facility data. TRIM.FaTE simulations were performed for every possible combination of these variable values to enable the estimation of appropriate site-specific threshold adjustment factors for scenarios with the corresponding characteristics. Based on the TRIM.FaTE results of these simulations (and the subsequent exposure and risk characterization, conducted using MIRC), a matrix of

Tier 2 threshold adjustment factors was calculated, with each element of the matrix corresponding to a unique combination of values from each of the selected variables.

These TRIM.FaTE and MIRC simulations are used to estimate part of the Tier 2 threshold adjustment factors. Wind direction is the other part of the Tier 2 threshold adjustment factors. The wind direction adjustment for a given facility is the ratio of the frequency that winds blow toward the Tier 1 farm and lake (43 percent of the time) and the frequency that winds blow toward the facility-specific farm and lake in Tier 2. These Tier 2 threshold adjustment factors are multiplied by each other and represent the ratio between the risk metric (i.e., cancer risk or HQ) obtained using the baseline Tier 1 screening scenario and the risk metric obtained from the Tier 2 TRIM.FaTE runs. For a given facility, an adjusted Tier 2 ratio (emissions compared to the emission threshold) can be estimated by dividing the Tier 1 emission ratio (the output of the Tier 1 screen) by the adjustment factor that best corresponds to the meteorological conditions present at the site and the presence and location of lakes at the site:

$$\textit{Tier 2 Ratio} = \textit{Tier 1 Ratio} \div \textit{Tier 2 Adjustment Factor}$$

Matrices of threshold adjustment factors from the TRIM.FaTE and MIRC simulations were separately developed for the four PB-HAPs that currently have screening emission thresholds in the Tier 1 process: benzo(a)pyrene (BaP, representative of PAHs), cadmium, divalent mercury and 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD, representative of dioxins). The wind direction threshold adjustment factors were irrespective of chemical (specific only to the facility). In implementing the Tier 2 process, a risk equivalency approach was used to convert speciated emissions of PAHs and dioxins into BaP and TCDD equivalents, respectively, similar to the Tier 1 screening approach.

Finally, to implement the Tier 2 screen, a Microsoft® Excel™ tool was created that includes the database of meteorological data and lake data as well as the Tier 2 adjustment factors for the combinations of variables simulated in the Tier 2 TRIM.FaTE simulations. In the tool, each facility is matched with the closest surface meteorological station, and the values for the four relevant parameters at that station are recorded (wind speed, wind direction, precipitation rate, and mixing height). The distance from the facility to the nearest qualifying lake in each octant around the facility are estimated using GIS and are also imported. These five values become the set of facility-specific parameters. The threshold adjustment factor corresponding to this set of site-specific data is then estimated using the matrix of adjustment factors and the wind direction adjustment Wind direction values are used as-is with no rounding or binning. If one of the four facility matrix variables (wind speed, precipitation rate, mixing height, or lake location) is between two of the computed levels available for that variable in the simulation matrix, the more health-protective of the two levels is selected (i.e., the level that resulted in the smaller adjustment to the baseline Tier 1 exposure). The Tier 1 screening emission threshold for a PB-HAP is then multiplied by the appropriate adjustment factors to obtain an updated Tier 2 emission threshold for that PB-HAP at that facility. A facility then passes the Tier 2 screen if the emission is below the Tier 2 threshold. Selection of Site-Specific Characteristics to Include in the Tier 2 Analysis

The screening scenario used to derive Tier 1 thresholds incorporates assumptions regarding meteorological conditions, the spatial configuration of the hypothetical exposure setting, physical parameters of the environment, and chemical-specific parameters that result in generally health-protective results. In Tier 2, selected assumptions used in the fate and transport modeling conducted using TRIM.FaTE are modified to reflect more site-specific information for the facilities being evaluated.[24] To determine which scenario characteristics should be incorporated into the Tier 2 analysis, the following issues were considered for TRIM.FaTE model parameters:

- How sensitive are the modeled risks to a specific user-input model parameter (e.g., wind direction, wind speed)?
- Do the plausible values for a given parameter span a large range when comparing different RTR facilty locations?
- Which site-specific characteristics can be found easily and reliably for facilities with emissions exceeding Tier 1 thresholds?
- In general, is the uncertainty associated with the parameter high or low?
- How complicated or time-consuming is the incorporation of a given parameter (e.g., wind speed) into the Tier 1 screening scenario set-up?

Addendum 1 to this attachment provides an exhibit showing all the TRIM.FaTE variables considered for the Tier 2 analysis. These variables were evaluated qualitatively using the criteria above to determine whether the variable was of high, medium, or low priority. The following five “high priority” variables were selected for implementation in the current Tier 2 analysis:

- Wind direction (the percent of time the wind blows toward the lake and farm),
- Wind speed,
- Precipitation,
- Mixing height, and
- Location of the nearest fishable lake relative to the facility.

These parameters were judged to represent a balance between range of potential variability, ease of implementation within the modeling scheme used for RTR, and ease of obtaining site-specific values with a relatively high level of confidence.

B.2 Estimation of Adjustment Factors for Selected Site-Specific Parameters

The purpose of including site-specific detail for a facility evaluated in Tier 2 is to develop a more realistic estimate of risk associated with facility emissions. This purpose is achieved within the analysis by generating revised emission thresholds of potential concern specific to a given PB-HAP on a facility-by-facility basis. However, instead of performing full-fledged, site-specific model runs for each facility that does not “screen out” in Tier 1, a set of generally applicable threshold adjustment factors for each PB-HAP was developed based on a set of model runs. For each PB-HAP, these runs corresponded to unique combinations of values for wind speed, precipitation rate, mixing height, and lake location (wind direction is assessed separately). These adjustment factors were based on a set of runs in which the values for these parameters were varied systematically. The wind direction adjustment factor is the ratio of the frequency

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[24] Only TRIM.FaTE parameters were considered for inclusion in Tier 2 adjustments because of the difficulty in identifying substantial ***location-related*** differences in values for exposure factors (and other inputs to MIRC). The exposure characteristics used in MIRC are considered to be generally consistent across different locations and facilities.

that winds blow toward the lake and farm in the Tier 1 screening scenario (43 percent) and the frequency that winds blow toward the facility's farm and lake in Tier 2. The appropriate adjustment factors are then applied to the Tier 1 threshold for that PB-HAP when evaluating a facility in Tier 2.

The analyses conducted to select the parameters to derive the threshold adjustment factors are described in this section. Section B.2.2 also describes the development of appropriate "bins" for the selected parameters. These bins correspond to the subset of parameter values for which adjustment factors were calculated, based on the anticipated range of plausible values for facilities evaluated in RTR.

B.2.1 Selection Values for Variables of Interest

For each site-specific parameter that is assessed in the Tier 2 analysis, other than wind direction, adjustment factors were estimated that correspond to a set of four to six particular values for the parameter. The adjustment factor for wind direction directly relates Tier 1 and site-specific Tier 2 wind direction frequencies, with respect to the directions of the lake and farm. These individual adjustment factors can the be multiplied for a particular variable combination to get an overall adjustment factor. To facilitate this, bins were created for each parameter of interest and a relevant range of values, with the exception of wind direction (as described below, representative bins were not necessary for this parameter). The rationale for selecting the range for each bin for each parameter of interest is described below.

Wind Direction: Within the context of the hypothetical exposure scenario used in Tier 1 (and under actual conditions), when the frequency with which the wind blows towards the modeled domain (i.e., where the hypothetical farm and lake are located) increases, greater pollutant deposition will occur over and around the farm and lake. The percentage of time the wind blows toward the farm and lake is therefore positively correlated with ingestion exposure and risk. In the screening scenario used to estimate Tier 1 thresholds, the wind is assumed to blow toward the modeled domain 3 days a week, or 43 percent of the time. This assumption is intended to approximate an unusually consistent long-term wind pattern and is representative of wind direction patterns in Yakima, Washington (where the wind blows eastward approximately 40 percent of the time, based on a review of wind direction data compiled by the National Weather Service).

In the model runs to develop the Tier 2 bins, this factor was changed to 1, 2, and 4 days per week, corresponding to 14 percent, 29 percent, and 57 percent of the time. This range of values was chosen to obtain a good understanding of the impact of wind direction on risk for the range of wind direction patterns likely to be present at real facilities. Review of these results indicated that, within this modeling scenario, estimated ingestion exposure varies directly with percentage of time the wind blows toward the farm and lake. Given the exactly linear nature of the relationship observed in model results obtained from these runs, the adjustment of the threshold for wind direction in Tier 2 is a direct, linear adjustment **using the actual site value** rather than an incremental, bin-based approach. In other words, the Tier 1 threshold is adjusted for wind direction in direct proportion to the difference between conditions for the actual facility location and the wind direction parameters included in the Tier 1 screening scenario (i.e., blowing toward the lake/farm 43 percent of the time on average).

Wind Speed: Although the impact of wind speed on non-inhalation risks also is likely to depend on configurational parameters such as the location of farms and lakes, in general it is reasonable to assume that higher wind speeds lead to more rapid chemical transfer out of the modeled domain, allowing less time for chemical deposition and, therefore, less total near-field deposition and a lower exposure and risk. The Tier 1 screening analysis assumed a wind speed of 2.8 m/s, corresponding to the 5th percentile (i.e., slower) of annual average speed for the contiguous United States (distribution was based on data from a climate publication from the National Oceanic and Atmospheric Administration [NOAA], which used data from over 200 stations nationwide).[25] This value is similar to the annual average wind speeds of the U.S. Deep South.[26] In the model runs to develop the Tier 2 threshold adjustment factors, we calculated the change to exposure resulting from increasing this value to 3.5 m/s, 4 m/s, and 5 m/s (values also shown in Exhibit_Att B-2; 5 m/s is the 88th percentile in the NOAA data). Based on these values, the bins used to classify wind speed are: 2.8–3.5 m/s, 3.5–4 m/s, 4–5 m/s and above 5 m/s. In all modeled cases, increasing the wind speed while maintaining constant lake location, wind direction, mixing height, and precipitation led to Tier 2 estimations of high-end risk or hazard that were smaller than that of Tier 1. To ensure that the approach is health-protective, a facility was assigned the lower end value of the bin into which it was placed. Facilities with wind speeds less than 2.8 m/s were assumed to have a wind speed of 2.8 m/s.

Exhibit_Att B-2. Lake Distance and Meteorological Parameter Values for which Adjustment Factors were Developed in Tier 2[a,b]

Parameter	Value
Wind Speed (m/s)	**2.8**
	3.5
	4
	5
Precipitation (mm/yr)	512
	924
	1,187
	1,500
Mixing Height (m)	**710**
	865
	1,097
	1,537
Lake Distance (km)	No lake
	2
	5
	10
	20
	40

[a] Bold indicates the value is equal to the value used in Tier 1.
[b] Wind direction is not shown here because its effect on modeled exposure and risk in TRIM.FaTE is linear.

Precipitation: Higher levels of precipitation over the modeled domain are expected to increase non-inhalation risks by increasing particulate and gaseous wet deposition near-field to the source. The screening scenario used in Tier 1 analysis assumed an annual precipitation rate of

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[25] http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001#TABLES – this website is updated every year, so the data it currently shows is not the exact data used to develop the wind speeds for screening analyses.

[26] National Climatic Data Center CliMaps (NCDC-CliMaps) (2007). http://cdo.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl

1,500 mm/year. This level of annual precipitation was estimated to represent rainy conditions in the U.S., such as parts of the U.S. Deep South and parts of the U.S. Northwest Coast[27]. Though the rate was an estimate, it does correspond to approximately the 95th percentile (i.e., higher rate) precipitation in the National Climatic Data Center's (NCDC) 30-year (1981–2010) data from U.S. stations.[28] To estimate adjustment factors in the Tier 2 analysis, model simulations were conducted with the parameter value set to three lower values (i.e., 1,187 mm/year, 924 mm/year and 512 mm/year; values also shown in Exhibit_Att B-2), corresponding to the 75th, 50th and 25th percentiles, respectively, of the NCDC data. Locations with lower precipitation levels were assumed to have a minimum precipitation of 512 mm/year. Based on these levels, the bins used to classify precipitation were: 0-512 mm/year, 512-924 mm/year, 924-1,187 mm/year, 1,187-1,500 mm/year and above 1,500 mm/year. In nearly all modeled cases, decreasing the precipitation rate while maintaining constant lake location, wind speed, wind direction, and mixing height led to Tier 2 estimations of high-end risk or hazard that were smaller than that of Tier 1. To be health-protective, a facility was assigned the upper end value of the bin in which it was placed. Facilities with precipitation levels above 1,500 mm/year were assumed to experience precipitation of 1,500 mm/year.

Mixing Height: Greater mixing heights can dilute the concentration of pollutants in air, resulting in lower deposition and other transfer rates from air to surfaces and consequently also lower ingestion exposures. The Tier 1 screening analysis assumed a mixing height of 710 meters. This value is the 5th percentile (i.e., lower) of annual average mixing heights for 463 U.S. locations, based on data obtained from EPA's SCRAM Web site.[29] To estimate adjustment factors in the Tier 2 analysis, mdoel simulations were conducted with the parameter value set to three larger values (i.e., 865 m, 1,079 m, and 1,537 m; values also shown in Exhibit_Att B-2). These values correspond to North Little Rock, Arkansas, Boise, Idaho, and Tucson, Arizona and are intended to encompass the range of annual average mixing heights experienced in different parts of the United States. Based on these levels, the following bins were selected for categorization of mixing height: 710–865 m, 865–1,079 m, 1,079–1,537 m, and above 1,537. In all modeled cases, increasing the mixing heights while maintaining constant lake location, wind direction, wind speed, and precipitation rate led to Tier 2 estimations of high-end risk or hazard that were smaller than that of Tier 1. To be health-protective, a facility was assigned the lower end value of the bin into which it was placed. Facilities with mixing heights above 1,537 m and those below 710 m were assumed to have mixing heights of 1,537 m and 710 m, respectively.

Lake Location: Moving the lake included in the hypothetical Tier 1 scenario to a location farther from the actual source in the modeled domain will reduce modeled (TRIM.FaTE) deposition to the lake and its watershed and consequently reduce exposures associated with the fish consumption pathway, which is an important pathway of exposure for several chemicals (for example, in the case of methyl mercury, it is by far the predominant exposure pathway). For the scenario modeled in Tier 1, the center of the lake was situated approximately 2 km from the source. To estimate lake location adjustment factors for use in Tier 2, we completed a series of model runs in which the lake was located 5 km, 10 km, 20 km, and 40 km from the source, as well as runs with no lake (values also shown in Exhibit_Att B-2). Accordingly, the bins used to classify lake location relative to the facility are: no lake, 2–5 km, 5–10 km, 10–20 km, 20–40 km, and 40–50 km (lakes farther than 50 km are not considered). To be health-

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[27] National Climatic Data Center Historical Climate Series (NCDC-HCS) (2007).

[28] http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

[29] Support Center for Regulatory Atmospheric Modeling; http://www.epa.gov/scram001/tt24.htm

protective, a facility was assigned the lower end value of the bin into which it was placed. A facility with a lake closer than 2 km was assumed to have a lake at 2 km.

In resituating the lake at these alternative locations, we maintained ratios consistent with those included in the Tier 1 screening scenario for (1) lake area to total land area in the modeled domain, (2) runoff watershed area to lake area, and (3) erosion watershed area to lake area. Exhibit_Att B-3 provides a diagram of the TRIM.FaTE layout in each of the alternate lake location simulations except no-lake. We used a “thin” lake shape (i.e., downwind width much smaller than the cross-wind length) that minimized the potential effect of declining deposition with distance from stack that might affect lakes that are long in the downwind direction. By controlling for these potentially confounding effects, we could isolate the effect of lake location on risk appropriately. Moving the lakes to increasing distances from the stack required expansion of the modeled domain. Maintaining the same overall ratio of land area to lake area in each domain resulted in scenarios with increasingly large lakes, with surface area increasing with distance from the source. This approach also was taken for reasons of modeling convenience (i.e., taking into account resource requirements associated with reconfiguring the TRIM.FaTE spatial layout). The changes in lake size between these four runs are not expected to have a substantial independent effect on exposure and risk because the effect of increased lake size is offset by greater total deposition and runoff. Furthermore, the lake depth was not changed, which might be as important a parameter as lake surface area in determining the chemical concentrations in the water column and sediment. As noted above, we set up the configurations to ensure that the lakes in the different scenarios received runoff and erosion from equivalent watersheds on a per surface area basis.

B.2.2 Estimation of Adjustment Factors

Adjustment factors were estimated for each variable described above and applied as multipliers to the Tier 1 emissions thresholds. The resulting Tier 2 emissions thresholds are used to assess whether facilities with corresponding configurations pose multipathway risks. Notably, facilities substantially exceeding a Tier 2 emission threshold carry some potential for significant multipathway health risk.

B.2.2.1 General Approach

The core principle in the estimation of adjustment factors is the assumption of direct proportionality of risk and emissions in the modeling approach used for RTR involving TRIM.FaTE and MIRC. Although not strictly present across all variations due to feedback mechanisms and other processes encompassed by the TRIM.FaTE model, a generally linear relationship between risk and emissions has been observed across model simulations conducted for RTR. This suggests that the ratio of total estimated exposures (and consequently risks) obtained for the screening scenario and any alternative configuration could be used as an adjustment factor to scale emissions for that specific alternative configuration. The risk in the alternative configuration following such a scaling of emissions would be equal to the risk in the screening scenario (which in Tier 1 was set at a risk level of 1E−6 incremental lifetime cancer risk or an incremental hazard quotient of 1, depending on the toxic effect of the chemical in question).

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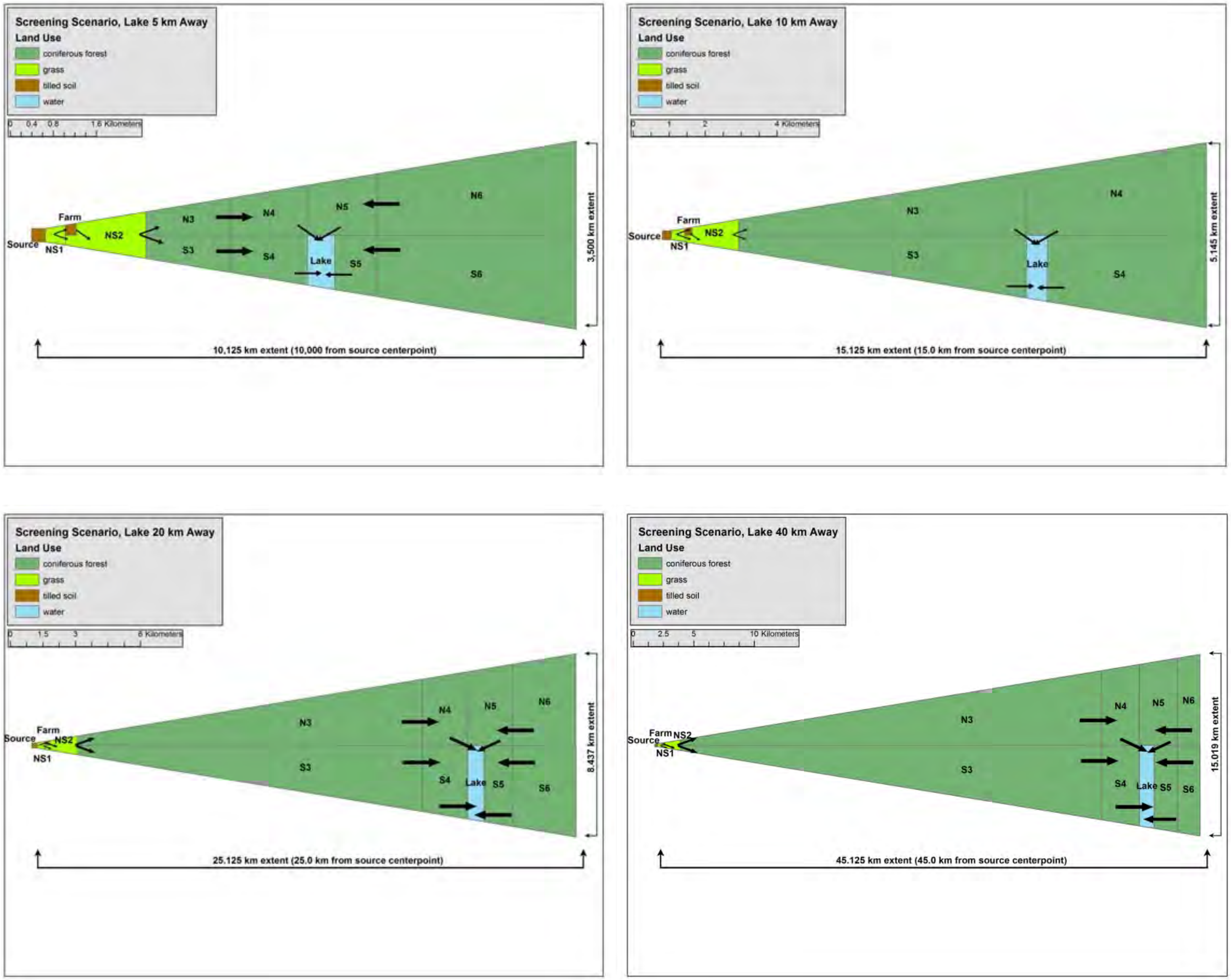
Exhibit_Att B-3. Layouts for Tier 2 TRIM.FaTE Simulations Using Alternate Distances Between the Facility and the Fishable Lake[a]



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[a] The no-lake scenario is not shown.

To account for potential interactions between the chosen Tier 2 variables, matrix adjustment factors were estimated by performing TRIM.FaTE runs for each unique combination of the specified variable values (that is, all permutations of the selected values for the wind speed, precipitation, mixing height, and lake location). Adjustment factors for each configuration were then estimated as the ratio of risks in the Tier 1 analysis to the estimated risk for the particular TRIM.FaTE configuration. This approach results in a large matrix of adjustment factors and has the advantage of accounting for all possible interaction effects between the variables.

The adjustment factor for wind direction is handled separately. Based on TRIM.FaTE test runs, the fraction of the time the wind blows in the direction of the farm and lake was observed to have a direct, linear effect on the resulting risk estimates. For this reason, it was not necessary to include this variable in the TRIM runs conducted to create the matrix of adjustment factors, as described above. Instead, the adjustment factor is calculated with a linear factor that divides the Tier 1 value (0.43, or 43% of the time in the direction of the farm and lake) by the site-specific facility value, as follows:

$$\textit{Adjustment Factor}_{\textit{Wind Direction}} = 0.43 / (\textit{fraction of time wind blows towards domain})$$

The adjustment factor for wind direction is then multiplied by the matrix adjustment factor discussed above to obtain a consolidated threshold adjustment factor that accounts for all the five variables considered in Tier 2.

B.2.2.2 Incorporation of the Risk Equivalency Approach

The adoption of a risk-equivalency approach to convert speciated emissions of PAHs and dioxins to BaP and TCDD equivalents, respectively, in Tier 1 required the development of risk equivalency factors (REFs) for each reported species in these groups. The REFs for PAHs and dioxins represent the ratio of the risk posed by a particular species to the risk posed by BaP and TCDD, respectively, at equivalent emissions rates in a given scenario.

The REFs can be represented as the product of exposure equivalency factors (EEFs) and toxicity equivalency factors (TEFs). For the PAHs, this can be expressed as:

$$REF_{PAH} = EEF_{PAH} \times TEF_{PAH}$$

The EEFs for PAHs represent the ratio of the exposure to a particular species to the exposure to BaP (and similarly for dioxins and TCDD) at equivalent emission rates. These ratios are thus specific to the TRIM.FaTE layout and input assumptions. The TEFs for PAHs and dioxins represent the ratio of the oral cancer slope factor (CSF) for a particular species to the CSF for BaP and TCDD, respectively, and are the same in Tier 1 and in Tier 2.

The EEFs depend on the TRIM.FaTE configuration, including layout and meteorlogical input values. For example, the exposure profile (i.e., how the different ingestion pathways contribute to total exposure and risk) is different for each PAH. For a PAH where fish is a dominant driver of risk, moving the lake will have a large effect on the overall risk; however, if produce is the dominant driver of risk, moving the lake will have a much smaller effect on overall risk. Thus, for Tier 2, EEFs were recomputed for each of the representative scenarios modeled in Tier 2 separately for the PAH species currently evaluated (some based on direct TRIM.FaTE modeling, others 15 based on K_{ow}-based regression estimates) and the dioxin species currently evaluated (most based on direct TRIM.FaTE modeling, and a small number assumed to behave like TCDD).

The following mathematical formulas demonstrate how the Tier 2 adjustment factors are estimated for the PAH and dioxin species. The formulas presented below are for a representative PAH species, but they are also applied to dioxin species.

For a given PAH species emitted at a rate E_{PAH} at a facility, the risk-equivalent BaP emission level can be expressed as:

$$E_{BAP\ EQIV} = E_{PAH\ SPECIES} \times EEF_{PAH\ SPECIES} \times TEF_{PAH\ SPECIES}$$

Then, the Tier 1 risk ratio is estimated by comparing the risk-equivalent BaP emissions to the BaP emission threshold:

$$Ratio_{TIER\ 1\_PAH\ SPECIES} = \frac{E_{TIER\ 1\_BAP\ EQUIV}}{Threshold_{TIER\ 1\_BAP}}$$

If the ratio is less than 1, the facility “screens out” of the Tier 1 analysis. Similarly, for Tier 2, the ratio of risk-equivalent BaP emissions to the Tier 2 BaP threshold may be expressed as:

$$Ratio_{TIER\ 2\_PAH\ SPECIES} = \frac{E_{TIER\ 2\_BAP\ EQUIV}}{Threshold_{TIER\ 2\_BAP}}$$

Using the definition of the risk-equivalent BaP emissions, this can be re-expressed for a given PAH species as:

$$Ratio_{TIER\ 2\_PAH\ SPECIES} = \frac{E_{PAH\ SPECIES} \times EEF_{TIER\ 2\_PAH\ SPECIES} \times TEF_{PAH\ SPECIES}}{Threshold_{TIER\ 2\_BAP}}$$

This expression may be further reconfigured, after some algebraic rearrangement, in terms of the Tier 1 ratio as:

$$Ratio_{TIER\ 2\_PAH\ SPECIES} = Ratio_{TIER\ 1\_PAH\ SPECIES} \times \frac{Threshold_{TIER\ 1\_BAP}}{Threshold_{TIER\ 2\_BAP}} \times \frac{EEF_{TIER\ 2\_PAH\ SPECIES}}{EEF_{TIER\ 1\_PAH\ SPECIES}}$$

$$Tier\ 2\ Adjustment\ Factor_{PAH\ SPECIES} = \frac{Threshold_{TIER\ 1\_BAP}}{Threshold_{TIER\ 2\_BAP}} \times \frac{EEF_{TIER\ 2\_PAH\ SPECIES}}{EEF_{TIER\ 1\_PAH\ SPECIES}}$$

These equations simply state that to adjust the Tier 1 threshold to a Tier 2 threshold for a particular PAH species, the adjustment factor must include the ratio of the BaP Tier 1 and 2 thresholds (as is true for cadmium, mercury, and TCDD, as discussed above) *and* the ratio of the EEFs for the particular PAH species in Tier 2 and Tier 1. This additional EEF factor is needed to account for the fact that the EEFs are different for each Tier 2 TRIM.FaTE configuration.

Finally, the ratio of total BaP equivalents contributed by all PAH species at a given facility to the BaP Tier 2 threshold may be expressed, by summing the above expression, as:

$$Ratio_{TIER\ 2\_ALL\ PAHs} = \sum^{ALL\ PAHs} Ratio_{TIER\ 1\_PAH\ SPECIES} \times \frac{Threshold_{TIER\ 1\_BAP}}{Threshold_{TIER\ 2\_BAP}} \times \frac{EEF_{TIER\ 2\_PAH\ SPECIES}}{EEF_{TIER\ 1\_PAH\ SPECIES}}$$

If the ratio of total BaP equivalents contributed by all PAH species to the BaP Tier 2 threshold is greater than 1, the facility would be deemed to have failed the Tier 2 screen for the PAH group.

B.3 Preparing National Databases of Lake and Meteorological Data

To facilitate the effective application of the Tier 2 screening procedures, databases were prepared containing national-scale information about lakes (locations and sizes) and meteorological data at available surface stations (including wind direction, wind speed, precipitation, and estimated mixing height). The development and content of these two databases are discussed in the following sections.

B.3.1 Processing Lake Data for Tier 2 Analysis

The lake database was built using a geospatial file (U.S. Water Bodies) provided by ESRI® for their ArcGIS™ products.[30] Because this geospatial file excluded water bodies in Alaska, Puerto Rico, and the U.S. Virgin Islands, it was augmented with water body information (directly from the USGS National Hydrography Dataset) for those other locations. The data generally have an estimated horizontal accuracy of 50 m. For the Tier 2 analysis, we focused on the hundreds of thousands of water bodies classified as “Lake/Pond” or “Reservoir” but not designated for disposal, evaporation, or treatment. We refer to these water bodies simply as “lakes” in the remainder of this document. The approximately 100,000 other water bodies (classified as canal/ditch, ice mass, inundation area, playa, stream/river, swamp marsh, or unclassified) were not included. In a more subjective step during the processing of the lake database for a specific source category (when Tier 2 is run “operationally”), the lake names (when provided) are scrutinized manually, and lakes are removed from the analysis when their names suggest industrial or treatment use (e.g., wastewater treatment ponds, sludge ponds, fly ash ponds, paper mill ponds, sewage pools, etc.). In this respect, the lake dataset is never truly final; lake names are scrutinized each time a new set of facilities is assessed using the Tier 2 methods and tools, which can lead to the permanent removal of some lakes from the dataset.

Early in the process of compiling this database, we encountered the question: “What size water body qualifies as a ‘lake’ for the purposes of this assessment?” The Tier 2 analysis must focus on lakes large enough to support relatively intensive angling pressure to be compatible with the assumed exposure scenario. To estimate the relationship between high fish consumption rates, harvest rates, and lake size, the following five key assumptions were made. Information and citations to peer-reviewed literature that support these assumptions are provided in Addendum 2 to this attachment. Note that in the TRIM.FaTE model screening scenario, water-column carnivores (WCCs) are modeled as trophic level 4 (TL4) fish (e.g., pickerel, largemouth bass), with all of their diet consisting of smaller “prey” or “pan” fish in the water column that are simulated as trophic level 3 (TL3). The benthic carnivores (BCs) in TRIM.FaTE are modeled to represent an intermediate trophic level between 3 and 4, i.e., TL3.5. The BCs (e.g., catfish) obtain half of their diet from TL2 (benthic invertebrates that feed on detritus at the sediment surface) and half from TL3 fish in the benthic environment. For the screening scenario, we assume that anglers consume fish biomass in a ratio of 50:50 from the BC and WCC

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[30] Specifically, the geospatial file in the ESRI® Data & Maps 2009 Data Update for ArcGIS™ version 9.3.1. It was derived by the United States Geological Survey (USGS), EPA, and ESRI® from the USGS National Hydrography Dataset (USGS 2012).

compartments, respectively. Together, these two fish compartments are referred to as piscivorous fish.

1. Piscivorous fish, when present, comprise approximately 21 percent of the standing biomass of fish. BC fish represent 17.5 percent of the standing fish biomass in natural lakes; WCC fish account for 3.5 percent of this total fish biomass. Thus, WCC (or TL4) fish represent the limiting compartment for angler fish harvesting and consumption.
2. Humans can harvest 10 percent of any single fish compartment without threatening the population due to overharvesting.
3. The minimum viable effective population size for a single fish species is at least 50 adult fish for a local population to survive over the short term (e.g., more than a decade).
4. Only 33 percent of the fish caught for consumption is edible fillet muscle. A 0.33 edible fraction is used to estimate total fish biomass associated with human consumption.
5. A total fish standing biomass of 40 g wet weight/m^2 represents an approximate upper bound for natural ponds and lakes in the United States.

Using the above assumptions and a series of equations (see Addendum 2 to this attachment), the maximum fish ingestion rates as a function of standing biomass and lake size were estimated. Exhibit_Att B-4 presents these findings, where the grey shading indicating when WCC fish would probably not be present, the white (unshaded) cells represent combinations of lake size and productivity that could sustain the listed fish ingestion rates over some time, and the yellow cells represent likely long-term sustainability associated with more than 500 adult WCC fish in the lake (see Exhibit notes).

The Tier 2 analysis is intended to retain most of the health-protective attributes of the screening scenario used in Tier 1 so that no facilities of potential concern erroneously “pass” the screen. For a given facility, the smaller the lake size threshold, the greater the number of lakes and the greater the probability that a lake is closer to the facility. Lakes closer to a facility will result in higher chemical concentrations in fish compared with lakes farther from the facility. Thus, Exhibit_Att B-4 was used to determine the smallest lake size that would support a TL4 population. At the assumed upper-limit standing fish biomass of 40 g ww/m^2, this corresponds to 25 acres (the first “white” box when moving from smaller to larger lakes).

The fish ingestion rate supported by a 25-acre lake is not as high as the adult ingestion rate used in the Tier 1 and Tier 2 analyses (i.e., 373 g ww fillet per day). Even a 100-acre lake is unlikely to sustain harvesting of piscivorous fish to support the 373 g ww fillet/day ingestion rate assumed for a subsistence angler. Exhibit_Att B-4 indicates that at a total fish biomass productivity of 40 g ww/m^2, the maximum sustainable fish harvest from the WCC compartment would correspond to an ingestion rate of only 103 g/day (with half that from the WCC and half from BC). However, to be health protective and to ensure that small lakes that might be more highly contaminated than estimated by the TRIM.FaTE screens were not eliminated, we selected 100 acres as the “cutoff” for the minimum size for an actual lake near a facility to be included in the Tier 2 analysis. In addition, larger lakes (larger than 100,000 acres) were not considered since they cannot be readily modeled in TRIM.FaTE. For the purposes of proximity matching lakes to emitting facilities (as described in Section B.4.2), the location of each lake is identified as the geographic centroid inside the lake.

Lakes smaller than 100 acres could be stocked annually at a rate adequate to support the assumed fish ingestion rate. For stocked fish, however, we would have to assume that when introduced to the lake, the fish were uncontaminated by the chemicals of interest. Moreover, the period over which accumulation of chemical from the lake could occur would be roughly three to six months (fishing season) for the majority of the fish stocked as adults (i.e., at approximately 2 kg), instead of several years for fish hatched in the lake.

To place an upper bound on the radial distance from the source up to which lake-derived risks need to be assessed, we took into account the limitations of TRIM.FaTE. We limited the lake analysis to an outward radial bound of 50 km from the stack. For facilities with no lakes within 50 km, lake-derived risk is assumed 0.

Exhibit_Att B-4. Maximum Fish Ingestion Rate (g/day) Associated with Sustainable Fishing[a]

Standing Biomass (g ww/m^2)[b]	Size of Pond or Lake (acres)															
	1	2	3	4	5	7.5	10	15	25	35	50	75	100	150	200	400
2	0	0	0	0	0	0	1	1	1	2	3	4	5	8	10	20
3	0	0	0	0	0	1	1	1	2	3	4	6	8	12	15	31
4	0	0	0	0	1	1	1	2	3	4	5	8	10	15	20	41
5.7	0	0	0	1	1	1	1	2	4	5	7	11	15	22	29	58
10	0	1	1	1	1	2	3	4	6	9	13	19	26	38	51	102
15	0	1	1	2	2	3	4	6	10	13	19	29	38	58	77	154
20	1	1	2	2	3	4	5	8	13	18	26	38	51	77	102	205
30	1	2	2	3	4	6	8	12	19	27	38	58	77	115	154	307
35	1	2	3	4	4	7	9	13	22	31	45	67	90	134	179	359
40	1	2	3	4	5	8	10	15	26	36	51	77	102	154	205	410
50	1	3	4	5	6	10	13	19	32	45	64	96	128	192	256	512
60	2	3	5	6	8	12	15	23	38	54	77	115	154	231	307	615
70	2	4	5	7	9	13	18	27	45	63	90	134	179	269	359	717
80	2	4	6	8	10	15	20	31	51	72	102	154	205	307	410	820
90	2	5	7	9	12	17	23	35	58	81	115	173	231	346	461	922
100	3	5	8	10	13	19	26	38	64	90	128	192	256	384	512	1025
110	3	6	8	11	14	21	28	42	70	99	141	211	282	423	563	1127
120	3	6	9	12	15	23	31	46	77	108	154	231	307	461	615	1229
130	3	7	10	13	17	25	33	50	83	117	166	250	333	499	666	1332

[a] Dark gray shading indicates insufficient population size for TL4 (WCC) fish (<50 adults) to be sustainable for more than a decade; yellow-shaded cells indicate the likelihood to provide long-term sustainable fish populations with at least 500 TL4 adult fish present; white area indicates medium-term sustainability.

[b] Represents the standing biomass of TL4 fish. At the upper-limit standing biomass of 40 g ww/ m^{2}estimated for natural lakes, 25 acres could support a water-column TL4 fish population, but would provide for no more than 26 grams of fillet per day for a single angler over a full year.

B.3.2 Processing Meteorological Data for Tier 2 Analysis

In addition to the lake database, a database of U.S. surface stations with complete data was created, so that each source category facility can be paired with the closest meteorological station data. This process of pairing dozens or hundreds of facilities with meteorological data is not unprecedented. In their report to the Science Advisory Board (SAB) on the 1996 NATA, EPA described pairing each facility with the closest meteorological station in an inventory of over 350 meteorological stations nationwide, creating an average facility-to-station distance of less than 50 km in the 1996 NATA (EPA 2001b). In a separate 2009 report to the SAB on the RTR program, EPA described using 158 meteorological stations to choose from nationwide, with a standard practice of selecting the station nearest to each facility unless the facility provides onsite meteorological data (EPA 2009). Using 156 petroleum refineries as a sample data set, the average facility-to-station distance was 72 km. In both instances, the SAB accepted this matching as standard practice when modeling large numbers of sources, although they recommended providing high-level siting maps (e.g., meteorological stations overlaid with terrain gradients or regional climate regimes) to qualify some of the uncertainties related to meteorological data in air dispersion modeling (EPA 2001a; EPA 2010). The current effort builds on this practice but increases the number of available meteorological stations as described below.

B.3.2.1 Sources of Meteorological Data

To construct a database of meteorological statistics for all available U.S. surface stations for use in multipathway screening assessments, EPA started with the same U.S. meteorology dataset used in RTR inhalation assessments. RTR inhalation assessments use data from 824 ASOS (Automated Surface Observing System) stations that record hourly and sub-hourly measurements. These data represent the year 2011, and the surface stations are paired with their closest, regularly-reporting upper-air stations. This number of stations is far greater than the 350 and 158 stations, respectively, used in the 1996 NATA report (EPA 2001b) and the 2009 RTR report (EPA 2009).

The 2011 precipitation measurements reflect 2011 weather conditions, and, like any other year, some areas of the country experienced rainfall that was significantly less than normal, and some areas received much more rainfall than normal. To reduce this bias in precipitation data, we used average annual precipitation data from the 1981−2010 National Climatic Data Center 30-year normal dataset wherever possible. If 30-year normal precipitation data were not available for a station, as was the case for a few stations in the dataset, we used the ASOS precipitation data as-is.

B.3.2.2 Coverage of Meteorological Stations Compared with Facility Locations

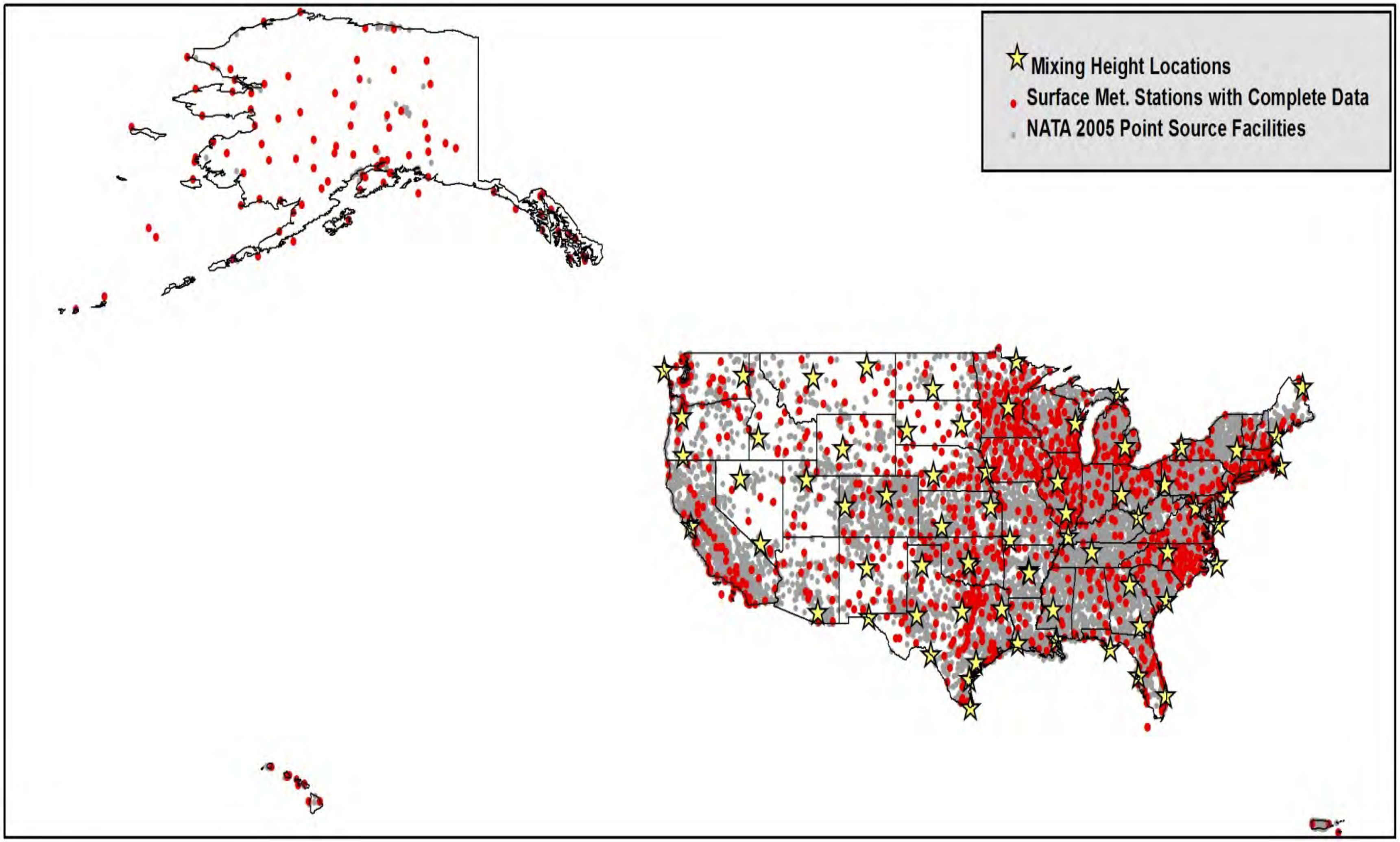
Exhibit_Att B-5 shows the proximity of the evaluated meteorology sites to the locations of U.S. point source facilities from the 2005 NATA. Generally, the spatial density of the surface meteorological stations in this dataset was similar to the spatial density of the 2005 NATA facilities. That is, the density tends to be greatest in the Great Lakes region, along the East and West Coasts, and in the Southern Plains, and tends to be lowest in the Rockies (except Colorado) and Northern Plains.

B.3.2.3 Data Processing

To facilitate application of the meteorological data to the Tier 2 analysis, EPA gathered wind information in directional octants that could be linked to the direction of the closest lake (see Introduction and Section B.4). EPA divided the periphery around a meteorological station into eight octants representing the direction toward which the wind was blowing:

N: >337.5 to 22.5 degrees
NE: >22.5 to 67.5 degrees
E: >67.5 to 112.5 degrees
SE: >112.5 to 157.5 degrees
S: >157.5 to 202.5 degrees
SW: >202.5 to 247.5 degrees
W: >247.5 to 292.5 degrees
NW: >292.5 to 337.5 degrees

Exhibit_Att B-5. The Locations of Meteorological Stations and Point Source Facilities[a]



[a] The 2005 NATA was the most recent, comprehensive, finalized dataset of nationwide point source emitters of hazardous air pollutants, and it is used here only for illustrative purposes. The 2005 NATA used a meteorological dataset different from the one used in this report.

A software program was developed to calculate the following statistics for each of these stations:

- Number of hourly observations,
- Number of hours with calm winds or missing winds,
- Percentage of time the wind blows into each octant (after excluding missing wind hours),
- Median wind speed blowing into each octant,
- Median mixing height used (if heat flux > 0, convective mixing height was used, otherwise mechanical mixing height was used), and
- Average annual precipitation (irrespective of wind octant and preferring 30-year normal data if available).

Total annual precipitation data in the 2011 meteorological data included anomalies (relative to normal conditions) in areas that experienced extreme drought conditions or large rainfall surplusses. To address this, the 30-year (1981-2010) average annual precipitation was used instead.[31]

The choice of using median values for wind speed and mixing height was based on a comparison of median and mean values. For nearly all stations, the median value was smaller than the mean value; because smaller values are more health protective, we selected the median statistic for all stations..

B.4 Implementation of Tier 2 Analysis

The Tier 2 screening analysis is conducted using a Microsoft® Excel™ tool. The tool was created so that all facilities in multiple source categories can be screened concurrently, if desired. The tool is controlled by a dashboard control panel (see Exhibit_Att B-6), where each of 7 sequential steps are controlled by a button on the panel. From the dashboard, the user is prompted to enter data on four worksheets.

Steps 1 and 2 are basic user input steps to prepare the tool for the analysis. In Step 1, the user verifies that the Tier 2 matrix results developed using the TRIM.FaTE model are current; this matrix remains static unless the methods used to derive the matrix must be updated or the chemicals currently in the matrix must be augmented. In Step 2, the user enters basic “global inputs” that include the source categories included in the analysis (Exhibit_Att B-7). Steps 1 and 2 on the dashboard should be performed prior to the start of any analysis to ensure that the user is using the most current information.

The remaining steps implementing the Tier 2 analysis are described in the below sections. Sections B.4.1 and B.4.2 contain discussions on Steps 3 and 4, where data for two additional input tables are entered into the Tier 2 analysis, after having been created using the Tier 1 Microsoft® Access™ screening tool and the ArcGIS™ lake database. Section B.4.3 contains a discussion on Step 5, where facilities in the analysis are linked with meteorology statistics from the same meteorology data used for the facilities in the RTR inhalation modeling. After all these input data have been supplied, Sections B.4.4 and B.4.5 respectively contain discussions on Step 6 (conducting the Tier 2 analysis) and Step 7 (producing output tables that summarize the results).

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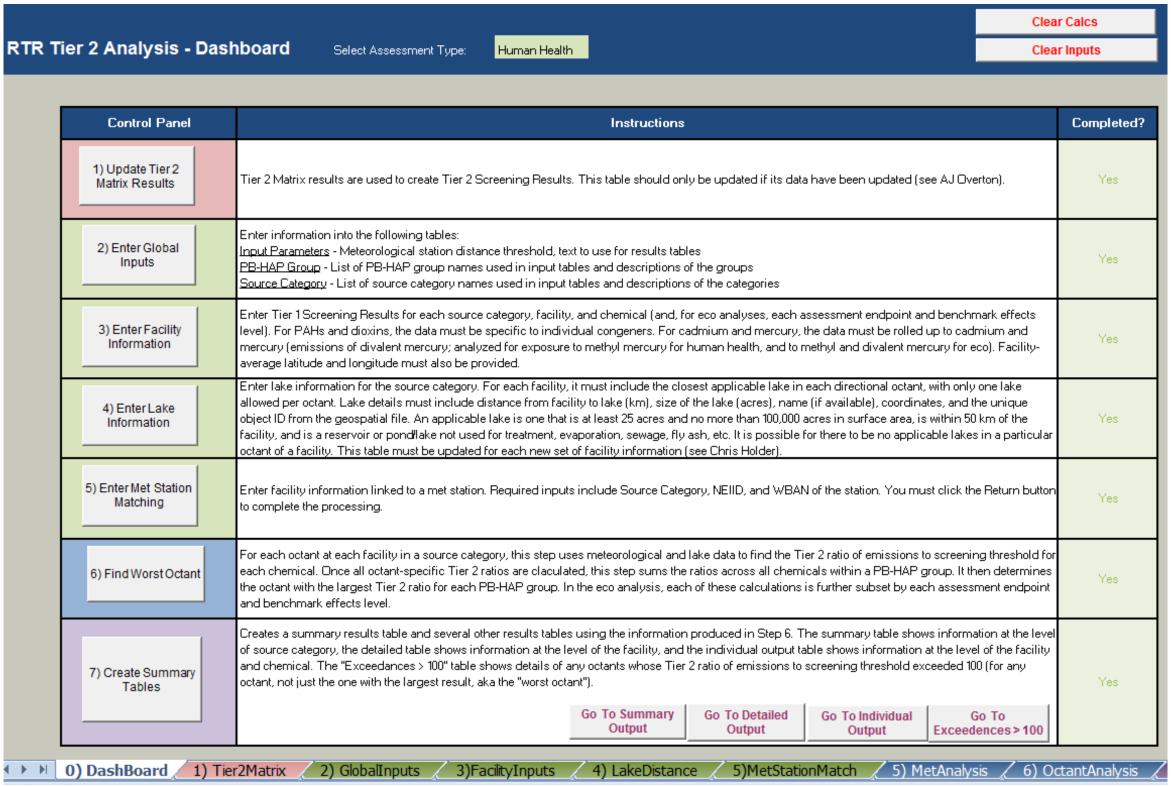
[31] 30-year average annual precipitation was obtained from the National Climatic Data Center (NCDC). http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html.

To facilitate explanation of the Tier 2 analysis implementation, example source categories with hypothetical PB-HAP emissions were run through the tool and screen shots, including the results, are provided to illustrate the overall 7-step process. These screen shots and accompanying descriptions represent the tool at one point in time (over a year into its development). While the tool is enhanced and improved periodically (e.g, to fix "bugs" and add/change features), these modifications generally do not significantly alter the look, feel, and purpose of the tool.

Exhibit_Att B-6. Example of the Dashboard To Conduct the Tier 2 Analysis

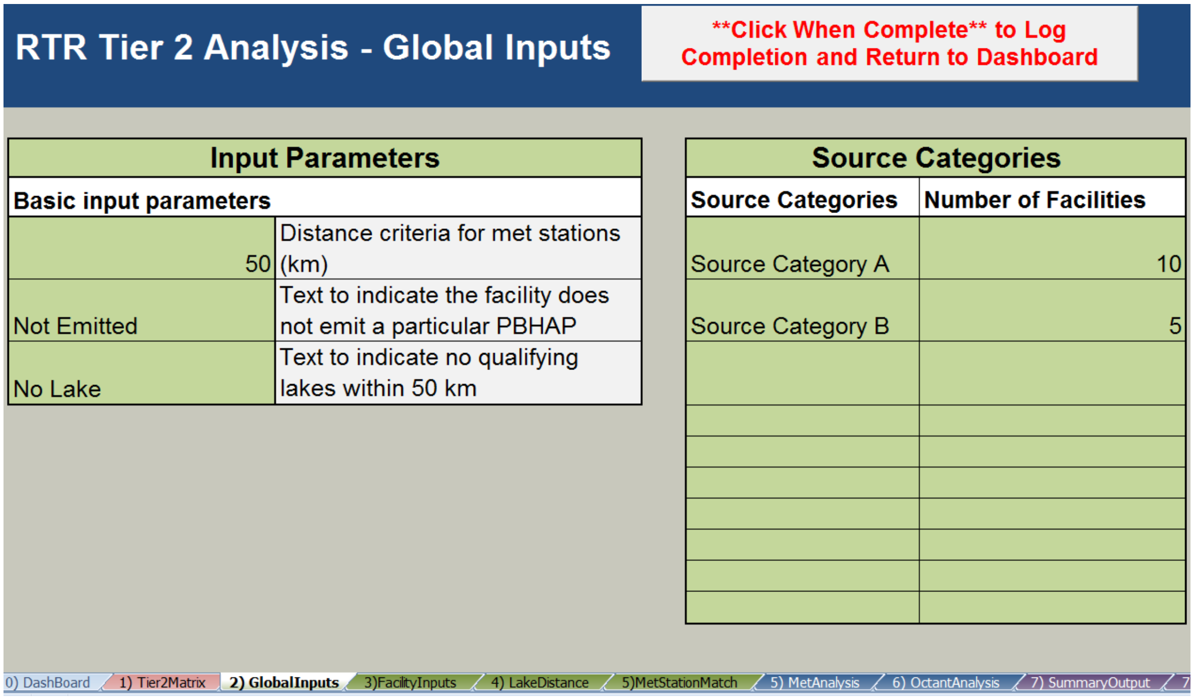


RTR Tier 2 Analysis - Dashboard

Select Assessment Type: Human Health

Control Panel	Instructions	Completed?
1) Update Tier 2 Matrix Results	Tier 2 Matrix results are used to create Tier 2 Screening Results. This table should only be updated if its data have been updated (see AJ Overton).	Yes
2) Enter Global Inputs	Enter information into the following tables: Input Parameters - Meteorological station distance threshold, text to use for results tables PB-HAP Group - List of PB-HAP group names used in input tables and descriptions of the groups Source Category - List of source category names used in input tables and descriptions of the categories	Yes
3) Enter Facility Information	Enter Tier 1 Screening Results for each source category, facility, and chemical (and, for eco analyses, each assessment endpoint and benchmark effects level). For PAHs and dioxins, the data must be specific to individual congeners. For cadmium and mercury, the data must be rolled up to cadmium and mercury (emissions of divalent mercury; analyzed for exposure to methyl mercury for human health, and to methyl and divalent mercury for eco). Facility-average latitude and longitude must also be provided.	Yes
4) Enter Lake Information	Enter lake information for the source category. For each facility, it must include the closest applicable lake in each directional octant, with only one lake allowed per octant. Lake details must include distance from facility to lake (km), size of the lake (acres), name (if available), coordinates, and the unique object ID from the geospatial file. An applicable lake is one that is at least 25 acres and no more than 100,000 acres in surface area, is within 50 km of the facility, and is a reservoir or pond/lake not used for treatment, evaporation, sewage, fly ash, etc. It is possible for there to be no applicable lakes in a particular octant of a facility. This table must be updated for each new set of facility information (see Chris Holder).	Yes
5) Enter Met Station Matching	Enter facility information linked to a met station. Required inputs include Source Category, NEIID, and WBAN of the station. You must click the Return button to complete the processing.	Yes
6) Find Worst Octant	For each octant at each facility in a source category, this step uses meteorological and lake data to find the Tier 2 ratio of emissions to screening threshold for each chemical. Once all octant-specific Tier 2 ratios are claculated, this step sums the ratios across all chemicals within a PB-HAP group. It then determines the octant with the largest Tier 2 ratio for each PB-HAP group. In the eco analysis, each of these calculations is further subset by each assessment endpoint and benchmark effects level.	Yes
7) Create Summary Tables	Creates a summary results table and several other results tables using the information produced in Step 6. The summary table shows information at the level of source category, the detailed table shows information at the level of the facility, and the individual output table shows information at the level of the facility and chemical. The "Exceedances > 100" table shows details of any octants whose Tier 2 ratio of emissions to screening threshold exceeded 100 (for any octant, not just the one with the largest result, aka the "worst octant").	Yes

Exhibit_Att B-7. Example of Global Inputs Used in the Tier 2 Analysis[a]



Input Parameters	
Basic input parameters	
50	Distance criteria for met stations (km)
Not Emitted	Text to indicate the facility does not emit a particular PBHAP
No Lake	Text to indicate no qualifying lakes within 50 km

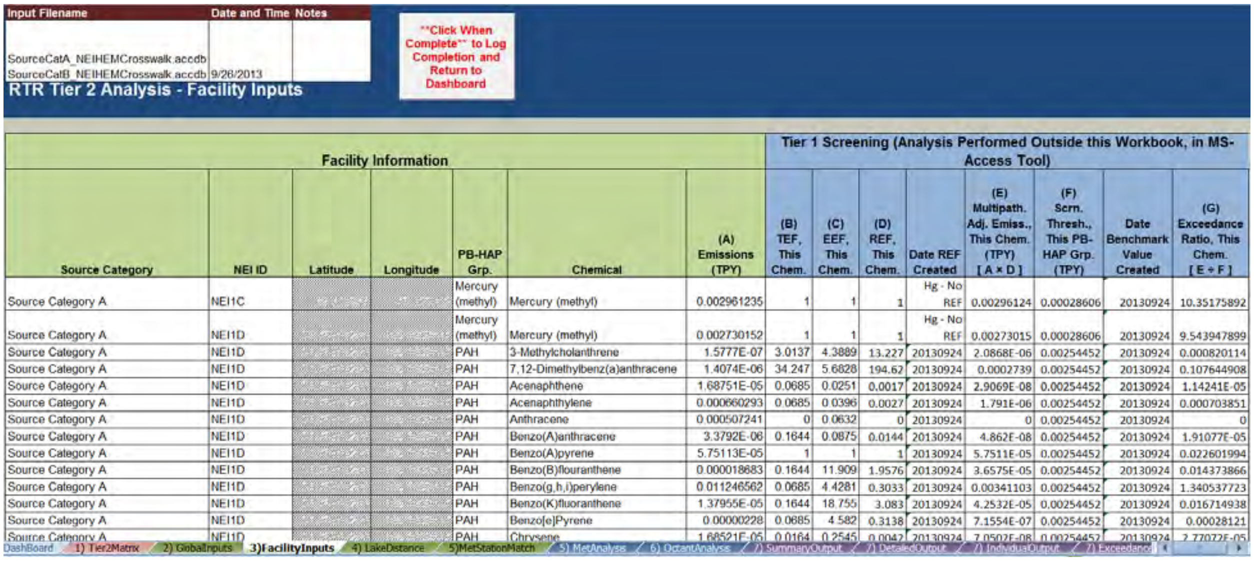
Source Categories	
Source Categories	**Number of Facilities**
Source Category A	10
Source Category B	5

[a]The screen shot examples shown in this section are for actual facilities; however their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

B.4.1 Facility List for Tier 2 Screen (Step 3)

After clicking Button 3 on the dashboard (see Exhibit_Att B-6), the user is brought to the facility input sheet to enter a list of all facilities in a source category (or multiple source categories) with emissions of any PB-HAP. Included in this list are the average latitude and longitude of the emission sources at the facility, the list of chemicals emitted (and their respective PB-HAP groups), the emissions of those chemicals, the Tier 1 exposure factors and screening thresholds, and the ratio of the emission rate (including REF-adjusted emission rate if applicable) to the Tier 1 screening threshold for each evaluated chemical. This table is generated using the Tier 1 Microsoft® Access™ screening tool, and it is pasted into the "Facility Inputs" sheet of the Excel™ tool, as shown in Exhibit_Att B-8.

Exhibit_Att B-8. Example of the Facility Input Data Required To Conduct the Tier 2 Analysis[a]



Input Filename	Date and Time	Notes
SourceCatA_NEIHEMCrosswalk.accdb SourceCatB_NEIHEMCrosswalk.accdb	9/26/2013	

RTR Tier 2 Analysis - Facility Inputs

Facility Information							Tier 1 Screening (Analysis Performed Outside this Workbook, in MS-Access Tool)							
Source Category	NEI ID	Latitude	Longitude	PB-HAP Grp.	Chemical	(A) Emissions (TPY)	(B) TEF, This Chem.	(C) EEF, This Chem.	(D) REF, This Chem.	Date REF Created	(E) Multipath. Adj. Emiss., This Chem. (TPY) [A × D]	(F) Scrn. Thresh., This PB-HAP Grp. (TPY)	Date Benchmark Value Created	(G) Exceedance Ratio, This Chem. [E ÷ F]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.002961235	1	1	1	Hg - No REF	0.00296124	0.00028606	20130924	10.35175892
Source Category A	NEI1D	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.002730152	1	1	1	Hg - No REF	0.00273015	0.00028606	20130924	9.543947899
Source Category A	NEI1D	[redacted]	[redacted]	PAH	3-Methylcholanthrene	1.5777E-07	3.0137	4.3889	13.227	20130924	2.0868E-06	0.00254452	20130924	0.000820114
Source Category A	NEI1D	[redacted]	[redacted]	PAH	7,12-Dimethylbenz(a)anthracene	1.4074E-06	34.247	5.6828	194.62	20130924	0.0002739	0.00254452	20130924	0.107644908
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Acenaphthene	1.68751E-05	0.0685	0.0251	0.0017	20130924	2.9069E-08	0.00254452	20130924	1.14241E-05
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Acenaphthylene	0.000660293	0.0685	0.0396	0.0027	20130924	1.791E-06	0.00254452	20130924	0.000703851
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Anthracene	0.000507241	0	0.0632	0	20130924	0	0.00254452	20130924	0
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo(A)anthracene	3.3792E-06	0.1644	0.0875	0.0144	20130924	4.862E-08	0.00254452	20130924	1.91077E-05
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo(A)pyrene	5.75113E-05	1	1	1	20130924	5.7511E-05	0.00254452	20130924	0.022601994
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo(B)flouranthene	0.000018683	0.1644	11.909	1.9576	20130924	3.6575E-05	0.00254452	20130924	0.014373866
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo(g,h,i)perylene	0.011246562	0.0685	4.4281	0.3033	20130924	0.00341103	0.00254452	20130924	1.340537723
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo(K)fluoranthene	1.37955E-05	0.1644	18.755	3.083	20130924	4.2532E-05	0.00254452	20130924	0.016714938
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Benzo[e]Pyrene	0.00000228	0.0685	4.582	0.3138	20130924	7.1554E-07	0.00254452	20130924	0.00028121
Source Category A	NEI1D	[redacted]	[redacted]	PAH	Chrysene	1.68521E-05	0.0164	0.2545	0.0042	20130924	7.0502E-08	0.00254452	20130924	2.77072E-05

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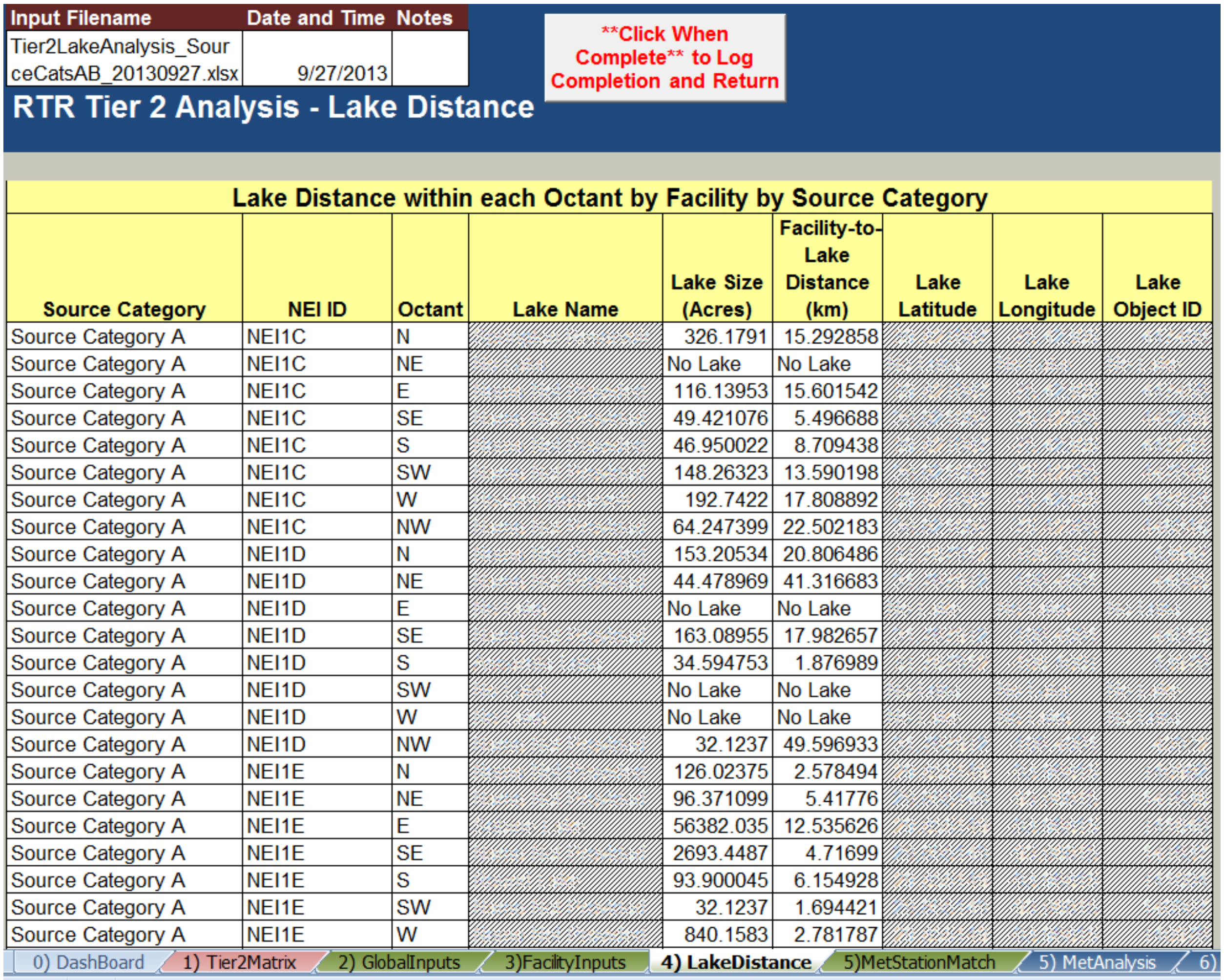
[a] The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

B.4.2 Facility/Lake Distance Table (Step 4)

After clicking Button 4 on the dashboard (see Exhibit_Att B-6), the user is brought to the lake distance sheet to enter details on the closest lake to each facility in each of the directional octants (N, NE, E, SE, S, SW, W, and NW). These lake data are assembled outside of this Excel™ tool using the following steps. First, the location of each facility is imported into ArcGIS™ along with the final database of lake centroids (Section B.2.1). Then, from within the ArcGIS™ software, all lakes with centroids within 50 km of each facility are identified. A table is created that shows the lake name, location relative to the facility (octant and distance), and size (note: the lake size is informational only, it is not used as part of Tier 2 except to be sure it is not smaller than 100 acres or larger than 100,000 acres). The table also specifies if there is no qualifying lake. The lake names (where available) are scrutinized to subjectively remove industrial and treatment water bodies, as discussed in Section B.2.1. This table is pasted in the "LakeDistance" sheet as shown in Exhibit_Att B-9.

Exhibit_Att B-9. Example of the Lake Distance Data Required To Conduct the Tier 2 Analysis[a]



Input Filename	Date and Time	Notes
Tier2LakeAnalysis_SourceCatsAB_20130927.xlsx	9/27/2013	

RTR Tier 2 Analysis - Lake Distance

Lake Distance within each Octant by Facility by Source Category

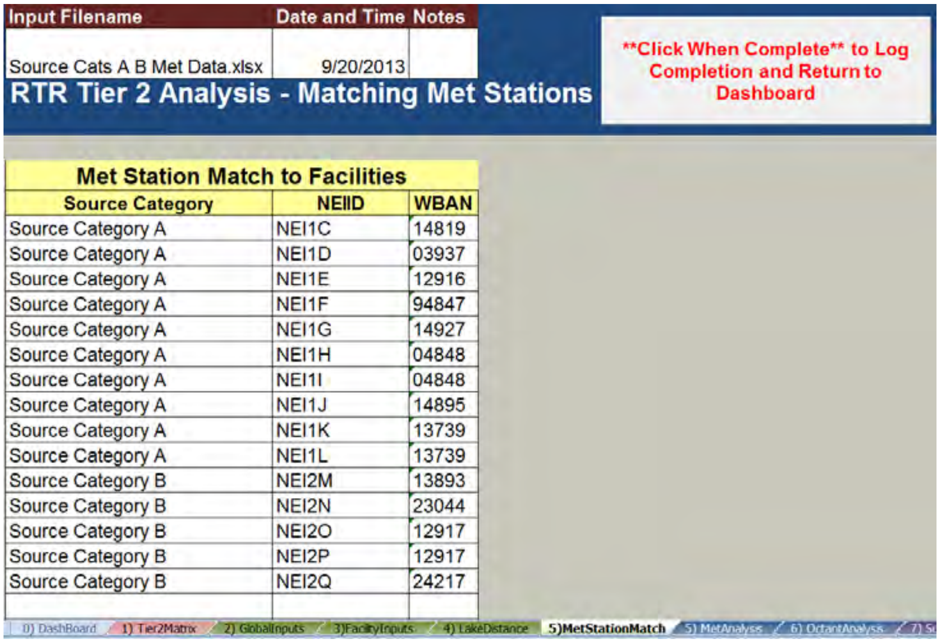
Source Category	NEI ID	Octant	Lake Name	Lake Size (Acres)	Facility-to-Lake Distance (km)	Lake Latitude	Lake Longitude	Lake Object ID
Source Category A	NEI1C	N	[redacted]	326.1791	15.292858	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	NE	[redacted]	No Lake	No Lake	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	E	[redacted]	116.13953	15.601542	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	SE	[redacted]	49.421076	5.496688	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	S	[redacted]	46.950022	8.709438	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	SW	[redacted]	148.26323	13.590198	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	W	[redacted]	192.7422	17.808892	[redacted]	[redacted]	[redacted]
Source Category A	NEI1C	NW	[redacted]	64.247399	22.502183	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	N	[redacted]	153.20534	20.806486	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	NE	[redacted]	44.478969	41.316683	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	E	[redacted]	No Lake	No Lake	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	SE	[redacted]	163.08955	17.982657	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	S	[redacted]	34.594753	1.876989	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	SW	[redacted]	No Lake	No Lake	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	W	[redacted]	No Lake	No Lake	[redacted]	[redacted]	[redacted]
Source Category A	NEI1D	NW	[redacted]	32.1237	49.596933	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	N	[redacted]	126.02375	2.578494	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	NE	[redacted]	96.371099	5.41776	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	E	[redacted]	56382.035	12.535626	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	SE	[redacted]	2693.4487	4.71699	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	S	[redacted]	93.900045	6.154928	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	SW	[redacted]	32.1237	1.694421	[redacted]	[redacted]	[redacted]
Source Category A	NEI1E	W	[redacted]	840.1583	2.781787	[redacted]	[redacted]	[redacted]

[a] The screen shot examples shown in this section are for actual facilities; however, their their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

B.4.3 Matching Facilities to Meteorology Data (Step 5)

The last required input data step is to assign a meteorological station to each of the facilities. By clicking Button 5, the user is brought to the “MetStationMatch” tab. On this tab, the user provides a list of facilities and the associated meteorological station WBAN ID that should be used in the analysis. These station WBANs must already be present in the tool with the wind, mixing height, and precipitation statistics used in the Tier 2 methods (i.e., the meteorology stations used in RTR inhalation modeling; in a separate, hidden sheet). Clicking the return button will check that all input stations are acceptable. An example is provided in Exhibit_Att B-10.

Exhibit_Att B-10. Example Results of the Meteorological Station Matching Required To Conduct the Tier 2 Analysis[a]



Input Filename	Date and Time	Notes
Source Cats A B Met Data.xlsx	9/20/2013	

RTR Tier 2 Analysis - Matching Met Stations

Met Station Match to Facilities

Source Category	NEIID	WBAN
Source Category A	NEI1C	14819
Source Category A	NEI1D	03937
Source Category A	NEI1E	12916
Source Category A	NEI1F	94847
Source Category A	NEI1G	14927
Source Category A	NEI1H	04848
Source Category A	NEI1I	04848
Source Category A	NEI1J	14895
Source Category A	NEI1K	13739
Source Category A	NEI1L	13739
Source Category B	NEI2M	13893
Source Category B	NEI2N	23044
Source Category B	NEI2O	12917
Source Category B	NEI2P	12917
Source Category B	NEI2Q	24217

[a] The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

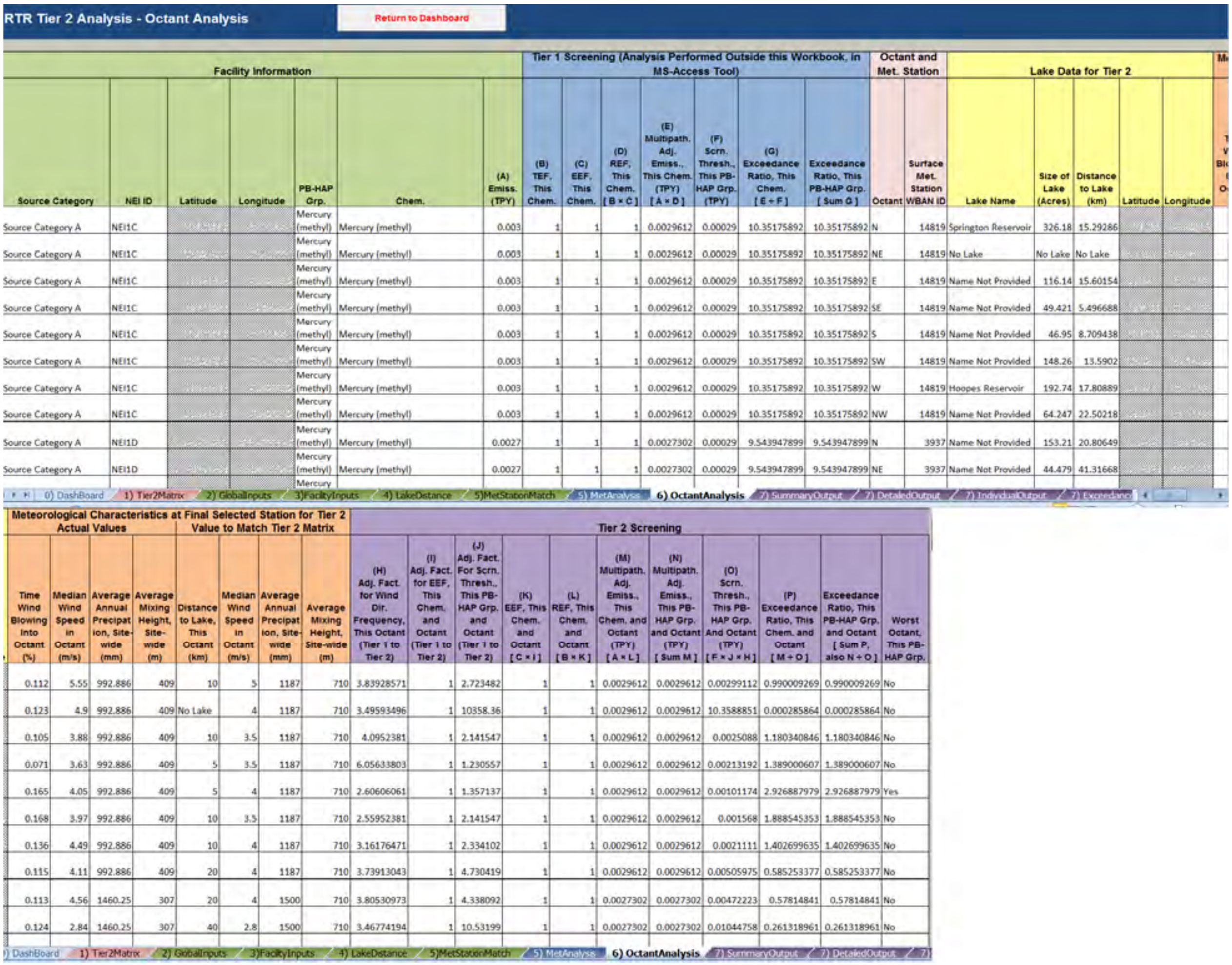
B.4.4 Assembling Threshold Adjustment Factors (Step 6)

Next, the tool calculates the facility-specific, octant-specific threshold adjustment factor for each chemical. When Button 6 is clicked (see Exhibit_Att B-6), the tool uses the meteorological parameters and lake locations to find the correct adjustment factor for each of the Tier 2 characteristics, as discussed in Section B.2. See example screen shot in Exhibit_Att B-11. The completed analysis is shown in the “OctantAnalysis” sheet. For each octant associated with a facility, the tool pairs its lake and meteorology parameters (lake location, wind speed, mixing height, and precipitation) with the closest matches in the Tier 2 matrix of EEF and screening threshold adjustment factors (Section B.2 describes this matrix, and a sample of the matrix is shown in Exhibit_Att B-12). The selection of adjustment factors is done in a health-protective manner, taking note of the direction of the correlation of the variable with risk. For example, smaller mixing heights are associated with larger risks, so a facility’s mixing height is matched with the closest evaluated Tier 2 value that is *smaller* than the facility’s value. Each octant also is associated with a wind direction adjustment factor, where the frequency of winds blowing into the Tier 1 screening scenario (43 percent) is ratioed to the observed frequency of winds blowing into the octant. The octant’s total adjustment factor is the product of the EEF, screening scearnio, and wind direction adjustment factors.

The math to go from the Tier 1 results to the Tier 2 results can be performed a number of different ways. To improve transparency and understanding of the Tier 2 analysis, the current tool normalizes the raw emissions of PAH and dioxin congeners to their surrogate congeners (BaP and TCDD, respectively) using the Tier 2 EEF adjustment factor ($\text{Emissions}_{\text{Surrogate}}$ = Emissions × TEF × ($\text{EEF}_{\text{Tier1}}$ × $\text{EEFAdjFact}_{\text{Tier2}}$)). Then, the adjusted emissions (or raw emissions in the case of mercury and cadmium) are ratioed to the Tier 2 emission screening thresholds ($\text{Result}_{\text{Tier2}}$ = $\text{Emissions}_{\text{Surrogate}}$ ÷ ($\text{Threshold}_{\text{Tier1}}$ × $\text{ThresholdAdjFactor}_{\text{Tier2}}$) ÷ ($\text{WindDirectionAdjFactor}_{\text{Tier2}}$)).

This evaluation occurs for each chemical in each octant of each facility, and for PAHs and dioxins the emissions are converted to BaP- and TCDD-equivalents using REFs. For PAHs and dioxins, the species-specific Tier 2 ratios (equivalent emissions/threshold) at a facility are summed to create the total PAH and total dioxin Tier 2 ratios. To maintain a health- protective focus in the analysis, the octant analysis then identifies the octant with the largest Tier 2 ratio for each PB-HAP at each facility.

Exhibit_Att B-11. Example Results of the Octant Analysis Required To Conduct the Tier 2 Analysis (shown in 2 pieces due to size)[a]



Facility Information							Tier 1 Screening (Analysis Performed Outside this Workbook, in MS-Access Tool)							Octant and Met. Station		Lake Data for Tier 2				
Source Category	NEI ID	Latitude	Longitude	PB-HAP Grp.	Chem.	(A) Emiss. (TPY)	(B) TEF, This Chem.	(C) EEF, This Chem.	(D) REF, This Chem. [B × C]	(E) Multipath. Adj. Emiss., This Chem. (TPY) [A × D]	(F) Scrn. Thresh., This PB-HAP Grp. (TPY)	(G) Exceedance Ratio, This Chem. [E ÷ F]	Exceedance Ratio, This PB-HAP Grp. [Sum G]	Octant	Surface Met. Station WBAN ID	Lake Name	Size of Lake (Acres)	Distance to Lake (km)	Latitude	Longitude
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	N	14819	Springton Reservoir	326.18	15.29286	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	NE	14819	No Lake	No Lake	No Lake	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	E	14819	Name Not Provided	116.14	15.60154	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	SE	14819	Name Not Provided	49.421	5.496688	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	S	14819	Name Not Provided	46.95	8.709438	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	SW	14819	Name Not Provided	148.26	13.5902	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	W	14819	Hoopes Reservoir	192.74	17.80889	[redacted]	[redacted]
Source Category A	NEI1C	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.003	1	1	1	0.0029612	0.00029	10.35175892	10.35175892	NW	14819	Name Not Provided	64.247	22.50218	[redacted]	[redacted]
Source Category A	NEI1D	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.0027	1	1	1	0.0027302	0.00029	9.543947899	9.543947899	N	3937	Name Not Provided	153.21	20.80649	[redacted]	[redacted]
Source Category A	NEI1D	[redacted]	[redacted]	Mercury (methyl)	Mercury (methyl)	0.0027	1	1	1	0.0027302	0.00029	9.543947899	9.543947899	NE	3937	Name Not Provided	44.479	41.31668	[redacted]	[redacted]

Meteorological Characteristics at Final Selected Station for Tier 2 Actual Values				Value to Match Tier 2 Matrix				Tier 2 Screening										
Time Wind Blowing Into Octant (%)	Median Wind Speed in Octant (m/s)	Average Annual Precipation, Site-wide (mm)	Average Mixing Height, Site-wide (m)	Distance to Lake, This Octant (km)	Median Wind Speed in Octant (m/s)	Average Annual Precipation, Site-wide (mm)	Average Mixing Height, Site-wide (m)	(H) Adj. Fact. for Wind Dir. Frequency, This Octant (Tier 1 to Tier 2)	(I) Adj. Fact. for EEF, This Chem. and Octant (Tier 1 to Tier 2)	(J) Adj. Fact. For Scrn. Thresh., This PB-HAP Grp. and Octant (Tier 1 to Tier 2)	(K) EEF, This Chem. and Octant [C × I]	(L) REF, This Chem. and Octant [B × K]	(M) Multipath. Adj. Emiss., This Chem. and Octant (TPY) [A × L]	(N) Multipath. Adj. Emiss., This PB-HAP Grp. and Octant (TPY) [Sum M]	(O) Scrn. Thresh., This PB-HAP Grp. And Octant (TPY) [F × J × H]	(P) Exceedance Ratio, This Chem. and Octant [M ÷ O]	Exceedance Ratio, This PB-HAP Grp. and Octant [Sum P, also N ÷ O]	Worst Octant, This PB-HAP Grp.
0.112	5.55	992.886	409	10	5	1187	710	3.83928571	1	2.723482	1	1	0.0029612	0.0029612	0.00299112	0.990009269	0.990009269	No
0.123	4.9	992.886	409	No Lake	4	1187	710	3.49593496	1	10358.36	1	1	0.0029612	0.0029612	10.3588851	0.000285864	0.000285864	No
0.105	3.88	992.886	409	10	3.5	1187	710	4.0952381	1	2.141547	1	1	0.0029612	0.0029612	0.0025088	1.180340846	1.180340846	No
0.071	3.63	992.886	409	5	3.5	1187	710	6.05633803	1	1.230557	1	1	0.0029612	0.0029612	0.00213192	1.389000607	1.389000607	No
0.165	4.05	992.886	409	5	4	1187	710	2.60606061	1	1.357137	1	1	0.0029612	0.0029612	0.00101174	2.926887979	2.926887979	Yes
0.168	3.97	992.886	409	10	3.5	1187	710	2.55952381	1	2.141547	1	1	0.0029612	0.0029612	0.001568	1.888545353	1.888545353	No
0.136	4.49	992.886	409	10	4	1187	710	3.16176471	1	2.334102	1	1	0.0029612	0.0029612	0.0021111	1.402699635	1.402699635	No
0.115	4.11	992.886	409	20	4	1187	710	3.73913043	1	4.730419	1	1	0.0029612	0.0029612	0.00505975	0.585253377	0.585253377	No
0.113	4.56	1460.25	307	20	4	1500	710	3.80530973	1	4.338092	1	1	0.0027302	0.0027302	0.00472223	0.57814841	0.57814841	No
0.124	2.84	1460.25	307	40	2.8	1500	710	3.46774194	1	10.53199	1	1	0.0027302	0.0027302	0.01044758	0.261318961	0.261318961	No

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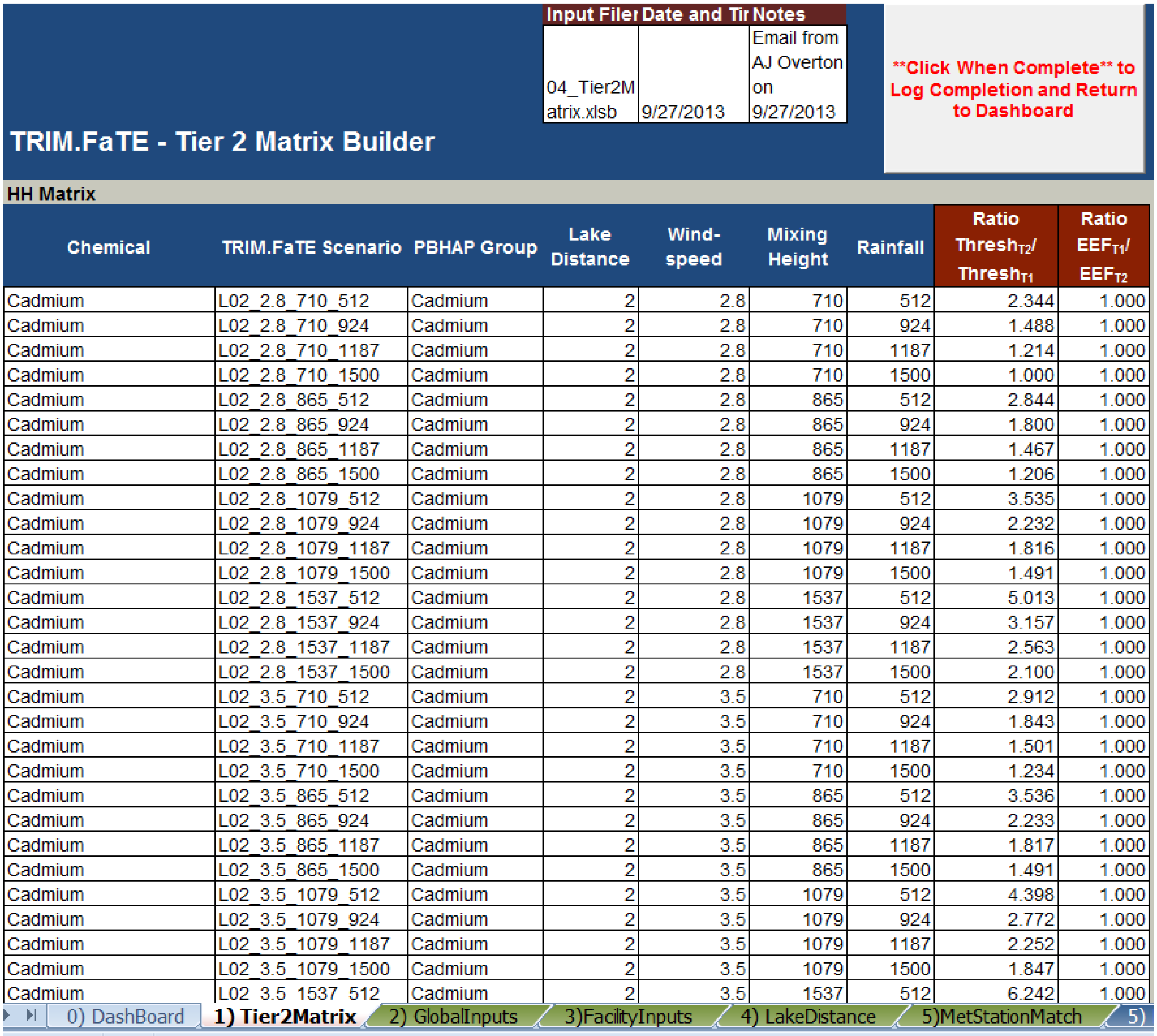
[a] The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

Exhibit_Att B-12. Example of the TRIM.FaTE Matrix Results Required To Conduct the Tier 2 Analysis



TRIM.FaTE - Tier 2 Matrix Builder

Input Filer	Date and Tir	Notes
04_Tier2Matrix.xlsb	9/27/2013	Email from AJ Overton on 9/27/2013

HH Matrix

Chemical	TRIM.FaTE Scenario	PBHAP Group	Lake Distance	Wind-speed	Mixing Height	Rainfall	Ratio $Thresh_{T2}$/ $Thresh_{T1}$	Ratio EEF_{T1}/ EEF_{T2}
Cadmium	L02_2.8_710_512	Cadmium	2	2.8	710	512	2.344	1.000
Cadmium	L02_2.8_710_924	Cadmium	2	2.8	710	924	1.488	1.000
Cadmium	L02_2.8_710_1187	Cadmium	2	2.8	710	1187	1.214	1.000
Cadmium	L02_2.8_710_1500	Cadmium	2	2.8	710	1500	1.000	1.000
Cadmium	L02_2.8_865_512	Cadmium	2	2.8	865	512	2.844	1.000
Cadmium	L02_2.8_865_924	Cadmium	2	2.8	865	924	1.800	1.000
Cadmium	L02_2.8_865_1187	Cadmium	2	2.8	865	1187	1.467	1.000
Cadmium	L02_2.8_865_1500	Cadmium	2	2.8	865	1500	1.206	1.000
Cadmium	L02_2.8_1079_512	Cadmium	2	2.8	1079	512	3.535	1.000
Cadmium	L02_2.8_1079_924	Cadmium	2	2.8	1079	924	2.232	1.000
Cadmium	L02_2.8_1079_1187	Cadmium	2	2.8	1079	1187	1.816	1.000
Cadmium	L02_2.8_1079_1500	Cadmium	2	2.8	1079	1500	1.491	1.000
Cadmium	L02_2.8_1537_512	Cadmium	2	2.8	1537	512	5.013	1.000
Cadmium	L02_2.8_1537_924	Cadmium	2	2.8	1537	924	3.157	1.000
Cadmium	L02_2.8_1537_1187	Cadmium	2	2.8	1537	1187	2.563	1.000
Cadmium	L02_2.8_1537_1500	Cadmium	2	2.8	1537	1500	2.100	1.000
Cadmium	L02_3.5_710_512	Cadmium	2	3.5	710	512	2.912	1.000
Cadmium	L02_3.5_710_924	Cadmium	2	3.5	710	924	1.843	1.000
Cadmium	L02_3.5_710_1187	Cadmium	2	3.5	710	1187	1.501	1.000
Cadmium	L02_3.5_710_1500	Cadmium	2	3.5	710	1500	1.234	1.000
Cadmium	L02_3.5_865_512	Cadmium	2	3.5	865	512	3.536	1.000
Cadmium	L02_3.5_865_924	Cadmium	2	3.5	865	924	2.233	1.000
Cadmium	L02_3.5_865_1187	Cadmium	2	3.5	865	1187	1.817	1.000
Cadmium	L02_3.5_865_1500	Cadmium	2	3.5	865	1500	1.491	1.000
Cadmium	L02_3.5_1079_512	Cadmium	2	3.5	1079	512	4.398	1.000
Cadmium	L02_3.5_1079_924	Cadmium	2	3.5	1079	924	2.772	1.000
Cadmium	L02_3.5_1079_1187	Cadmium	2	3.5	1079	1187	2.252	1.000
Cadmium	L02_3.5_1079_1500	Cadmium	2	3.5	1079	1500	1.847	1.000
Cadmium	L02_3.5_1537_512	Cadmium	2	3.5	1537	512	6.242	1.000

B.4.5 Assembling Results (Step 7)

By clicking Button 7, the Excel™ tool creates three separate results tables, shown in the sheets "SummaryOutput," "DetailedOutput," and "IndividualOutput."

The summary table shows the Tiers 1 and 2 human health multipathway screening results at the level of source category and PB-HAP group (cadmium, mercury, total PAH, and total dioxin; see example screen shot in Exhibit_Att B-13). Cells with red highlighting call attention to cases where facilities exceeded the Tier 1 or Tier 2 thresholds.[32] Using Source Category A as an example – there were 10 facilities in the category. For this source category, four, eight, and five facilities emitted dioxins, mercury, and PAHs, respectively, at levels exceeding the Tier 1 threshold (there were no emissions of cadmium). The table indicates which facility's emissions

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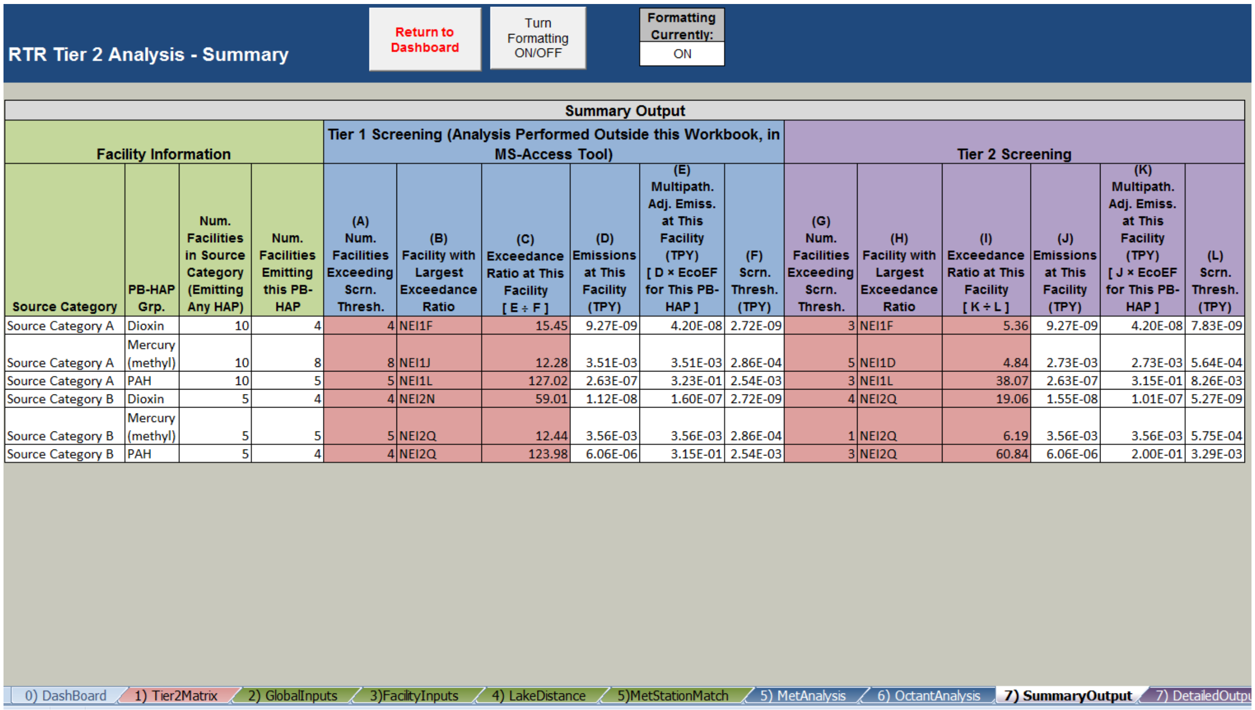
[32] The tool shading schemes have been revised so that only ratios of at least 1.5 indicate an exceedance of the threshold. The 1.1 value in the fourth data row would not be shaded red, and its value for number of facilities exceeding would go from 1 to 0.

most exceeded each threshold and by how much. The Tier 2 adjustment factors caused many but not all of these facilities to screen out at Tier 2, leaving three, five, and three facilities respectively exceeding the Tier 2 screening thresholds for dioxins, mercury, and PAHs, respectively. The largest Tier 2 exceedance ratios were far smaller than the largest Tier 1 exceedance ratios.

Exhibit_Att B-13. Example of Summary Output Table Created by the Tier 2 Tool[a]



Summary Output

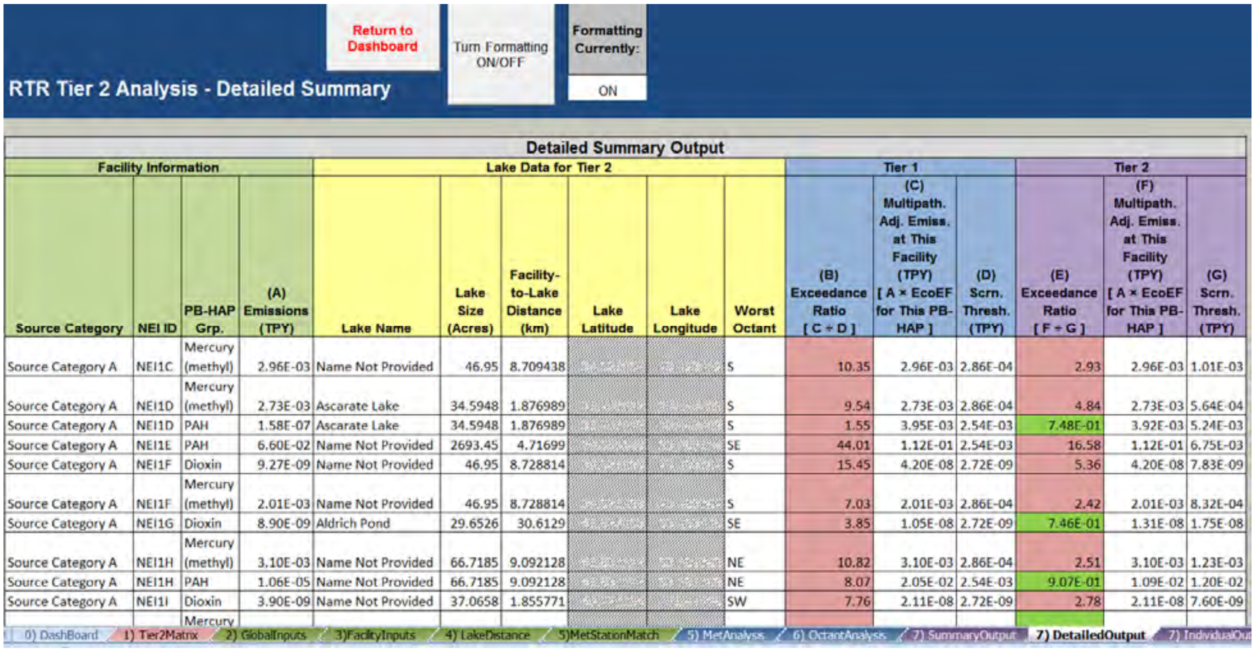
Facility Information				Tier 1 Screening (Analysis Performed Outside this Workbook, in MS-Access Tool)						Tier 2 Screening					
Source Category	PB-HAP Grp.	Num. Facilities in Source Category (Emitting Any HAP)	Num. Facilities Emitting this PB-HAP	(A) Num. Facilities Exceeding Scrn. Thresh.	(B) Facility with Largest Exceedance Ratio	(C) Exceedance Ratio at This Facility [E ÷ F]	(D) Emissions at This Facility (TPY)	(E) Multipath. Adj. Emiss. at This Facility (TPY) [D × EcoEF for This PB-HAP]	(F) Scrn. Thresh. (TPY)	(G) Num. Facilities Exceeding Scrn. Thresh.	(H) Facility with Largest Exceedance Ratio	(I) Exceedance Ratio at This Facility [K ÷ L]	(J) Emissions at This Facility (TPY)	(K) Multipath. Adj. Emiss. at This Facility (TPY) [J × EcoEF for This PB-HAP]	(L) Scrn. Thresh. (TPY)
Source Category A	Dioxin	10	4	4	NEI1F	15.45	9.27E-09	4.20E-08	2.72E-09	3	NEI1F	5.36	9.27E-09	4.20E-08	7.83E-09
Source Category A	Mercury (methyl)	10	8	8	NEI1J	12.28	3.51E-03	3.51E-03	2.86E-04	5	NEI1D	4.84	2.73E-03	2.73E-03	5.64E-04
Source Category A	PAH	10	5	5	NEI1L	127.02	2.63E-07	3.23E-01	2.54E-03	3	NEI1L	38.07	2.63E-07	3.15E-01	8.26E-03
Source Category B	Dioxin	5	4	4	NEI2N	59.01	1.12E-08	1.60E-07	2.72E-09	4	NEI2Q	19.06	1.55E-08	1.01E-07	5.27E-09
Source Category B	Mercury (methyl)	5	5	5	NEI2Q	12.44	3.56E-03	3.56E-03	2.86E-04	1	NEI2Q	6.19	3.56E-03	3.56E-03	5.75E-04
Source Category B	PAH	5	4	4	NEI2Q	123.98	6.06E-06	3.15E-01	2.54E-03	3	NEI2Q	60.84	6.06E-06	2.00E-01	3.29E-03

[a] The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

The detailed summary table shows much of the same information as the summary table, but the screening results for each facility are shown (see example screen shot in Exhibit_Att B-14). This detailed table is helpful because it shows which facilities exceeded the thresholds and by how much. It also shows the “worst” octant per facility and PB-HAP group as well as the lake analyzed in that octant. Green shading in Tier 2 columns call attention to cases where the Tier 1 screening threshold was exceeded but the Tier 2 threshold was not.

The individual summary table is similar to the detailed summary table, but it adds the details of the screening results for each chemical (not just PB-HAP groups) and the Tier 2 adjustment factors (see example screen shot in Exhibit_Att B-15). The Tier 2 adjustment factors are specific to each chemical and each facility. The ratios to screening level by chemical are summed at the facility level to produce the ratios to screening level by PB-HAP group. The shading is specific to the PB-HAP-total ratios rather than the chemical ratios.

Exhibit_Att B-14. Example of Detailed Output Table Created by the Tier 2 Tool[a]



RTR Tier 2 Analysis - Detailed Summary

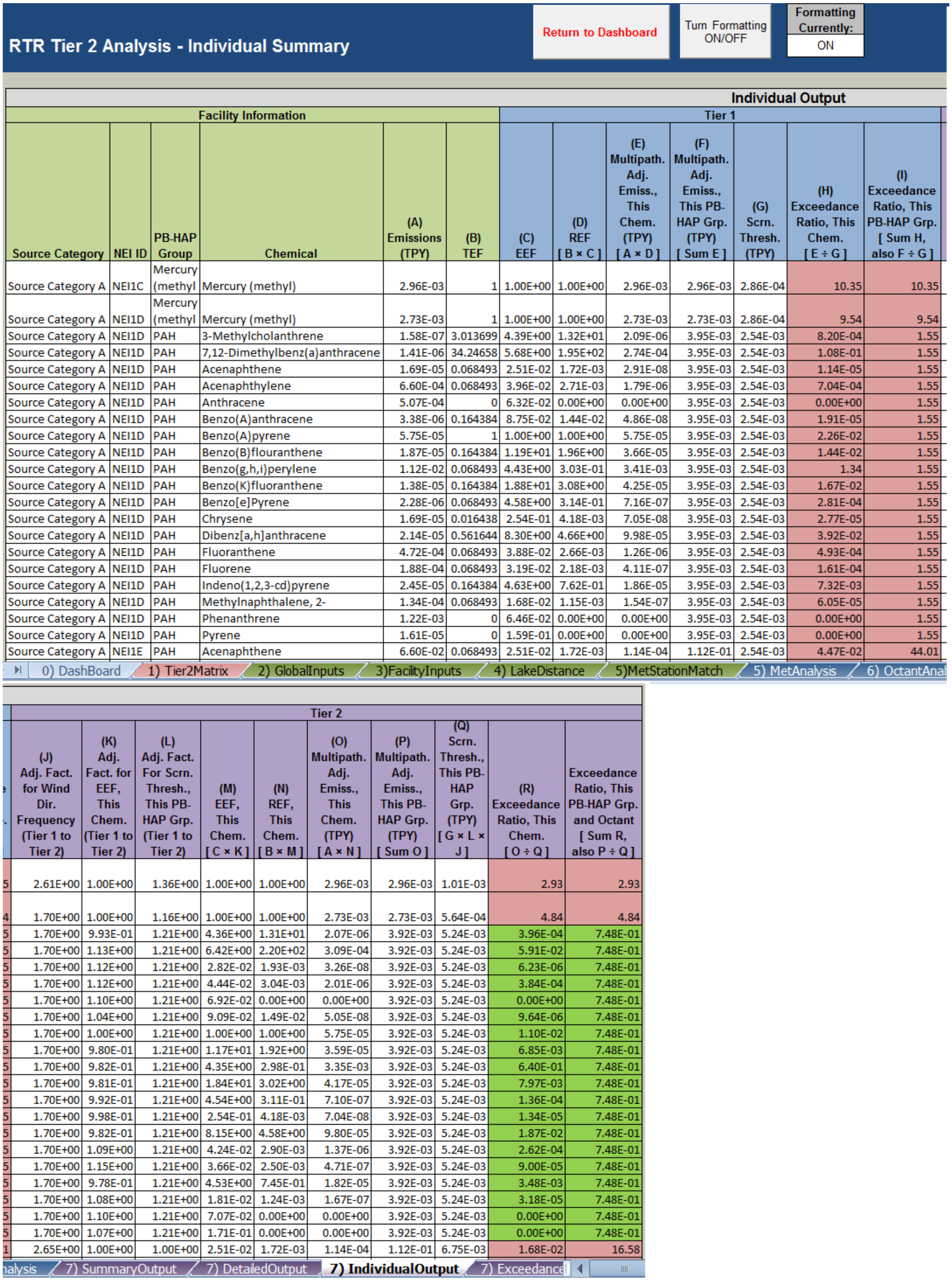
Formatting Currently: ON

Detailed Summary Output

Facility Information				Lake Data for Tier 2							Tier 1			Tier 2		
Source Category	NEI ID	PB-HAP Grp.	(A) Emissions (TPY)	Lake Name	Lake Size (Acres)	Facility-to-Lake Distance (km)	Lake Latitude	Lake Longitude	Worst Octant	(B) Exceedance Ratio [C ÷ D]	(C) Multipath. Adj. Emiss. at This Facility (TPY) [A × EcoEF for This PB-HAP]	(D) Scrn. Thresh. (TPY)	(E) Exceedance Ratio [F ÷ G]	(F) Multipath. Adj. Emiss. at This Facility (TPY) [A × EcoEF for This PB-HAP]	(G) Scrn. Thresh. (TPY)
Source Category A	NEI1C	Mercury (methyl)	2.96E-03	Name Not Provided	46.95	8.709438	[redacted]	[redacted]	S	10.35	2.96E-03	2.86E-04	2.93	2.96E-03	1.01E-03
Source Category A	NEI1D	Mercury (methyl)	2.73E-03	Ascarate Lake	34.5948	1.876989	[redacted]	[redacted]	S	9.54	2.73E-03	2.86E-04	4.84	2.73E-03	5.64E-04
Source Category A	NEI1D	PAH	1.58E-07	Ascarate Lake	34.5948	1.876989	[redacted]	[redacted]	S	1.55	3.95E-03	2.54E-03	7.48E-01	3.92E-03	5.24E-03
Source Category A	NEI1E	PAH	6.60E-02	Name Not Provided	2693.45	4.71699	[redacted]	[redacted]	SE	44.01	1.12E-01	2.54E-03	16.58	1.12E-01	6.75E-03
Source Category A	NEI1F	Dioxin	9.27E-09	Name Not Provided	46.95	8.728814	[redacted]	[redacted]	S	15.45	4.20E-08	2.72E-09	5.36	4.20E-08	7.83E-09
Source Category A	NEI1F	Mercury (methyl)	2.01E-03	Name Not Provided	46.95	8.728814	[redacted]	[redacted]	S	7.03	2.01E-03	2.86E-04	2.42	2.01E-03	8.32E-04
Source Category A	NEI1G	Dioxin	8.90E-09	Aldrich Pond	29.6526	30.6129	[redacted]	[redacted]	SE	3.85	1.05E-08	2.72E-09	7.46E-01	1.31E-08	1.75E-08
Source Category A	NEI1H	Mercury (methyl)	3.10E-03	Name Not Provided	66.7185	9.092128	[redacted]	[redacted]	NE	10.82	3.10E-03	2.86E-04	2.51	3.10E-03	1.23E-03
Source Category A	NEI1H	PAH	1.06E-05	Name Not Provided	66.7185	9.092128	[redacted]	[redacted]	NE	8.07	2.05E-02	2.54E-03	9.07E-01	1.09E-02	1.20E-02
Source Category A	NEI1I	Dioxin	3.90E-09	Name Not Provided	37.0658	1.855771	[redacted]	[redacted]	SW	7.76	2.11E-08	2.72E-09	2.78	2.11E-08	7.60E-09
		Mercury					[redacted]	[redacted]							

[a]The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

Exhibit_Att B-15. Example of Individual Output Table Created by the Tier 2 Tool



RTR Tier 2 Analysis - Individual Summary

Individual Output

Facility Information						Tier 1							Tier 2									
Source Category	NEI ID	PB-HAP Group	Chemical	(A) Emissions (TPY)	(B) TEF	(C) EEF	(D) REF [B × C]	(E) Multipath. Adj. Emiss., This Chem. (TPY) [A × D]	(F) Multipath. Adj. Emiss., This PB-HAP Grp. (TPY) [Sum E]	(G) Scrn. Thresh. (TPY)	(H) Exceedance Ratio, This Chem. [E ÷ G]	(I) Exceedance Ratio, This PB-HAP Grp. [Sum H, also F ÷ G]	(J) Adj. Fact. for Wind Dir. Frequency (Tier 1 to Tier 2)	(K) Adj. Fact. for EEF, This Chem. (Tier 1 to Tier 2)	(L) Adj. Fact. For Scrn. Thresh., This PB-HAP Grp. (Tier 1 to Tier 2)	(M) EEF, This Chem. [C × K]	(N) REF, This Chem. [B × M]	(O) Multipath. Adj. Emiss., This Chem. (TPY) [A × N]	(P) Multipath. Adj. Emiss., This PB-HAP Grp. (TPY) [Sum O]	(Q) Scrn. Thresh., This PB-HAP Grp. (TPY) [G × L × J]	(R) Exceedance Ratio, This Chem. [O ÷ Q]	Exceedance Ratio, This PB-HAP Grp. and Octant [Sum R, also P ÷ Q]
Source Category A	NEI1C	Mercury (methyl	Mercury (methyl)	2.96E-03	1	1.00E+00	1.00E+00	2.96E-03	2.96E-03	2.86E-04	10.35	10.35	2.61E+00	1.00E+00	1.36E+00	1.00E+00	1.00E+00	2.96E-03	2.96E-03	1.01E-03	2.93	2.93
Source Category A	NEI1D	Mercury (methyl	Mercury (methyl)	2.73E-03	1	1.00E+00	1.00E+00	2.73E-03	2.73E-03	2.86E-04	9.54	9.54	1.70E+00	1.00E+00	1.16E+00	1.00E+00	1.00E+00	2.73E-03	2.73E-03	5.64E-04	4.84	4.84
Source Category A	NEI1D	PAH	3-Methylcholanthrene	1.58E-07	3.013699	4.39E+00	1.32E+01	2.09E-06	3.95E-03	2.54E-03	8.20E-04	1.55	1.70E+00	9.93E-01	1.21E+00	4.36E+00	1.31E+01	2.07E-06	3.92E-03	5.24E-03	3.96E-04	7.48E-01
Source Category A	NEI1D	PAH	7,12-Dimethylbenz(a)anthracene	1.41E-06	34.24658	5.68E+00	1.95E+02	2.74E-04	3.95E-03	2.54E-03	1.08E-01	1.55	1.70E+00	1.13E+00	1.21E+00	6.42E+00	2.20E+02	3.09E-04	3.92E-03	5.24E-03	5.91E-02	7.48E-01
Source Category A	NEI1D	PAH	Acenaphthene	1.69E-05	0.068493	2.51E-02	1.72E-03	2.91E-08	3.95E-03	2.54E-03	1.14E-05	1.55	1.70E+00	1.12E+00	1.21E+00	2.82E-02	1.93E-03	3.26E-08	3.92E-03	5.24E-03	6.23E-06	7.48E-01
Source Category A	NEI1D	PAH	Acenaphthylene	6.60E-04	0.068493	3.96E-02	2.71E-03	1.79E-06	3.95E-03	2.54E-03	7.04E-04	1.55	1.70E+00	1.12E+00	1.21E+00	4.44E-02	3.04E-03	2.01E-06	3.92E-03	5.24E-03	3.84E-04	7.48E-01
Source Category A	NEI1D	PAH	Anthracene	5.07E-04	0	6.32E-02	0.00E+00	0.00E+00	3.95E-03	2.54E-03	0.00E+00	1.55	1.70E+00	1.10E+00	1.21E+00	6.92E-02	0.00E+00	0.00E+00	3.92E-03	5.24E-03	0.00E+00	7.48E-01
Source Category A	NEI1D	PAH	Benzo(A)anthracene	3.38E-06	0.164384	8.75E-02	1.44E-02	4.86E-08	3.95E-03	2.54E-03	1.91E-05	1.55	1.70E+00	1.04E+00	1.21E+00	9.09E-02	1.49E-02	5.05E-08	3.92E-03	5.24E-03	9.64E-06	7.48E-01
Source Category A	NEI1D	PAH	Benzo(A)pyrene	5.75E-05	1	1.00E+00	1.00E+00	5.75E-05	3.95E-03	2.54E-03	2.26E-02	1.55	1.70E+00	1.00E+00	1.21E+00	1.00E+00	1.00E+00	5.75E-05	3.92E-03	5.24E-03	1.10E-02	7.48E-01
Source Category A	NEI1D	PAH	Benzo(B)flouranthene	1.87E-05	0.164384	1.19E+01	1.96E+00	3.66E-05	3.95E-03	2.54E-03	1.44E-02	1.55	1.70E+00	9.80E-01	1.21E+00	1.17E+01	1.92E+00	3.59E-05	3.92E-03	5.24E-03	6.85E-03	7.48E-01
Source Category A	NEI1D	PAH	Benzo(g,h,i)perylene	1.12E-02	0.068493	4.43E+00	3.03E-01	3.41E-03	3.95E-03	2.54E-03	1.34	1.55	1.70E+00	9.82E-01	1.21E+00	4.35E+00	2.98E-01	3.35E-03	3.92E-03	5.24E-03	6.40E-01	7.48E-01
Source Category A	NEI1D	PAH	Benzo(K)fluoranthene	1.38E-05	0.164384	1.88E+01	3.08E+00	4.25E-05	3.95E-03	2.54E-03	1.67E-02	1.55	1.70E+00	9.81E-01	1.21E+00	1.84E+01	3.02E+00	4.17E-05	3.92E-03	5.24E-03	7.97E-03	7.48E-01
Source Category A	NEI1D	PAH	Benzo[e]Pyrene	2.28E-06	0.068493	4.58E+00	3.14E-01	7.16E-07	3.95E-03	2.54E-03	2.81E-04	1.55	1.70E+00	9.92E-01	1.21E+00	4.54E+00	3.11E-01	7.10E-07	3.92E-03	5.24E-03	1.36E-04	7.48E-01
Source Category A	NEI1D	PAH	Chrysene	1.69E-05	0.016438	2.54E-01	4.18E-03	7.05E-08	3.95E-03	2.54E-03	2.77E-05	1.55	1.70E+00	9.98E-01	1.21E+00	2.54E-01	4.18E-03	7.04E-08	3.92E-03	5.24E-03	1.34E-05	7.48E-01
Source Category A	NEI1D	PAH	Dibenz[a,h]anthracene	2.14E-05	0.561644	8.30E+00	4.66E+00	9.98E-05	3.95E-03	2.54E-03	3.92E-02	1.55	1.70E+00	9.82E-01	1.21E+00	8.15E+00	4.58E+00	9.80E-05	3.92E-03	5.24E-03	1.87E-02	7.48E-01
Source Category A	NEI1D	PAH	Fluoranthene	4.72E-04	0.068493	3.88E-02	2.66E-03	1.26E-06	3.95E-03	2.54E-03	4.93E-04	1.55	1.70E+00	1.09E+00	1.21E+00	4.24E-02	2.90E-03	1.37E-06	3.92E-03	5.24E-03	2.62E-04	7.48E-01
Source Category A	NEI1D	PAH	Fluorene	1.88E-04	0.068493	3.19E-02	2.18E-03	4.11E-07	3.95E-03	2.54E-03	1.61E-04	1.55	1.70E+00	1.15E+00	1.21E+00	3.66E-02	2.50E-03	4.71E-07	3.92E-03	5.24E-03	9.00E-05	7.48E-01
Source Category A	NEI1D	PAH	Indeno(1,2,3-cd)pyrene	2.45E-05	0.164384	4.63E+00	7.62E-01	1.86E-05	3.95E-03	2.54E-03	7.32E-03	1.55	1.70E+00	9.78E-01	1.21E+00	4.53E+00	7.45E-01	1.82E-05	3.92E-03	5.24E-03	3.48E-03	7.48E-01
Source Category A	NEI1D	PAH	Methylnaphthalene, 2-	1.34E-04	0.068493	1.68E-02	1.15E-03	1.54E-07	3.95E-03	2.54E-03	6.05E-05	1.55	1.70E+00	1.08E+00	1.21E+00	1.81E-02	1.24E-03	1.67E-07	3.92E-03	5.24E-03	3.18E-05	7.48E-01
Source Category A	NEI1D	PAH	Phenanthrene	1.22E-03	0	6.46E-02	0.00E+00	0.00E+00	3.95E-03	2.54E-03	0.00E+00	1.55	1.70E+00	1.10E+00	1.21E+00	7.07E-02	0.00E+00	0.00E+00	3.92E-03	5.24E-03	0.00E+00	7.48E-01
Source Category A	NEI1D	PAH	Pyrene	1.61E-05	0	1.59E-01	0.00E+00	0.00E+00	3.95E-03	2.54E-03	0.00E+00	1.55	1.70E+00	1.07E+00	1.21E+00	1.71E-01	0.00E+00	0.00E+00	3.92E-03	5.24E-03	0.00E+00	7.48E-01
Source Category A	NEI1E	PAH	Acenaphthene	6.60E-02	0.068493	2.51E-02	1.72E-03	1.14E-04	1.12E-01	2.54E-03	4.47E-02	44.01	2.65E+00	1.00E+00	1.00E+00	2.51E-02	1.72E-03	1.14E-04	1.12E-01	6.75E-03	1.68E-02	16.58

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[a] The screen shot examples shown in this section are for actual facilities; however, their source categories, NEI IDs, and coordinates have been altered or masked so the data are not linked to specific facilities. Only a portion of the table might be shown.

B.5 References

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Addendum 1. Summary of TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

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Exhibits, Addendum 1

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Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Meteorological Parameters				
Wind direction (% of time wind blows toward the lake and farm)	In previous runs, direct deposition accounted for the bulk of chemical input onto farms and into lakes. Because wind direction is strongly correlated to direct deposition in a given location, media concentrations are potentially highly sensitive to this parameter. Also, because the percentage of time the prevailing wind blows in the direction of lakes and farms can vary considerably across locations, differences in this parameter might also result in significant changes in important environmental concentrations.	**Highly Significant**: Previous sensitivity analyses have confirmed this to be a very sensitive parameter in the Tier 1 Screening modeling set-up. Changing the fraction of time the wind blows toward the lake and farm by a factor of two corresponds to a change in the risk by a factor of two. **Low Effort to Implement:** This variable is relatively straightforward to vary in the Tier 2 screening scenarios.	**Low to Moderate:** The average fraction of time the wind blows in a given direction can be estimated for any surface meteorological station. Then, facilities can be linked to the closest surface meteorological station.	**High**
Wind speed	Wind speed can affect the location of the "peak" concentration and deposition patterns in a given model configuration, as well as the risk-distance profile.	**Highly Significant**: Previous sensitivity analyses have confirmed this to be a very sensitive parameter. However, wind speed does not vary widely across U.S. locations which could reduce its potential influence. **Low Effort to Implement:** This variable is relatively straightforward to vary in the Tier 2 screening scenarios.	**Low to Moderate:** The annually-averaged wind speed can be estimated for any surface meteorological station. Then, facilities can be linked to the closest surface meteorological station.	**High**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Precipitation	Chemicals for which wet vapor or wet particle deposition processes are important are likely to be sensitive to the assumed level of precipitation.	**Highly Significant**: Previous sensitivity analyses have indicated a relatively high sensitivity of risk to precipitation for most PB-HAPs (PAHs, cadmium, and mercury). **Moderate Effort to Implement:** In implementing changes in precipitation in TRIM, care must be taken to also preserve the overall water balance in the model.	**Low to Moderate:** The annually-averaged precipitation rate can be estimated for the subset of surface meteorological stations that capture rainfall data. Then, facilities can be linked to the closest surface meteorological station with available data.	**High**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Mixing height	Greater mixing heights increase the dispersion of pollutants in the atmosphere and consequently reduce deposition to the ground in the areas around the stack. This is likely to be a highly sensitive parameter if there is a sizeable variation in mixing heights between facilities.	**Highly Significant**: Previous sensitivity analyses have shown risk to be very sensitive to mixing height. **Low Effort to Implement:** This variable is relatively straightforward to vary in the Tier 2 screening scenarios.	**Moderate to High:** Mixing height estimates are available for upper air meteorological stations, and this set of stations is more limited than the set of surface meteorological stations. Each surface station can be linked to the closest upper air station to estimate the average mixing height. Then, facilities can be linked to the closest surface meteorological station. The relative uncertainty in mixing height for a given facility is high, given diurnal variations in mixing height and the smaller number of upper air stations.	**High**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Configurational Parameters				
Distance of lake from stack	Deposition is known to decrease with distance from stack, although this relationship also depends on meteorological parameters such as wind speed and wind direction.	**Significance Difficult to Determine:** Limited results from previous TRIM model runs show an inconclusive relationship between risk and distance from stack, possibly as a result of limited statistical power. Some studies in the literature show a definite decreasing risk gradient with distance but others report too many confounding factors to isolate the precise relationship. **Moderate Effort to Implement:** This variable requires updates to the layout coordinates and requires more effort to vary in the Tier 2 screening scenarios than the meteorological parameters.	**Low:** The lakes within a given radius of each facility can be found using ArcGIS™ (see section 4).	**High**
Distance of farm from stack	Deposition is known to decrease with distance from stack, although this relationship also depends on meteorological parameters such as wind speed and wind direction.	**Significance Difficult to Determine:** Limited results from previous TRIM model runs show an inconclusive relationship between risk and distance from stack, possibly as a result of limited statistical power. Some studies in the literature show a definite decreasing risk gradient with distance but others report too many confounding factors to isolate the precise relationship. **Moderate Effort to Implement:** This variable requires updates to the layout coordinates and requires more effort to vary in the Tier 2 screening scenarios than the meteorological parameters.	**High:** Although the distance to the farm will likely affect risk, it is difficult to determine the precise land parcels near each facility that are actually used for farming now or in the future.	**Medium**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Watershed: lake area ratio	A higher watershed:lake area ratio potentially increases the chemical input of water-soluble or particle-attached chemicals into the lake. But the associated higher flush rate will likely reduce this effect.	**Significance Difficult to Determine**: Changes in the watershed to lake ratio affect risk, but the interaction depends on other variables involved in the water balance. **Moderate Effort to Implement:** In implementing changes in the watershed:lake ratios in TRIM, care must be taken to also preserve the overall water balance in the model.	**High:** The portion of land serving as a watershed to a particular lake is difficult to determine.	**Medium**
Area and depth of lake	A higher lake area would capture more deposition but this effect might be counterbalanced by the ensuing larger volume of water, which reduces chemical concentration. Similarly, a deeper lake would also reduce concentrations, but this effect might be counterbalanced by the ensuing lower flush rates at a constant level of precipitation/runoff.	**Significance Difficult to Determine**: The impact of these parameters is inconclusive based on current studies using the TRIM model. **Moderate Effort to Implement:** The lake area variable requires updates to the layout coordinates and requires more effort to vary in the Tier 2 screening scenarios than the meteorological parameters. In implementing changes in these variables in TRIM, care must be taken to also preserve the overall water balance in the model.	**High:** While the area of lakes near a facility can be determined using GIS, the depth cannot.	**Medium**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Physical Parameters				
Flush rate	A higher flush rate out of the lake would result in a higher rate of chemical output from the lake, assuming constant inflow and volume.	**Significance Difficult to Determine**: The impact of this parameter is inconclusive based on current studies using the TRIM model. **Moderate Effort to Implement:** In implementing changes in the flush rate in TRIM, care must be taken to also preserve the overall water balance in the model.	**High:** The flush rate of a lake cannot be determined easily for any lake found near a facility. In addition, erosion rates, watershed information, and lake depth needed to estimate the flushing rate are not readily available.	**Medium**
Runoff rate and fraction	A higher runoff rate (or fraction) would likely result in greater chemical input into the lake for some chemicals but also potentially a higher flush rate out of the lake.	**Significance Difficult to Determine**: The impact of this parameter is inconclusive based on current studies using the TRIM model. **Moderate Effort to Implement:** In implementing changes in the runoff rate and fraction in TRIM, care must be taken to also preserve the overall water balance in the model.	**High:** As with the flush rate, the runoff rate and fraction for any lake near a facility cannot be readily determined.	**Medium**
Erosion rate and fraction	A higher erosion rate would likely result in greater chemical input into the lake for particle-bound chemicals. It would also result in greater chemical transport onto farmlands, but this might be counterbalanced by equally greater erosion off farmland.	**Highly Significant**: Previous analyses have shown risk to be sensitive to this parameter for some chemicals. **Moderate Effort to Implement:** In implementing changes in the erosion rate and fraction in TRIM, care must be taken to also preserve the overall water balance in the model.	**High:** As with the flush rate, the erosion rate and fraction for any lake near a facility cannot be readily determined.	**Medium**

Exhibit Add B1-1. TRIM.FaTE Parameters Considered for Inclusion in Tier 2 Analysis

Parameter	Mechanism of Potential Influence in TRIM	Assessment of Parameter Significance and Ease in Implementation	Uncertainty in Site-Specific Data for Facilities	Priority for Inclusion
Chemical Parameters				
Methylation/ demethylation rates (Hg)	For Hg, methylation and demethylation rates in lake sediment and surface water are potentially sensitive parameters affecting risk. A literature survey has indicated a relatively high range for rate constants describing these processes.	**Highly Significant**: Previous analyses run in TRIM have confirmed the high sensitivity of these parameters for Hg. **Low Effort to Implement:** This variable is relatively straightforward to vary in the Tier 2 screening scenarios.	**High:** The specific methylation / demethylation rates for mercury in the vicinity of a specific facility cannot be readily determined.	**Low**
Total phosphorus levels in the lake	The total phosphorus content of a lake is used as part of the TRIM.FaTE parameterization process to estimate the biomass content of different trophic levels. These biomass levels affect the biomagnification of chemicals up the food chain and potentially risk to human consumers of fish.	**Not Significant**: Previous analyses have shown limited sensitivity to total phosphorus levels. This is likely because the empirical equations predicting biomass in each trophic level depend in similar ways on the level of total phosphorus. So changes in total phosphorus do not significantly affect the ratio of biomass between the different trophic levels. **Low Effort to Implement:** This variable is relatively straightforward to vary in the Tier 2 screening scenarios.	**High:** The total phosphorus levels in lakes near a specific facility cannot be readily determined.	**Low**

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Addendum 2. Analysis of Lake Size and Sustainable Fish Population

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CONTENTS, ADDENDUM 2

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1. Introduction

Identifying the smallest size of a lake that might maintain self-sustaining populations of fish from trophic levels (TL) 3 and 4 and is sufficient to support at least one angler at a specified fish ingestion rate requires consideration of many factors. Some factors depend on assumptions about the behavior of anglers who consume fish from a lake (see Section 2 below). Other factors depend upon the general biology of fish populations in North American ecoregions (see Section 3). Based on evaluation of these factors, a set of assumptions was developed to support the estimation of minimum lake sizes that are needed to sustain a particular total human ingestion rate in grams/day (see Section 4). Then, equations were developed (see Section 5) that were used to create Exhibit_Att B-4, which was used to determine the threshold lake size of 100 acres.

2. Angler Behavior

Several assumptions regarding angler behavior are important for estimating a minimum lake size that is fishable. The first is a conservative assumption that anglers (and their family members) consume about 50:50 top carnivore fish from both the benthos and from the water column. Benthic carnivores (BC), such as catfish and chub that consume benthic invertebrates and small benthic fish, can grow to large sizes (e.g., 2 kg). Assuming a diet of 50 percent benthic invertebrates and 50 percent small benthic fish (e.g., young of the year that feed on algae or detritus), the BC fish category would represent trophic level (TL) 3.5. Pelagic piscivores—water column carnivores (WCC)—include species such as largemouth bass, lake trout, pickerel, and walleye. The WCC are modeled as TL 4, with 100 percent of their diet comprised of water column omnivores (WCO, e.g., pan fish such as bluegill and white perch), and the diet of the WCO is assumed to be 100 percent minnow-sized fish that feed on zooplankton and algae . The assumption of 50:50 WCC and BC consumption is conservative, because smaller, pan fish, are not included. Although anglers might prefer to catch and consume the pelagic (TL4) game fish species, their generally lower abundance compared with fish that also consume benthic invertebrates dictates that anglers will more often capture the benthic (TL3.5) carnivores. Some TL2 (herbivorous) fish such as carp attain “catchable” size, but they generally are not popular fish for consumption and are not considered here. .

A second assumption is that anglers and their family members consume only the fillet portion of a fish. According to Ebert et al. (1993), the edible fraction of fish as a proportion of total fresh body weight is 0.4 for salmon, 0.78 for smelt, and 0.3 for all other species. EPA recommends use of 0.30 for the consumable fraction of fish (USEPA, 1989). For this analysis, a 0.33 edible fraction for TL4 fish was assumed. That factor is roughly one-third, which we considered preferable to 0.30 to account for some proportion of salmon likely in the diet. This factor is used in the lake size analysis to estimate total fish biomass required to support specified human fish consumption rates.

A third assumption relates to ingestion rates of the angler or angler family. Fish ingestion rates used for the purpose of the Tier 2 analysis are the same as those in Tier 1 and are consistent with subsistence angler ingestion rates (see Exhibit_Att A-16. Summary of RTR Tier 1 Screening Scenario Assumptions).

The final assumption is that the lake must support a sustainable fishery despite fish harvesting by humans; in other words, the lake shouldn’t be “fished out” by the harvest rate required to meet the subsistence angler fish ingestion rate. The productivity of any particular fishery (local population of a species of fish) and the proportion of adult fish that can be harvested for human consumption are difficult values to estimate, and models to predict sustainable harvests of different fisheries are numerous and complex. Species-specific parameters of key to such models include fecundity with age and size; survivorship of eggs, fry, and juveniles to sexual maturity (recruitment); natural predation pressures; and temporal variation in food availability. For the purpose of this analysis, simplifying assumptions are required. In the analysis by Håkanson and Boulion (2004), which included a survey of 122 lakes, the authors noted that a typical loss from fishing by birds, mammals, and humans would be approximately 10 percent of the fish biomass in the prey fish compartment (TL3) and 10 percent of the biomass in the predator fish compartment (TL4). The authors also found that as overall lake productivity increased, the biomass of prey (TL3) fish increased more rapidly than the biomass of predator (TL4) fish. For our lake size analysis, we assumed that anglers can harvest 10 percent of the biomass of pelagic WCC fish without diminishing the fish population size.

3. Fish Biology

Fish life histories also are key to estimating the minimum surface area of a pond or lake that could support a sustainable fish population of WCC. The productivity and trophic structure of fish communities in ponds and lakes across the United States are varied. Thus, any set of assumptions is unlikely to all hold true at any given location. Nonetheless, three factors are important to any estimate of a minimum lake surface area for sustainable pelagic TL4 fishing: the general productivity of a lake (expressed as grams of fish wet weight per meter squared, g ww/m^2); the maximum likely proportion of the total fish biomass in a lake that is comprised of the top trophic level fish; and the minimum viable population (MVP) size required for the fish species to be self-sustaining in the short term (for at least a few decades).

3.1. Lake Productivity

The general productivity of a lake depends on many factors, including latitude, seasonal temperatures, and nutrients supporting the base of the food web. For lakes at approximately the same latitude in the same climate, nutrients play a key role in the total fish biomass that a lake might support. In a regression analysis of data on total phosphorus (TP) and fish biomass for 31 lakes across North America, Europe, and Russia, Nürnberg (1996) summarized the "limits" among three TP-defined lake trophic status categories with respect to total fish wet weight biomass per unit area:

Oligo-meso (TP = 10 µg/L) = 1.9 g ww/m^2
Meso-eutro (TP = 30 µg/L) = 3.7 g ww/m^2
Eutro-hypereutro (TP = 100 µg/L) = 8.5 g ww/m^2

Nürnberg (1996) also summarized total fish biomass limits from Bachmann et al. (1996) for the same lake trophic status categories based on a sample of 60 lakes in Florida:

Oligo-meso (TP = 10 µg/L) = 7.4 g ww/m^2
Meso-eutro (TP = 30 µg/L) = 10.6 g ww/m^2
Eutro-hypereutro (TP = 100 µg/L) = 15.6 g ww/m^2

As might be expected, for the same TP concentrations, standing fish biomass per unit area in the Florida lakes is two to three times higher than standing fish biomass for more northerly lakes with shorter growing seasons.

Hanson and Legget (1982) estimated the relationship between TP and standing stock of fish using a regression model based on samples from 21 lakes ranging in surface area from 0.1–25,000 hectares (~0.25–62,000 acres) and located between 0° and 56° N latitude and

121° E to 122° W longitude. Their linear regression relating TP to total fish standing biomass (B) had a correlation coefficient (r^2) of 0.84:

$$B = 0.792 + 0.072\ (TP)$$

where:

B = total fish biomass (kg/hectare)

TP = total phosphorous (µg/L)

The regression model of Hanson and Legget (1982) predicted total fish biomass densities in lakes of 3.0–9.5 g ww/m^2 for TP concentrations ranging from 10–50 µg/L for oligo-mesotrophic to mid-range eutrophic lakes. Another regression model from Hoyer and Canfield (1991) predicted fish biomass densities in streams of 2.6–6.6 g ww/m^2 over the same range of TP concentrations.

In general, for very small lakes, relatively low fish productivity is likely. For example, Demers et al. (2001) found fish standing biomass values of 2.73 and 3.81 g ww/m^2 in two lakes of 27 and 22 acres (11 and 9 hectares), respectively, in south-central Ontario. Brönmark and Weisner (1996) reported on aquatic communities from a sample of 44 small ponds in southern Sweden (most were less than 5 hectares ≈ 12 acres). They found no fish in 5 of the smaller ponds (mean surface area of 0.20 ± 0.097 acres)—which also exhibited lower TP concentrations than the larger ponds—and no piscivorous fish in another 11 of the 44 ponds (mean surface area of 0.46 ± 0.27 acres). For the 28 ponds with piscivorous (TL4) fish present, the mean pond surface area was 1.4 (±1.3 SD) acres.

Scientists have also examined the relationship between TP and total fish biomass in reservoirs. Yurk and Ney (1989) examined the relationship between TP and standing stock of fish in 22 reservoirs in southern Appalachia sampled in 1973. Their logarithmic regression relating TP to total fish standing biomass (B) used the following equation and had an r^2 of 0.75:

$$Log_{10}\ (B) = 1.07 + 1.14 \times Log_{10}\ (TP)$$

Use of the equations from Hanson and Legget (1982) and Yurk and Ney (1989) yielded similar predications of total fish biomass at low to intermediate TP concentrations. At low TP (e.g., 10 µg/L), predictions of total fish biomass were 3.0 g ww/m^2 (Yurk and Ney, 1989) and 1.6 g ww/m^2 (Hanson and Legget, 1982); at high TP (e.g., 100 µg/L), fish biomass predicted by the two models were 15.5 and 22.4 g ww/m^2, respectively.

Ideally, one would have data indicating TP levels in lakes in the vicinity of facilities for a Tier 2 analysis. Such data, however, are rarely readily available. For purposes of the screening assessment, therefore, we assume that fish productivity per unit area is independent of lake size over a wide range of lake sizes and that TP levels are unknown.

Leidy and Jenkins (1977) reported analyses of several large data sets to support modeling of fish productivity and carrying capacity in reservoirs across the United States for the National Reservoir Research Program. The analyses included studies of fish standing biomass by species in 61 reservoirs across the midwestern and eastern United States sampled at different times between 1952 and 1975. Only reservoirs of at least 500 acres (202 hectares) in size were included, with some exceeding 65,000 acres (in the Missouri drainage basin). Considering all 61 reservoirs, the mean biomass density of fish was 41.3 (± 30.4 SD) g ww/m^2. The minimum and maximum total fish biomass densities were 3.2 and 133.2 g ww/m^2, respectively, and the median value was 30.9 g ww/m^2. Reservoirs typically have large drainage basins, which in some areas can receive excess TP from large expanses of agricultural areas.

In summary, the fish productivity in lakes and reservoirs can vary by more than three orders of magnitude. The reservoirs surveyed by Leidy and Jenkins (1977) in general were much larger (and were often more shallow and nutrient rich) than the natural lakes surveyed by others discussed above. The mean standing fish biomass of approximately 41.3 g ww/m^2 from the reservoir survey is likely to be higher than a mean value for representative samples of natural lakes in the United States. For the purpose of estimating the minimum lake size that would support a sustainable WCC fishery, we rounded that value down to a single significant digit of 40 g ww/m^2 as the upper limit for total fish biomass in a lake. That standing biomass is higher than predicted by the regression models of Hanson and Legget (1982), Yurk and Ney (1989), and Nürnberg (1996) at a high total phosphorus of 100 µg/L (where phosphorous is the limiting nutrient). Less productive lakes would support fewer fish per unit area, and, therefore, would have to be larger to support a specified fish ingestion rate.

3.2. Proportion of Fish Biomass by Trophic Level

As indicated previously, for the Tier 2 analysis, the proportion of fish in an angler's diet that consists of WCC (TL4) and BC (TL3.5) is assumed to be 50:50 by biomass (not numbers) for lakes that support the four trophic levels. In smaller lakes, TL4 fish are likely to be missing or rare, with TL3 fish in the water column (e.g., sunfish) being the highest trophic level supported by the primary productivity (algal/plant production) in some lakes. As a "rule of thumb" in ecology, 10 percent or less of the energy produced at one trophic level usually can be converted to biomass in the next trophic level (i.e., approximately 90 percent loss of energy) per trophic step. However, with different species having different energy assimilation efficiencies and with smaller species generally having higher turnover rates than larger species, the 10 percent energy rule does not necessarily translate into a standing biomass pyramid of similar proportions. In this section, the proportion of fish (based on biomass) that might be expected in the WCC and the BC fish compartments relative to total standing fish biomass are examined assuming that the lake is large enough to support WCC (pelagic TL4 fish).

Examination of several studies of fish biomass by trophic level indicated that top trophic level fish might comprise up to 20 percent of the standing fish biomass in many locations. Ploskey and Jenkins (1982) estimated that piscivorous fish, both those that are generally free-swimming or pelagic (e.g., pike, gar, walleye) and those that rest and forage primarily in the benthos (e.g., various species of catfish, suckers) comprise 22 percent of the total fish biomass in DeGray Lake, Arkansas (averaged across several years). Leidy and Jenkins (1977) estimated that 18 percent of the fish biomass across the 61 reservoirs they examined was piscivorous (minimum of 14 percent and maximum 24 percent). Demers et al. (2001) categorized 2 percent and 15 percent of the total fish biomass in two small lakes of 27 and 22 acres in size, respectively, as piscivorous/benthivorous fish (e.g., largemouth bass, creek chub); primary benthivores (e.g., catfish, suckers) dominated at >70 percent in both lakes.

One of the more recent food web models for freshwater lakes is that of Håkanson and Boulion (2004). They designed their model to predict productivity and standing crop of prey and predatory fishes in lakes of northern Europe. The authors acknowledged that fish feeding patterns are complicated by the fact that fish change their feeding preferences as they age. Some fish species consume zooplankton or benthic invertebrates in their first year, and switch to small fish and then to larger fish as they mature and grow in size.

Håkanson and Boulion (2004) created a “distribution coefficient” to indicate what proportion of the total fish biomass in a lake is prey versus predatory fish. Based on data from 122 lakes in Europe and North America, they concluded that 27 percent by biomass is a “normal” portion of predatory fish in a balanced system. They noted further, however, that for eutrophic lakes with TP levels >100 µg/L, the proportion of fish represented by piscivores declines to less than 20 percent. The piscivores included both benthic and pelagic species. We note that most benthic piscivores also consume benthic macroinvertebrates.

Based on the information above, the top trophic level fish are assumed to comprise 21 percent of the total fish biomass. With the bulk of productivity in lakes originating from detritus in the benthos, the total biomass of strictly pelagic game fish is expected to be less than that of benthic fish. Therefore, for purpose of this lake size analysis, the piscivorous/benthivorous fish were separated into two compartments, with 17.5 percent of the total fish biomass in a benthic carnivore (TL3.5 or BC) compartment and 3.5 percent of the total in a pelagic piscivore (WCC) compartment. Thus, the TL4 fish, when present, represent the limiting compartment for angler fish harvesting and consumption.

3.3. Minimum Viable Population Size

The final step in estimating the minimum lake size that can support sustainable fishing of its WCC fish species is to invoke the concept of minimum viable population (MVP) size. MVP is a concept used frequently in conservation biology for animals and is defined as the smallest population that will persist for a specified duration (e.g., 100 years) with a given probability (e.g., 95 percent). MVP for any given species and location depends on many attributes of the species biology (e.g., body size, reproductive rate, home range size, corridors between populations, variability in environmental characteristics that impact fecundity and survival). At lower numbers, the likelihood of population extinction increases due to environmental and demographic stochasticity (Menzie et al., 2008). As for fisheries biology, entire text books have been dedicated to applied population ecology with population simulations incorporating demographic and life-history characteristics, spatial separation of habitat patches and metapopulations, the probability of local catastrophes, genetic variation (e.g., drift), and other factors with predictions of time-to-extinction or probability of extinction within specified time periods (e.g., Soulé, 1987; Akçakaya et al., 1999). Consideration of such models in population-level ecological risk assessment has begun, but faces many challenges (Barnthouse et al., 2008). Moreover, that level of effort is beyond the resources available for screening-level analyses.

Much of the initial work on MVP investigated the genetic minima required for short-term survival, continuing adaptation to environmental change, and ultimately evolution. Inbreeding has been considered the primary threat to short-term survival and genetic drift the principal threat to losing the genetic variation required for adaptation (Shaffer, 1987). Several analyses (Senner, 1980; Franklin, 1980; Soulé, 1980; Frankel and Soulé, 1981; Lande and Barrowclough, 1987) have led to the conclusion that minimum effective population sizes on the order of 50 are required for short-term survival (e.g., several generations, decades), while effective population sizes on the order of 500 are necessary to provide adequate genetic variation for continuing adaptation over the long term (e.g., tens of generations, centuries for some animals) (Shaffer, 1981; 1987). Effective population size, N_e, is a measure of the rate of genetic drift (loss of genetic diversity or inbreeding), and its definition generally depends on the population in question (Rieman and Allendorft, 2001). N_e can be estimated mathematically based on stochastic behavior of gene frequencies in a diploid population. Simple models assume a fixed population size, constant fecundity, specified sex ratio, and no overlap between generations (see studies cited in NRC, 1986). For animals with 50:50 sex ratios, the effective population size is essentially the same as the actual breeding adult population size (Ewens et al., 1987). One of the most extensive population viability analyses in the United States has been conducted on the spotted owl (Boyce, 1993). Given the number and complexity of factors that influence MVP, however, including the definitions of time horizon (e.g., 100 years) and probability of survival (e.g., 95 percent), population biologists caution against using a “rule of thumb” for MVP across circumstances (Ewens et al., 1987).

Note that the MVP is appropriate for a single species of fish, not for generic categories of fish such as WCC or TL4. For this Tier 2 analysis, the MVP of 50 associated with short-term population survival was assumed for a TL4 fish species isolated in a lake. In reality, short-term extirpations from a lake can be countered by purposeful introductions from other lakes or during flooding events. Thus, an MVP of 500 was not considered necessary for game fish in lakes.

4. Summary of Assumptions for the Lake Size Analysis

The following assumptions were used in processing lake data for the Tier 2 analysis and in estimating the relationship between fish ingestion and sustainable harvest rates and lake size (see Section B.3.1 of Attachment B).

1. Piscivorous fish (WCC and BC), when present, comprise approximately 21 percent of the standing biomass of fish (ignoring seasonal changes). The BC fish represent 17.5 percent of the standing fish biomass; WCCs account for 3.5 percent of the total fish biomass. Thus, WCC fish, when present, represent the limiting compartment for angler fish harvesting and consumption.
2. Humans can harvest 10 percent of the biomass of a fish compartment without threatening the population due to overharvesting.
3. The MVP size for a single WCC species is at least 50 adult fish for a local population to survive over the short term (more than a decade).
4. Only 33 percent of the fish is edible fillet muscle.

5. Equations Used to Determine Lake Fish Populations

The standing biomass of WCC (TL4) fish supported in Lake X can be calculated as the total standing biomass of fish (Total SB) multiplied by 0.035, based on the assumption that TL4 fish represent approximately 3.5 percent of the standing biomass in Lake X.

$$WCC\ SB = Total\ SB\ x\ Fraction\ WCC \qquad \textit{(Equation 1)}$$

where:

WCC SB = Standing biomass of WCC fish (g wet weight [ww]/m^2) in Lake X
Total SB = Total standing biomass of fish (g ww/m^2) in Lake X
Fraction WCC = Fraction of WCC fish in Lake X (i.e., 0.035)

Using WCC SB and the size of Lake X (Lake Size), the total number of WCC fish supported in Lake X can be calculated using Equation 2 below.

$$No.WCC = \frac{Lake\ Size\ x\ WCC\ SB\ x\ CF}{BW_a} \qquad \textit{(Equation 2)}$$

where:

No. WCC = Total number of WCC fish in Lake X

Lake Size = Size of Lake X (acres)

WCC SB = Standing biomass of WCC fish (g ww/m^2; from Equation 1)

CF = 4047 (unit conversion factor m^2/acre)

BW_a = Body weight of adult TL4 fish (2000 g; assumed)

The likely annual productivity of WCC fish (kg/year) in Lake X can be estimated using .

$$Productivity\ WCC = \frac{Lake\ Size\ x\ WCC\ SB\ x\ CF1}{CF2} \quad \textit{(Equation 3)}$$

where:

Productivity WCC= Likely annual productivity of WCC fish in Lake X (kg/year)

Lake Size = Size of the Lake X (acres)

WCC SB = Standing biomass of WCC fish (g ww/m^2; from Equation 1)

CF1 = 4047 (unit conversion factor 1, m^2/acre)

CF2 = 1000 (unit conversion factor 2, g/kg)

The maximum fish ingestion rate (g/day) for WCCs plus BCs associated with sustainable fishing can be predicted using Equation 4. It assumes that the anglers consume 50 percent WCC and 50 percent BC, represented by the factor of 2 in Equation 4.

$$Max\ Sustain\ IR\ (BC + WCC) = \frac{2\ x\ Productivity\ WCC\ x\ FF\ x\ HF\ x\ CF1}{CF2} \quad \textit{(Equation 4)}$$

where:

Max Sustain IR (BC + WCC) = Predicted maximum sustainable ingestion rate for BC and WCCfish (g/day)

Productivity WCC = Likely annual productivity of WCC fish in Lake X (kg/year; from)

FF = Fillet fraction; represents the assumed edible portion of fish (0.33; unitless)

HF = Annual harvest fraction (0.10; unitless)

CF1 = 1000 (unit conversion factor 1, g/kg)

CF2 = 365 (unit conversion factor 2, days/year)

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Appendix 5:

Analysis of data on short-term emission rates relative to long-term emission rates

Analysis of data on short-term emission rates relative to long-term emission rates

Ted Palma
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1. Introduction

1.1. The problem

The process of listing hazardous air pollutants (HAPs) provided by the Clean Air Act (CAA, section 112(b)(2)) explicitly includes acute toxicity as a listing criterion. For this reason, in addition to chronic exposures, EPA considers acute exposures in risk-based decision-making for the HAP regulatory program. Estimating acute exposures via dispersion modeling requires input data on hourly meteorological conditions (available for most areas of the US) and short-term emission rates of individual facilities (almost universally absent from the National Emissions Inventory (NEI), the Toxic Release Inventory (TRI), and state emission databases).

Lacking short-term emission rates, we must estimate peak short-term rates based on annual average rates, which are available. For Risk and Technology Review (RTR) rulemakings, we have assumed that the 1-hour emission rate for each facility could exceed the annual average hourly emission rate by as much as tenfold, and further assumed that this tenfold emission spike could coincide with worst-case meteorological conditions and the presence of a human receptor at the facility boundary, as a means of screening for potentially significant acute exposures.

In a consultation on the “RTR Assessment Plan”, a panel of the EPA’s Science Advisory Board (SAB), several reviewers questioned the appropriateness of the factor of ten; some even suggested that this tenfold assumption may underestimate actual maximum short-term emissions for some facilities, and thereby also underestimate maximum acute risks. The SAB recommended an analysis of available short-term emissions data for HAP to test this assumption. This analysis responds to that SAB recommendation and attempts to test the protectiveness of the tenfold assumption using a database of “event emissions” collected from facilities in the Houston-Galveston area, to compare events representative of HAP releases to long-term release rates. We welcome comments from the public on the methods used and the conclusions reached by this analysis.

2. Methods

2.1. Texas Commission on Environmental Quality event emissions database

The Texas Commission on Environmental Quality (TCEQ) collects emissions data using online reporting required of any facility releasing 100 pounds or more of a listed chemical (primarily ozone-forming VOCs) during a non-routine event. The TCEQ data are intended to improve the state’s knowledge of how short-term releases affect tropospheric ozone levels in that area. The database we utilized in our analysis was a subset of the TCEQ data covering emission events that occurred in an eight-county area in eastern Texas during a 756-day period between January 31, 2003 and February 25, 2005.

The complete emissions event data were obtained in April 2007 from Cynthia Folsom Murphy, a research scientists with the University of Texas at Austin (UTA) Center for Energy and Environmental Resources. The data were provided in four Excel spreadsheets generated from an original MS Access file. We used these Excel files to reconstruct a MS Access database in order to facilitate selection of a representative subset of records for this analysis.

Although some of the released substances were HAPs, this was incidental to the database's primary purpose of enhancing the TCEQ's knowledge of photochemical activity. Thus, more than 80% of the released mass was ethene and propene, neither of which are HAPs. The database included release events caused by accidents, equipment failures, maintenance, startup, and shutdown. It also contained facility names, information on amounts of individual compounds released. To provide a basis for comparing the event releases with "typical" emissions, the UTA staff included total VOC emissions data for each facility for calendar year 2004, obtained from the EPA Toxic Release Inventory (TRI). The database did *not* contain any records for facilities that did not experience any reportable events during this period.

2.2. Data filtering

Because the event release data were intended for modeling short-term releases of ozone-producing VOCs, the database includes releases from accidents (which are regulated under section 112(r) of the CAA and are therefore not considered in residual risk assessments) and releases of light hydrocarbon compounds that are not HAPs and are much more volatile than most HAPs. This intent of this analysis, on the other hand, was to evaluate short-term releases of HAPs due to normal process variability or scheduled startups, shutdowns, and maintenance, relative to long-term release rates. Because the full emission events database was not representative of likely HAP emissions normally considered under the residual risk program, we filtered the release data as follows in an attempt to improve its representativeness:

1. Hydrocarbons of C5 or less were dropped, except that all HAPs (including non-VOCs) were retained regardless of molecular structure;

2. Accidental releases were dropped, but all others (including startup, shutdown, and maintenance) were retained;

3. Only facilities whose long-term VOC releases exceeded 0.068 tons per day (25 tons per year) were retained, to approximate the population of facilities likely to be subject to residual risk standards (i.e., major facilities);

4. A few release records had to be dropped because their facility numbers did not link to any facility in the database;

5. A few facilities had to be dropped because the database did not include their 2004 TRI VOC release information.

2.3. Analysis

Annual VOC emissions and emission event release data were both converted to lb/hr. In order to conform to our atmospheric dispersion models, which estimate ambient concentrations for periods of 1 hour or more, amounts released during events shorter than 1 hour were assigned to the whole hour. For example, a release of 100 lb in ten minutes was converted to 100 lb/hr. Events longer than 1 hour were converted normally, e.g., a release of 100 lb in 120 minutes was converted to 50 lb/hr. The event release rates for individual compounds were summed, yielding a total release rate for each event. This total release rate for each event was divided by the annual VOC release rate for the facility to derive the ratio of peak-to-mean emission rate for the event.

3. Results and Discussion

3.1. Database filtering

The original database contained 505 individual contaminants, including multiple redundancies. These redundancies did not affect this analysis, so we did not resolve them. After filtering out light, non-HAP, VOCs, 317 contaminants remained (Table 1).

The database contained release records for 150 unique facilities. Of these, 48 facilities (Table 2) were major VOC emitters that reported releases of at least one of the contaminants in Table 1.

The database contained 3641 individual release events reported by the original 150 facilities. Of these, 319 events involved a Table 1 contaminant released by a Table 2 facility during startup, shutdown, or maintenance. For evaluating short-term releases for residual risk assessments, these 319 events comprise the most representative subset of the full database.

3.2. Descriptive statistics

For this subset of emission events, ratios of event release rate to long-term release rate varied from 0.00000004 to 74. Distribution statistics appear in Tables 3 and 4. The 99th percentile ratio was 9 (i.e., an event release rate nine times the long-term average). Only 3 ratios exceeded our default assumption of 10, and of these only one exceeded 11. The full cumulative probability density of the ratios is shown in Figure 1.

Figure 2 shows the relationship between ratio and event duration. As expected, the ratio declined as duration increased. Only 18 events lasted less than 2 hours, but these events produced the three highest ratios. Figure 3 is a similar ratio vs. duration plot, but with duration as a percentage of total time. Only 35 events exceeded 1% of the total period covered by the database. Figure 4 shows the relationship between ratio and total amount released, and suggests that the highest ratios were produced by facilities whose routine VOC emissions were relatively small. Thus, the events themselves also tended to be relatively small in absolute terms.

3.3. Discussion

These results suggest that the tenfold ratio assumption for short-term releases is protective, and that the facilities for which it may underestimate event releases may tend to be smaller emitters.

However, this analysis is limited in the following ways by the nature of the database and the filtering that we applied:

1. The only long-term release data available from the database were total VOC emissions for 2004. Ideally, we would have preferred to have routine release rates for each individual contaminant. However, retrieving these data from other sources and linking them to this database was not feasible.

2. Removing VOCs that are not representative of HAPs, and comparing the releases against all VOCs, would tend to underestimate the true ratios. This effect could be quantitatively large.

3. Retaining HAPs that are not VOCs (such as toxic metals), and including them in the total to be compared against all VOCs, would tend to overestimate the true ratios. The size of this effect is not known, but seems likely to be less than for (2) above.

4. The database contains only facilities that had at least one release event during the reporting period. The number of facilities in the statistical population that did not experience an event is not known. The lack of data for these facilities (whose ratios in this analysis would have been zero) would cause the descriptive statistics to be skewed toward an overestimate. The size of this effect is unknown.

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
2-Methyloctane	No	3221-61-2	90008
2-Methylpentane	No	107-83-5	43229
2-methylhexane	No	591-76-4	43263
2-Methylpentane	No	107-83-5	43229
2,2,3-Trimethylpentane	No	564-02-3	
2,2,4-Trimethylpentane	Yes	540-84-1	43250
dimethyl butane	No	75-83-2	43291
2,3-Dimethylbutane	No	79-29-8	43276
2,3,4-Trimethylpentane	No	565-75-3	43252
2,3-Dimethylbutane	No	79-29-8	43276
2,4-Dimethylpentane	No	108-08-7	43247
2-methylheptane	No	592-27-8	43296
2-methylhexane	No	591-76-4	43263
2-Methylpentane	No	107-83-5	43229
3-Methylhexane	No	589-34-4	43295
3-Methylpentane	No	96-14-0	43230
3-Methylhexane	No	589-34-4	43295
3-Methylpentane	No	96-14-0	43230
3-Methylheptane	No	589-81-1	43253
3-Methylhexane	No	589-34-4	43295
3-Methylpentane	No	96-14-0	43230

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
Acetaldehyde	Yes	75-07-0	43503
Acetic Acid	No	64-19-7	43404
Acetonitrile	Yes	75-05-8	70016
Acetophenone	Yes	98-86-2	
Acrolein	Yes	107-02-8	43505
Acrylic acid	Yes	79-10-7	43407
Acrylonitrile	Yes	107-13-1	43704
alkylphenol	No	none	
Benzene	Yes	71-43-2	45201
Benzo[a]anthracene	Yes	56-55-3	46716
Benzo[a]pyrene	Yes	50-32-8	46719
Benzo[b]fluoranthene	Yes	205-99-2	46717
Biphenyl	Yes	92-52-4	45226
Butanol	No	35296-72-1	
Butyl Acrylate	No	141-32-2	43440
t-Butyl Alcohol	No	75-65-0	43309
butylcyclohexane	No	1678-93-9	90101
Butyraldehyde	No	123-72-8	43510
C9 Aromatics	No	none	
Naphthalene	Yes	91-20-3	46701
Nonane	No	111-84-2	43235
C9+	No	none	
Carbon tetrachloride	Yes	56-23-5	43804
Carbonyl Sulfide	Yes	463-58-1	43933
Chloral	No	75-87-6	
Trichloromethane	Yes	67-66-3	43803
Chlorothalonil	No	1897-45-6	
Petroleum	No	8002-05-9	
Petroleum	No	8002-05-9	
Cumene	Yes	98-82-8	45210
Cyclohexane	No	110-82-7	43248
Cyclohexanol	No	108-93-0	43317
Cyclohexanone	No	108-94-1	43561
Cyclohexanone	No	108-94-1	43561
Decane	No	124-18-5	43238
Decane	No	124-18-5	43238
1,2-Dichloroethane	No	107-06-2	43815
Diethylbenzene (mixture)	No	25340-17-4	45106
Methyl Ether	No	115-10-6	43350
Dimethylcyclohexane	No	27195-67-1	98059
Dimethylcyclopentane	No	28729-52-4	90064

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
Dimethylcyclopentane	No	28729-52-4	90064
Dimethyl formamide	Yes	68-12-2	43450
Dimethylhexane	No	28777-67-5	90067
Dimethyl pentane	No	38815-29-1	90063
Epichlorohydrin	Yes	106-89-8	43863
Ethyl Alcohol	No	64-17-5	43302
Ethyl Acrylate	Yes	140-88-5	43438
Ethyl Alcohol	No	64-17-5	43302
Ethyl Benzene	Yes	100-41-4	45203
Ethyl Chloride	Yes	75-00-3	43812
Ethylcyclohexane	No	1678-91-7	43288
ethylacetylene	No	107-00-6	43281
Ethyl Benzene	Yes	100-41-4	45203
Ethylene Oxide	Yes	75-21-8	43601
ethylmethylbenzene	No	25550-14-5	45104
formaldehyde	Yes	50-00-0	43502
Furfural	No	98-01-1	45503
straight-run middle distillate	No	64741-44-2	
Gasoline	No	86290-81-5	
Gasoline	No	86290-81-5	
Heavy Olefins	No	none	
n-Heptane	No	142-82-5	43232
n-Heptane	No	142-82-5	43232
Heptylene	No	25339-56-4	
hexane	Yes	110-54-3	43231
hexane	Yes	110-54-3	43231
2-Methylpentane	No	107-83-5	43229
hexane	Yes	110-54-3	43231
Hexene	No	25264-93-1	43289
Indeno[1,2,3-cd]pyrene	Yes	193-39-5	46720
Isobutyraldehyde	No	78-84-2	43511
2-Methyl-1-propanol	No	78-83-1	43306
2-Methyl-1-propanol	No	78-83-1	43306
Isobutyraldehyde	No	78-84-2	43511
Isoheptanes (mixture)	No	31394-54-4	43106
2-Methylpentane	No	107-83-5	43229
2,2,4-Trimethylpentane	No	540-84-1	43250
2,2,4-Trimethylpentane	No	540-84-1	43250
Isopar E	No		
Isoprene	No	78-79-5	43243
2-Propanol	No	67-63-0	43304

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
2-Propanol	No	67-63-0	43304
Cumene	Yes	98-82-8	45210
Isopropylcyclohexane	No	696-29-7	90128
Diisopropyl ether	No	108-20-3	85005
Kerosene	No	64742-81-0	
Methyl ethyl ketone	No	78-93-3	43552
Methyl isobutenyl ketone	Yes	141-79-7	
Methanol	Yes	67-56-1	43301
Methyl Acetylene	No	74-99-7	43209
Cresol	Yes	1319-77-3	45605
Methyl Chloride	Yes	74-87-3	43801
methyl cyclohexane	No	108-87-2	43261
Methyl ethyl ketone	No	78-93-3	43552
Iodomethane	No	74-88-4	86025
Methyl Mercaptan	No	74-93-1	43901
methyl cyclohexane	No	108-87-2	43261
Methylcyclopentane	No	96-37-7	43262
2-Methyldecane	No	6975-98-0	98155
Methylheptane	No	50985-84-7	90045
2-methylheptane	No	592-27-8	43296
2-Methyl nonane	No	871-83-0	90047
Tert-butyl methyl ether	No	1634-04-4	43376
meta-xylene	No	108-38-3	45205
Nonane	No	111-84-2	43235
Naphtha	No	8030-30-6	45101
Naphthalene	Yes	91-20-3	46701
Naphtha	No	8030-30-6	45101
Naphthalene	No	91-20-3	46701
Butyl acetate	No	123-86-4	43435
Butyraldehyde	No	123-72-8	43510
Nonane	No	111-84-2	43235
Nonane	No	111-84-2	43235
Octadecene	No	27070-58-2	
n-Octane	No	111-65-9	43233
Octene (mixed isomers)	No	25377-83-7	
ortho-xylene	No	95-47-6	45204
Parathion	Yes	56-38-2	
4-Aminohippuric Acid	No	61-78-9	
Phenol	Yes	108-95-2	45300
Silicone	No	63148-62-9	
Naphtha	No	8030-30-6	45101

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
Naphtha	No	8030-30-6	45101
Polyethylene	No	9002-88-4	
Poly(Isobutylene)	No	9003-27-4	
Chloromethyl pivalate	No	18997-19-8	
Process fuel gas	No	none	
Propionic Acid	No	79-09-4	43405
Propylene oxide	No	75-56-9	43602
para-xylene	No	106-42-3	45206
Styrene	Yes	100-42-5	45220
Sulfolane	No	126-33-0	
t-Butyl Alcohol	No	75-65-0	43309
t-Butyl Alcohol	No	75-65-0	43309
tert-butyl hydroperoxide	No	75-91-2	
Toluene	Yes	108-88-3	45202
Aqualyte(TM), LSC cocktail	No	25551-13-7	45107
1,3,4-Trimethylbenzene	No	95-63-6	45208
trimethylcyclopentane	No	30498-64-7	98058
trimethylpentane	No	29222-48-8	90092
Undecane	No	1120-21-4	43241
Vinyl acetate	Yes	108-05-4	43453
Vinyl acetate	Yes	108-05-4	43453
Vinyl chloride	Yes	75-01-4	43860
vinyl resin	No	none	
Vinylcyclohexane	No	695-12-5	
xylenes	Yes	1330-20-7	45102
xylenes	Yes	1330-20-7	45102
meta-xylene	Yes	108-38-3	45205
ortho-xylene	Yes	95-47-6	45204
para-xylene	Yes	106-42-3	45206
Mineral spirits	No	64475-85-0	43118
Propylene glycol	No	57-55-6	43369
Vinyl chloride	Yes	75-01-4	43860
1-Decene	No	872-05-9	90014
2-Ethyl-1-hexanol	No	104-76-7	43318
2-Pyrrolidone	No	616-45-5	
Aromatic	No	none	
Decene	No	25339-53-1	90014
2-N,N-Dibutylaminoethanol	No	102-81-8	86007
Diisopropanolamine	No	110-97-4	86004
N,N-Dimethylethanolamine	No	108-01-0	84004
trifluoroethane	No	27987-06-0	

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
2,2'-Oxybisethanol	No	111-46-6	43367
Hydrocarbons	No	none	
Methyl Formate	No	107-31-3	43430
Isopropylamine	No	75-31-0	86014
n-Butanol	No	71-36-3	43305
Polypropylene glycol ether	No		
N-Vinyl-2-Pyrrolidinone	No	88-12-0	
1,1-Di(t-Amylperoxy) Cyclohexane	No	15667-10-4	
1,2,3-Trimethyl-4-ethylbenzene	No	none	
2-Methyldecane	No	6975-98-0	98155
2-methylheptane	No	592-27-8	43296
2-Methyl nonane	No	871-83-0	90047
2,5-Dimethylhexane-2,5-dihydroperoxide	No	3025-88-5	
Butyl ether	No	142-96-1	43372
1,2-Dichloroethane	Yes	107-06-2	43815
Hydrindene	No	496-11-7	98044
Methylheptane	No	50985-84-7	90045
methyl methacrylate	No	80-62-6	43441
Naphtha	No	8030-30-6	45101
hexane	Yes	110-54-3	43231
tert-amyl hydroperoxide	No	3425-61-4	
1,3,4-Trimethylbenzene	No	95-63-6	45208
n-Butanol	No	71-36-3	43305
2-Butoxy ethanol	Yes	111-76-2	43308
hexane	Yes	110-54-3	43231
cycloheptane	No	291-64-5	43115
n-Heptane	No	142-82-5	43232
n-Octane	No	111-65-9	43233
Hexyl Carbitol	No	112-59-4	
Nonene	No	27215-95-8	
Silane, ethenyltrimethoxy	No	2768-02-7	
tetrahydrofuran	No	109-99-9	70014
Vinyl chloride	Yes	75-01-4	43860
Methyl Formate	No	107-31-3	43430
Phenyl ether	No	101-84-8	
phosgene	Yes	75-44-5	
1,2-Dichloroethane	No	107-06-2	43815
2-Butoxy ethanol	Yes	111-76-2	43308
Gasoline	No	86290-81-5	
1-Tridecanol	No	112-70-9	

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
1,2,4-Trichlorobenzene	Yes	120-82-1	45208
2-(2-Butoxyethoxy)ethanol	Yes	112-34-5	43312
2,3,4-trihydroxybenzophenone Ester	No	1143-72-2	
Methyl n-amyl ketone	No	110-43-0	43562
4,4-Cyclohexylidenebis[phenol]	No	843-55-0	
Anisole	No	100-66-3	
2-Butoxy ethanol	Yes	111-76-2	43308
Cresol-Formaldehyde novolac Resin	No	proprietary	
Decane	No	124-18-5	43238
gamma-Butyrolactone	No	96-48-0	
Dimethyl pentane	No	38815-29-1	90063
Dodecyl Benzenesulfonic Acid	No	27176-87-0	
Ethanol Amine	No	141-43-5	43777
ethyl lactate	No	687-47-8	
Hexamethyldisilazane	No	999-97-3	
Methyl ethyl ketone	No	78-93-3	43552
Cresol	Yes	1319-77-3	45605
Naphthalene Sulfonic Acid Resin	No		
Naphthalene Sulfonic Acid Resin	No		
n-Butanol	No	71-36-3	43305
Decane	No	124-18-5	43238
1-Methyl-2-pyrrolidinone	No	872-50-4	70008
Pentyl Ester Acetic Acid	No		
Phenol Formaldehyde Resin, Novolac	No		
Phenol Formaldehyde Resin, Novolac	No		
Propylene Glycol Monomethyl Ether	No	107-98-2	70011
Pyrocatechol	No	120-80-9	
Carbon Disulfide	Yes	75-15-0	43934
Hexene	No	592-41-6	43245
VOC	No	none	
Methacrylic acid	No	79-41-4	84009
Methyl 3-hydroxybutyrate	No	1487-49-6	
t-Butyl Alcohol	No	75-65-0	43309
methyl valeraldehyde	No	123-15-9	
Butyl Methacrylate	No	97-88-1	85008
dipropyl ether	No	111-43-3	
n-Propanol	No	71-23-8	43303
Propyl propionate	No	106-36-5	86052

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
1,2-Epoxybutane	Yes	106-88-7	
Methylamine	No	74-89-5	
1,1-Dimethylcyclohexane	No	590-66-9	
1,1-Dimethylcyclopentane	No	1638-26-2	
2-Methylpentane	No	107-83-5	43229
dimethyl butane	No	75-83-2	43291
2,3,3-Trimethylpentane	No	560-21-4	
2,3-Dimethylhexane	No	584-94-1	
2,3-Dimethylpentane	No	565-59-3	
2,4-Dimethylhexane	No	589-43-5	
2,5-Dimethyl-hexane	No	592-13-2	
2-Butoxy ethanol	Yes	111-76-2	43308
2-mercaptoethanol	No	60-24-2	
Bisphenol A	No	80-05-7	
straight-run middle distillate	No	64741-44-2	
4-Vinylcyclohexene	No	100-40-3	
straight-run middle distillate	No	64741-44-2	
Allyl alcohol	No	107-18-6	
xylenes	Yes	1330-20-7	45102
Naphthalene	Yes	91-20-3	46701
3-Methylethylcyclohexane	No		
VOC	No	none	
Gasoline	No	86290-81-5	
Butyl ether	No	142-96-1	
dimethyl butane	No	75-83-2	
Dodecene	No	25378-22-7	
Styrene	Yes	100-42-5	45220
tetrahydrofuran	No	109-99-9	70014
hexane	Yes	110-54-3	43231
2-Propanol	No	67-63-0	43304
liquified petroleum gas	No	68476-85-7	
Methyl acetylene propadiene	No		
methyl isobutyl ketone	Yes	108-10-1	
Methyl n-amyl ketone	No	110-43-0	43562
Methylpentane	No	43133-95-5	
Tert-butyl methyl ether	Yes	1634-04-4	43376
Toluene	Yes	108-88-3	45202
Mineral oil	No	8012-95-1	
Gasoline	No	86290-81-5	
2,2-Dimethylpropane	No	463-82-1	43222
n-propylbenzene	No	103-65-1	

Table 1. Event emissions in the Houston-Galveston area. Representative contaminants included in the analysis, selected because they are either HAPs or VOCs with more than 5 carbon atoms. (These data were retrieved directly from the original database, which included multiple redundancies that did not affect the analysis and were left intact.)

Contaminant	*HAP*	*CAS*	*SAROAD*
propylcyclohexane	No	1678-92-8	
n-Octane	No	111-65-9	43233
ortho-xylene	No	95-47-6	45204
Gasoline	No	86290-81-5	
propylenimine	No	75-55-8	
Gasoline	No	86290-81-5	
Technical White Oil	No		
Total Alkylate - non-speciated	No		
Trichloroethylene	Yes	79-01-6	
Di(2-ethylhexyl) peroxydicarbonate	No	16111-62-9	
trimethylcyclopentane	No	30498-64-7	98058
Ultraformate	No		
4-Vinylcyclohexene	No	100-40-3	

Table 2. Event emissions in the Houston-Galveston area. Major emitters reporting at least one release event of a representative substance.

Company Name	*2004 VOC Emission Rate (lb/h)*
ATOFINA PETROCHEMICALS LA PORTE PLANT	47.88
BALL METAL BEVERAGE CONTAINER CONROE FACILITY	24.18
BASF FREEPORT SITE	46.47
BELVIEU ENVIRONMENTAL FUELS	112.3
BOC GROUP CLEAR LAKE BOC GASES PLANT	9.52
BP AMOCO CHEMICAL CHOCOLATE BAYOU PLANT	130.4
BP AMOCO CHEMICAL PASADENA PLANT	36.92
BP AMOCO POLYMERS	57.18
BP PRODUCTS NORTH AMERICA TEXAS CITY	737.4
BP TEXAS CITY CHEMICAL PLANT B	112.2
CELANESE BAY CITY PLANT	17.12
CELANESE CLEAR LAKE PLANT	53.11
CELANESE PASADENA PLANT	5.934
CHEVRON PHILLIPS CEDAR BAYOU PLANT	105.3
CHEVRON PHILLIPS CHEMICAL SWEENY COMPLEX	106.7
CHEVRON PHILLIPS HOUSTON CHEMICAL COMPLEX	215.7
CROWN BEVERAGE PACKAGING	18.05
CROWN CENTRAL PETROLEUM PASADENA PLANT	114.3
CROWN CORK & SEAL	18.10
DEER PARK LIQUID STORAGE TERMINAL	124.8
DOW CHEMICAL LA PORTE SITE	5.902
DOW TEXAS OPERATIONS FREEPORT	203.2
E I DUPONT DE NEMOURS AND COMPANY - LA PORTE PLANT	51.30
EQUISTAR CHEMICALS CHANNELVIEW COMPLEX	275.4
EQUISTAR CHEMICALS CHOCOLATE BAYOU COMPLEX	84.87
EQUISTAR CHEMICALS LA PORTE COMPLEX	90.97
EXXON MOBIL CHEMICAL BAYTOWN OLEFINS PLANT	84.73
EXXONMOBIL CHEMICAL BAYTOWN CHEMICAL PLANT	313.7
EXXONMOBIL CHEMICAL MONT BELVIEU PLASTICS PLANT	40.64
GOODYEAR HOUSTON CHEMICAL PLANT	85.68
ISP TECHNOLOGIES TEXAS CITY PLANT	22.12
KANEKA TEXAS CORPORATION	20.55
KINDER MORGAN LIQUID TERMINALS PASADENA	913.9
KINDER MORGAN LIQUIDS TERMINALS	132.7
LBC HOUSTON BAYPORT TERMINAL	12.83
LYONDELL CHEMICAL BAYPORT PLANT	30.04
LYONDELL CHEMICAL CHANNELVIEW	74.15
MARATHON ASHLAND PETROLEUM TEXAS CITY REFINERY	111.8
MOBIL CHEMICAL HOUSTON OLEFINS PLANT	26.29
MORGANS POINT PLANT	31.03
PASADENA PLANT	13.40

Table 2. Event emissions in the Houston-Galveston area. Major emitters reporting at least one release event of a representative substance.

Company Name	*2004 VOC Emission Rate (lb/h)*
SHELL OIL DEER PARK	405.2
SOLUTIA CHOCOLATE BAYOU PLANT	53.09
STOLTHAVEN HOUSTON TERMINAL	7.347
SWEENY COMPLEX	157.1
UNION CARBIDE TEXAS CITY OPERATIONS	174.4
VALERO REFINING TEXAS CITY	260.1
WHARTON GAS PLANT	7.552

Table 3. Frequency distribution for ratio of event emission rate to long-term emission rate

Bin	*Frequency*	*Cumulative Frequency*
1.00E-08	0	0
3.16E-08	0	0
1.00E-07	2	2
3.16E-07	1	3
1.00E-06	0	3
3.16E-06	2	5
1.00E-05	1	6
3.16E-05	2	8
1.00E-04	5	13
3.16E-04	9	22
1.00E-03	15	37
3.16E-03	28	65
1.00E-02	33	98
3.16E-02	41	139
1.00E-01	59	198
3.16E-01	38	236
1.00E+00	33	269
3.16E+00	31	300
1.00E+01	16	316
3.16E+01	2	318
1.00E+02	1	319
3.16E+02	0	319

Table 4. Statistics for ratio of event emission rate to long-term emission rate

Statistic for Ratio	*Value*
Median	0.043923
75th %ile	0.342655
90th %ile	2.204754
95th %ile	3.344422
96th %ile	3.400832
97th %ile	3.8126
98th %ile	4.790098
99th %ile	8.973897
Max	74.37138
Average	0.815352

Figure 1. Cumulative probability density for ratio of event to routine emission rates.

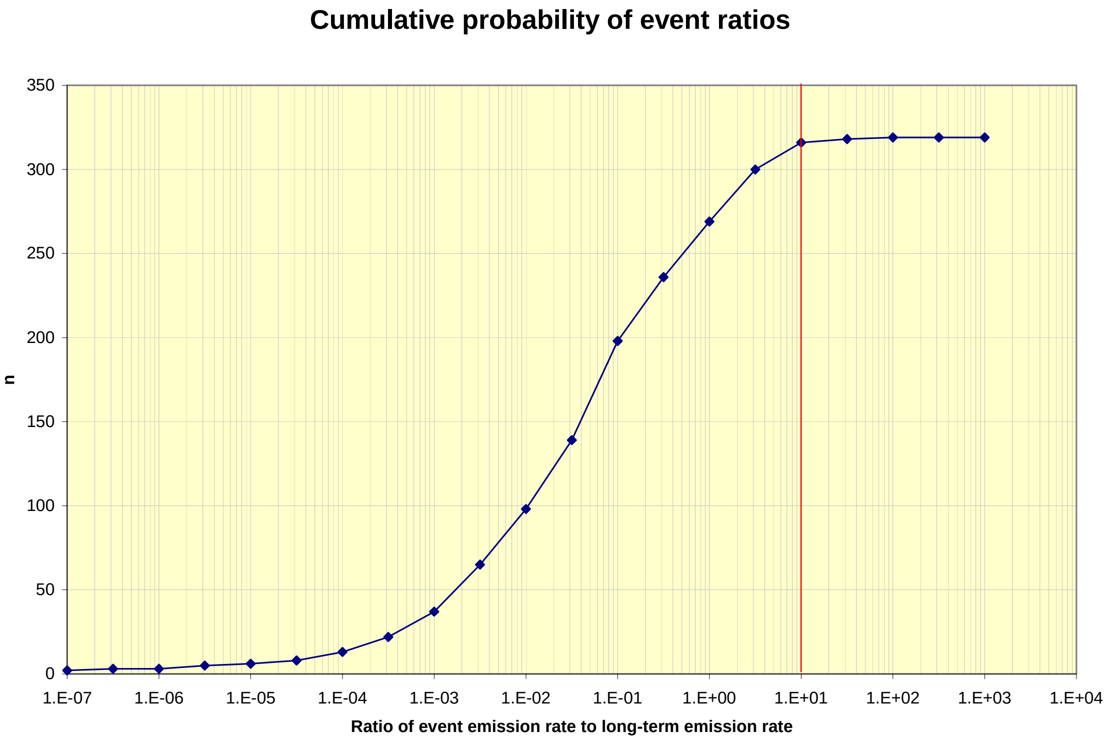


Figure 2. Relationship between ratio of event to duration emission rate and emission duration.

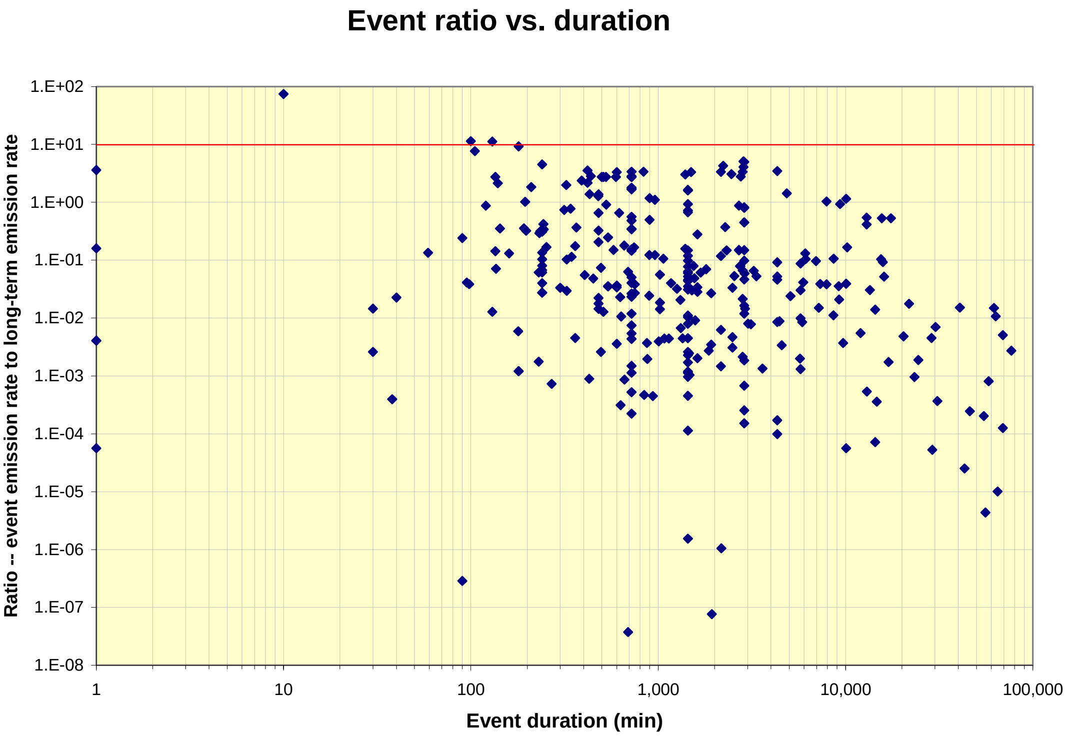


Figure 3. Relationship between ratio of event to duration emission rate and emission duration, as percentage of total time.

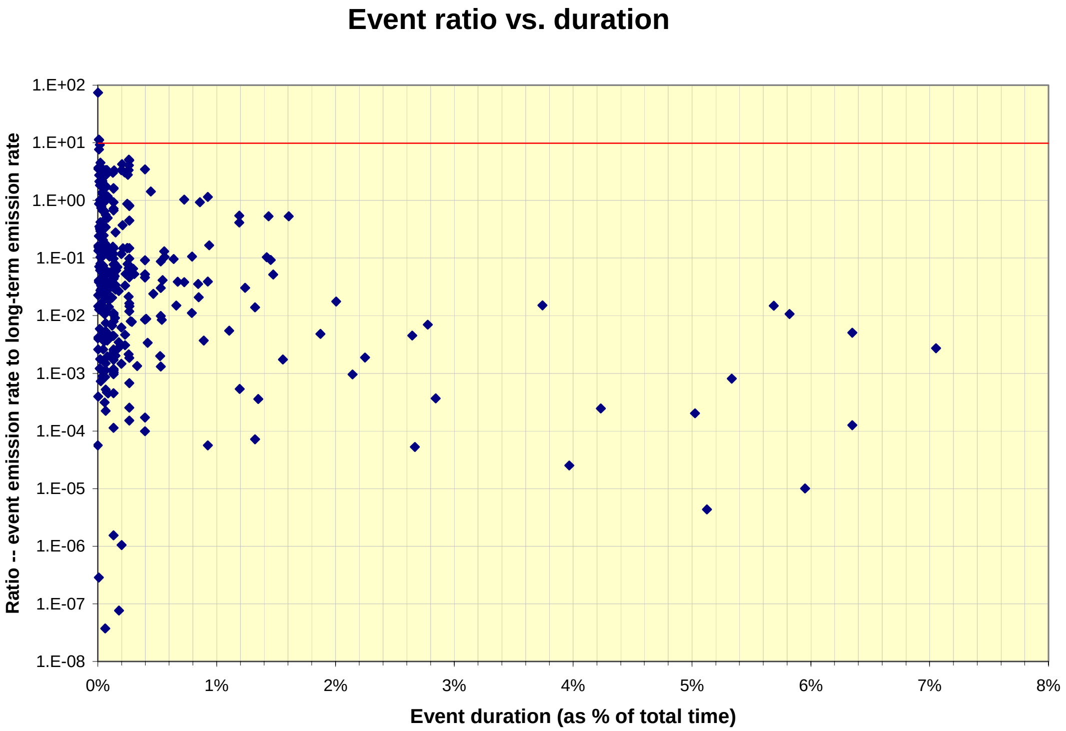
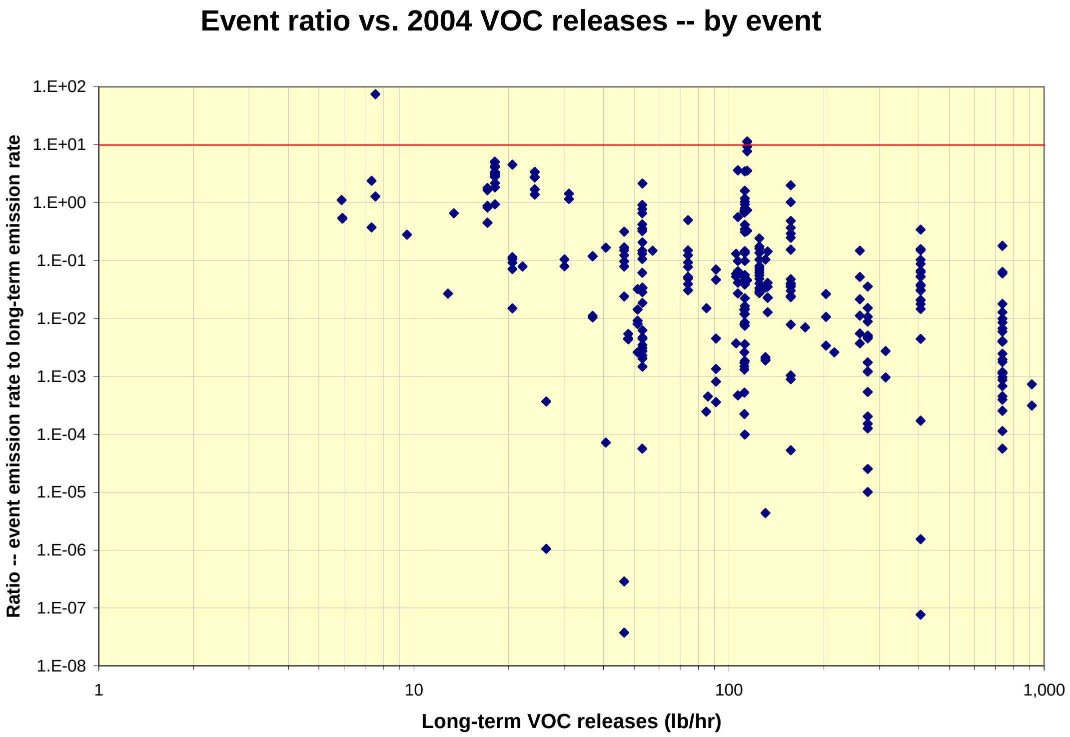


Figure 4. Relationship between ratio of event to duration emission rate and total amount emitted during the event.



Technical Memorandum

TO: EPA Docket No. EPA-HQ-OAR-2010-0682

FROM: Brenda Shine, Environmental Engineer
Refining and Chemicals Group, SPPD (E143-01)

DATE: March 15, 2012

SUBJECT: Derivation of Hourly Emission Rates for Petroleum Refinery Emission Sources Used in the Acute Risk Analysis

I. Purpose:

This memorandum documents the assumptions used to derive the hourly emission rates used to estimate acute risks from emissions of petroleum refinery emission sources. In past Risk and Technology (RTR) rulemakings, when we have lacked hourly emissions data or other specific information about the source category processes, we assumed that the 1-hour emission rate for any emission point could be 10 times higher than its average hourly emissions, calculated by dividing annual emissions by 8760 hours per year. The basis for this assumption was derived from an analysis of short term release information collected from facilities in the Houston-Galveston area and a comparison against routine emission rates for an entire facility. The conclusions of this analysis were that the hourly emissions from any single release event to the average annual VOC release rate for an entire facility was seldom greater than a factor of 10. For the petroleum refinery source category, we have additional knowledge of the emission point release characteristics that enable us to refine the default factor of 10 to something more realistic for this source category.

II. Acute Factors for the Petroleum Refinery Source Category:

Instead of using the default factor of 10 described above, we estimated variability of hourly emissions based on the operating characteristics of refinery emission sources in the following manner:

a. For many sources that are associated with continuous operations and are essentially steady state, such as Fluid Catalytic Cracking Units (FCCU), and sulfur recovery plants (SRU), we would not expect significant variability in hourly emissions. Typical source test variablility is typically ±30 to 50%. We have applied an hourly multiplier of 2 to estimate maximum hourly rates as an upper range of the expected variability. This assumption was used for the following types of sources: FCCU, SRU, Chemical Processes, miscellaneous process vents, refinery processes (not specified) and incinerators.

b. For delayed cokers, we considered the average venting cycle time in calculating our hourly emission rate. The process cycle for delayed cokers is 1 day (24 hours), with the depressurization vent having an average venting cycle time of, on average, 2 to 3 hours per cycle. Since the depressurization vent opens for 730 to 1,095 hours per year, a factor of 8 to 12 times the annual average emission rate could be used to account for this emission process. The emissions are expected to be somewhat variable, with higher emissions at the start of the venting cycle. We therefore applied an hourly multiplier of 20 to estimate maximum hourly rates for delayed coker emissions.

c. There are three types of catalytic reformers: Continuous, cyclic, and semi-regenerative. Continuous reformers (SCC 30601602) are expected to have stable operations (much like the FCCU and SRU), so a factor of 2 is appropriate for estimating the maximum hourly emissions rate. Cyclic reformers (SCC 30601603) typically vent for 2,000 to 4,000 hours per year, suggesting a factor of 2 to 4 for these units. However, their emissions over the venting period are expected to be somewhat variable, so a factor of 10 is applied as a conservative estimate. Semi-regenerative reformers (SCC 30601604) are expected to vent approximately 10-15 days per year, suggesting a factor of 30 or 40. The venting is not expected to be uniform over this period, so a factor of 60 is applied for these units.

d. For evaporative loss sources such as wastewater, we expect moderate variability in maximum hourly emissions from annual average emissions. Emissions from wastewater are dependent on organic loading to the unit and on the mass transfer (volatilization) rate from the wastewater surface (which is dependent on the wastewater temperature and air wind speed). The loading rates are expected to vary by a factor of 2 during normal operations and the mass transfer rates are expected to vary by a factor of 2 due to seasonal/meterological variations. We therefore applied an hourly multiplier of 4 to estimate maximum hourly rates from wastewater sources.

e. For fugitives from equipment leaks, we note that the current methods of estimating emissions make use of correlation equations in conjunction with Method 21 readings that ultimately provide an hourly emission rate for the monitoring period in question. The actual emission rates estimated based on the direct Method 21 readings are commonly divided by two to estimate the average emission rate between monitoring intervals (i.e., assuming the leak started mid-way between monitoring intervals as described in the emissions protocol). We expect the emission estimates from the direct Method 21 readings to provide a direct measure of the maximum hourly emissions (as leak repair will be applied to reduce hourly emissions immediately after a monitoring cycle). Therefore, we applied an hourly multiplier of 2 to estimate maximum hourly rates from the annual average emission rates.

f. For storage vessels, higher hourly rates from loading operations can occur; however, the majority of tanks are floating roof tanks; emissions from these tanks are associated with wind-driven losses from fitting controls and clingage from exposure of external floating roof tank shells. These emissions would not be expected to vary as significantly as fixed roof tanks, but the emissions from floating roof tanks are expected to be dependent on temperature (seasonal variability) and, in the case of external floating roofs, wind speed.

There may also be variability in the crude oil processed or the intermediates and products stored in a given tank. As with wastewater sources, each of these factors is expected to cause a factor of 2 variability. We therefore applied an hourly multiplier of 4 to estimate maximum hourly rates from storage tanks.

g. For other transfer and loading operations, maximum hourly rates can be approximated from pumping rates; a factor of 2 for these sources would not adequately account for higher maximum hourly emissions in most cases. Considering the hours of actual product loading during the year (commonly 1,000 to 2,000 hours per year), we applied a factor of 10 to these emission sources.

Appendix 6 Detailed Risk Modeling Results

Table 1 - Facility Identification Information

Source Category	Facility NEI ID	Facility Name	Address	City	State
Ferroalloys	39167NEI11660	Eramet	16705 State Route 7 South	Marietta	OH
Ferroalloys	54053NEIWV053FELMAN	NEW HAVEN PLANT	US ROUTE 62 NORTH	NEW HAVEN	WV

Table 2 – Maximum Predicted HEM-3 Chronic Risks

Facility NEI ID	Source Category Chronic Risk[1] Cancer MIR	Cancer Incidence	Noncancer Max HI	Target Organ
Baseline scenario				
54053NEIWV053FELMAN	**1.97E-05**	7.12E-04	**3.05E+00**	neurological
39167NEI11660	**1.05E-05**	1.36E-03	**3.70E+00**	neurological
Control Scenario				
54053NEIWV053FELMAN	**9.39E-06**	3.81E-04	9.82E-01	neurological
39167NEI11660	**6.28E-06**	6.97E-04	1.03E+00	neurological

1 BOLD indicates a cancer risk greater than 1 in a million or a noncancer risk greater than 1

Table 3 – Maximum Predicted Acute Risks (HEM3)

Ferroalloys

Baseline Modeling Scenario						
		Maximum Hazard Quotient[1]				
Facility NEI ID	Pollutant	REL	AEGL1	ERPG1	AEGL2	ERPG2
39167NEI11660	Arsenic compounds	**2.2E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00
39167NEI11660	Hydrofluoric acid	**2.1E+00**	6.0E-01	3.1E-01	2.5E-02	3.1E-02
54053NEIWV053FELMAN	Arsenic compounds	**1.6E+00**	0.0E+00	0.0E+00	0.0E+00	0.0E+00
54053NEIWV053FELMAN	Hydrofluoric acid	**1.5E+00**	4.5E-01	2.3E-01	1.8E-02	2.3E-02
39167NEI11660	Formaldehyde	1.1E+00	5.6E-02	5.2E-02	3.7E-03	5.2E-03
54053NEIWV053FELMAN	Formaldehyde	8.4E-01	4.2E-02	3.9E-02	2.7E-03	3.9E-03
54053NEIWV053FELMAN	Mercury (elemental)	2.1E-01	0.0E+00	0.0E+00	7.6E-05	6.4E-05
54053NEIWV053FELMAN	Hydrochloric acid	1.8E-01	1.4E-01	8.2E-02	1.1E-02	1.2E-02
39167NEI11660	Mercury (elemental)	1.2E-01	0.0E+00	0.0E+00	4.4E-05	3.7E-05
39167NEI11660	Hydrochloric acid	1.0E-01	8.2E-02	4.9E-02	6.7E-03	7.3E-03

Post-Control Modeling Scenario						
		Maximum Hazard Quotient[1]				
Facility NEI ID	Pollutant	REL	AEGL1	ERPG1	AEGL2	ERPG2
54053NEIWV053FELMAN	Hydrofluoric acid	6.4E-01	1.9E-01	9.5E-02	7.6E-03	9.5E-03
54053NEIWV053FELMAN	Formaldehyde	4.2E-01	2.1E-02	1.9E-02	1.4E-03	1.9E-03
54053NEIWV053FELMAN	Arsenic compounds	3.7E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00
39167NEI11660	Arsenic compounds	3.5E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00
54053NEIWV053FELMAN	Mercury (elemental)	2.1E-01	0.0E+00	0.0E+00	7.4E-05	6.3E-05
39167NEI11660	Hydrofluoric acid	1.8E-01	5.3E-02	2.7E-02	2.2E-03	2.7E-03
39167NEI11660	Formaldehyde	1.7E-01	8.4E-03	7.7E-03	5.4E-04	7.7E-04
39167NEI11660	Mercury (elemental)	7.7E-02	0.0E+00	0.0E+00	2.7E-05	2.3E-05
54053NEIWV053FELMAN	Hydrochloric acid	5.8E-02	4.5E-02	2.7E-02	3.7E-03	4.0E-03
39167NEI11660	Hydrochloric acid	9.8E-03	7.6E-03	4.6E-03	6.2E-04	6.9E-04

[1] Some maximum acute impacts may be at onsite locations.

Note: **BOLD** indicates acute risks greater than 1

Table 4 – Maximum Predicted Acute Risks Greater than 1 (Refined Approach)

Ferroalloys

Baseline Modeling Scenario

Facility NEI ID	Pollutant	Criteria	HEM-3 (Screening)	Refined Results [1]	Refined Modeling Approach [2]
54053NEIWV053FELMAN	Hydrofluoric acid	REL	2	1	Examined results for maximum off-site impact
54053NEIWV053FELMAN	Arsenic compounds	REL	2	1	
39167NEI11660	Arsenic compounds	REL	2	1	
39167NEI11660	Hydrofluoric acid	REL	2	1	

Post-Control Modeling Scenario

Facility NEI ID	Pollutant	Criteria	HEM-3 (Screening)	Refined Results [1]	Refined Modeling Approach [2]
54053NEIWV053FELMAN	Hydrofluoric acid	REL	0.6	0.6	Examined results for maximum off-site impact
54053NEIWV053FELMAN	Arsenic compounds	REL	0.4	0.4	
39167NEI11660	Arsenic compounds	REL	0.4	0.4	
39167NEI11660	Hydrofluoric acid	REL	0.2	0.2	

Appendix 7
Acute Impacts Refined Analysis Figures

Refined Acute Modeling Approach

Initial acute screening risk calculations were performed with the HEM3 model using the maximum hourly emissions estimates described in the memorandum *Revised Development of the Risk and Technology Review (RTR) Emissions Dataset for the Ferroalloys Production Source Category*, which can be found in Appendix 1 to this report. HEM3 estimates acute (1-hour) impacts at both polar and census block receptors. It is assumed for this short period of time that an exposed individual could be located at any off-site location. The lack of readily available detailed property boundary information for many of the facilities evaluated made it difficult to determine whether receptors were on- or off-site. In the absence of such information, the first ring of polar receptors was placed 100 meters from the plant center for many facilities. However, these polar rings often transected on-site locations, restricting public access to exposures at these levels and thereby overestimating exposures.

The screening approach used by HEM3 to estimate maximum 1-hour exposures also likely overestimates exposures. To estimate maximum 1-hour concentrations at each receptor, HEM3 sums the maximum concentrations attributed to each source, regardless of whether those maximum concentrations occurred during the same hour. In other words, HEM3 assumes that the maximum impact from each source at each receptor occurs at the same time. In actuality, maximum impacts from different sources may occur at different times.

This appendix addresses refinements to determine the maximum off-site values by plotting the HEM3 polar grid results on aerial photographs of the facilities for those facilities and pollutants that exceeded short-term health benchmarks. These photographs were examined to determine off-site locations that may be accessible to the public (*e.g.,* roadways and public buildings.). The attached figures present the estimated property lines of the facilities and the estimated hazard quotient values (the modeled 1-hour concentration of a pollutant divided by its short-term health benchmark) at the polar receptors near the facilities. Table 1 provides the resulting change in acute risks taking into account these off-site locations for the baseline modeling scenario.

Table 1. Refined Acute Risks Due to Off-site Receptors – Baseline Modeling Scenario

Facility NEI ID	Pollutant	Criteria	Original Acute Hazard Quotient	Off-site Hazard Quotient
39167NEI11660	Arsenic compounds	REL	2	1
39167NEI11660	Hydrofluoric acid	REL	2	<1
54053NEIWV053FELMAN	Arsenic compounds	REL	2	<1
54053NEIWV053FELMAN	Hydrofluoric acid	REL	2	<1

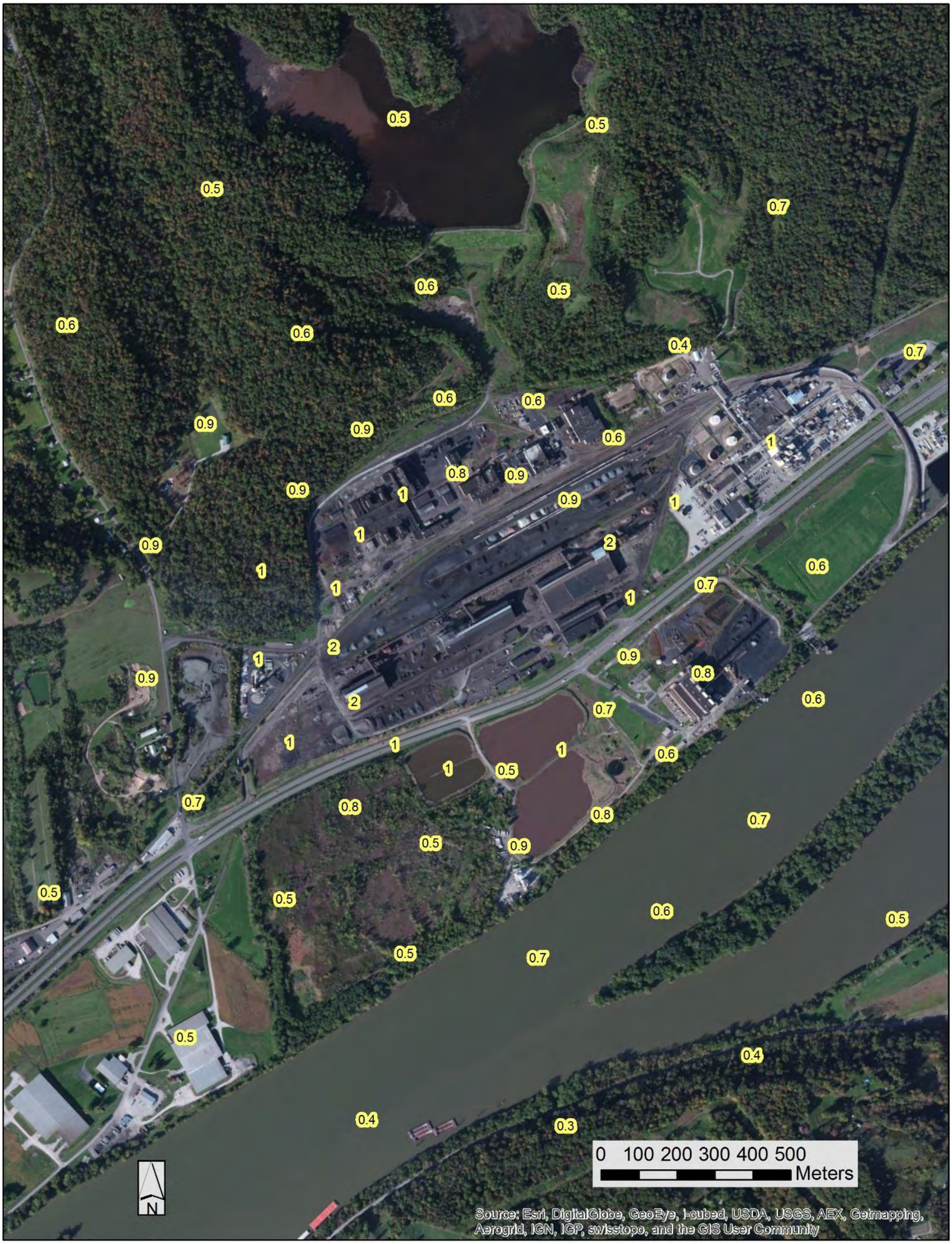
Ferroalloys Facilities

Figure 1 – Estimated Eramet Fenceline

Figure 2 – Estimated Felman Fenceline

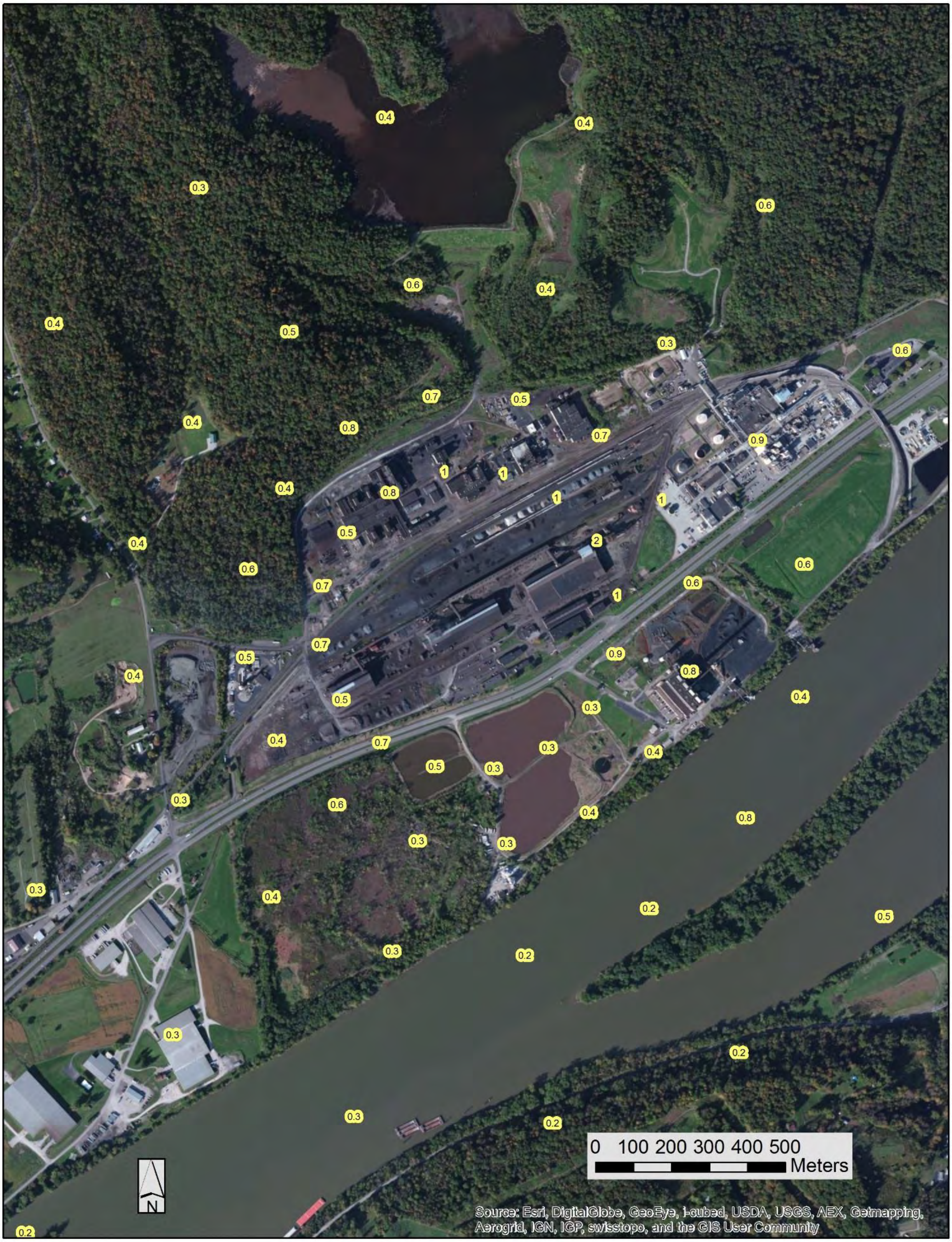
Ferroalloys Facilities –
Baseline Modeling Scenario

Figure 3 – 39167NEI11660 Acute Arsenic HQ (REL)



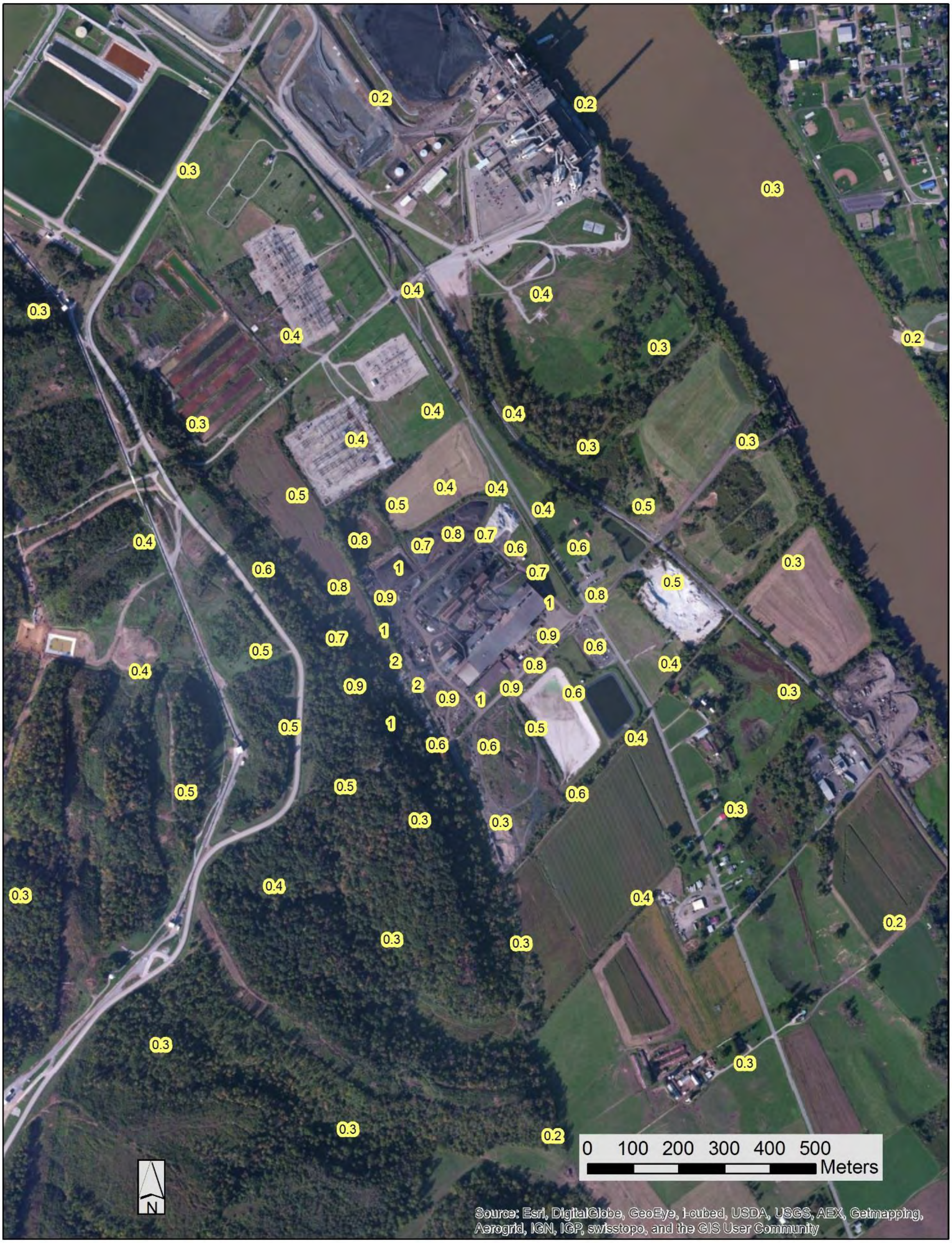
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4 – 39167NEI11660 Acute HF HQ (REL)



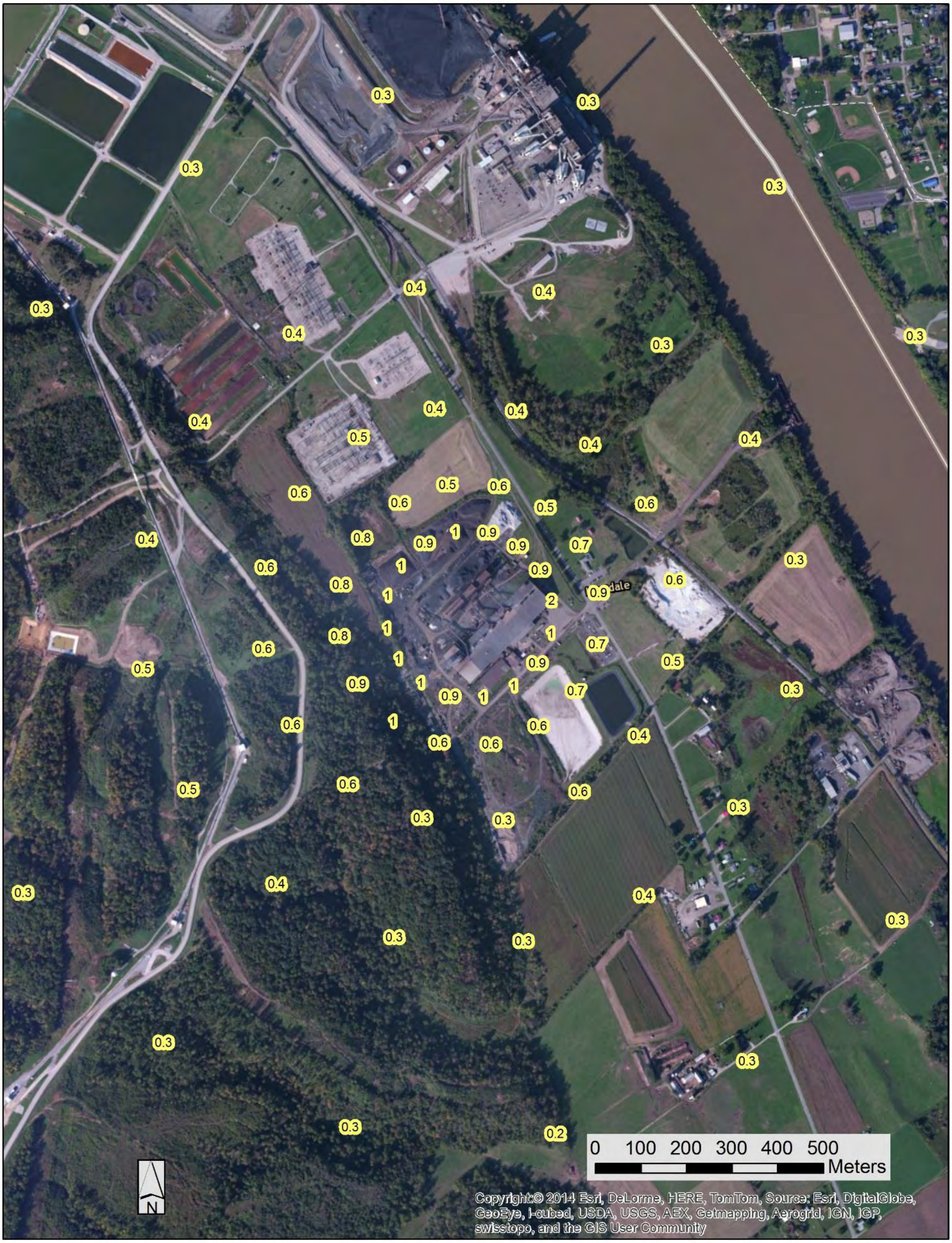
Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5 – NEIWV053FELMAN Acute Arsenic HQ (REL)



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6 – NEIWV053FELMAN Acute HF HQ (REL)



Copyright:© 2014 Esri, DeLorme, HERE, TomTom, Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Appendix 8
Dispersion Model Receptor Revisions and Additions

Dispersion Model Receptor Revisions and Additions for the Ferroalloys Source Category

To estimate ambient concentrations for evaluating long-term exposures, the HEM-3 model uses the geographic centroids of census blocks (currently utilizing the 2010 Census) as dispersion model receptors. The census block centroids are generally good surrogates for where people live within a census block. A census block generally encompasses about 40 people or 10-15 households. However, in cases where a block centroid is located on industrial property, or where a census block is large and the centroid less likely to be representative of the block's residential locations, the block centroid may not be an appropriate surrogate.

Census block centroids that are on facility property can sometimes be identified by their proximity to emission sources. In cases where a census block centroid was within 300 meters of any emission source, we viewed aerial images of the facility to determine whether the block centroid was likely located on facility property. The selection of the 300-meter distance reflects a compromise between too few and too many blocks identified as being potentially on facility property. Distances smaller than 300 meters would identify only block centroids very near the emission sources and could exclude some block centroids that are still within facility boundaries, particularly for large facilities. Distances significantly larger than 300 meters would identify many block centroids that are outside facility boundaries, particularly for small facilities. Where we confirmed a block centroid on facility property, we moved the block centroid to a location that best represents the residential locations in the block.

In addition, census block centroids for blocks with large areas may not be representative of residential locations. Risk estimates based on such centroids can be understated if there are residences nearer to a facility than the centroid, and overstated if the residences are farther from the facility than the centroid. To avoid understating the maximum individual risk associated with a facility, in some cases we relocated block centroids, or added dispersion model receptors other than the block centroid. We examined aerial images of all large census blocks within one kilometer of any emission source. Experience from previous risks characterizations show that in most cases the MIR is generally located within 1 km of the facility boundary. If the block centroid did not represent the residential locations, we relocated it to better represent them. If residential locations could not be represented by a single receptor (that is, the residences were spread out over the block), we added additional receptors for residences nearer to the facility than the centroid.

For this source category, the table below contains each census block for which we changed the centroid location because it was on facility property or was otherwise not representative of the residential locations in the block. The table also contains the locations of additional receptors that were included to represent residential locations nearer to the facility than the block centroid.

Revised Census Block Centroid Locations and Additional Receptors for the Ferroalloys Source Category

Centroid Revisions				
Block ID	**NEI ID**	**New Latitude**	**New Longitude**	**Comment**
391670203001029		39.36404	-81.53392	Not representive of population
540539548022127		38.952101	-81.922325	On plant property
540539548022183		38.944595	-81.921297	Not representive of population
	39167NEI11660	39.384305	-81.509796	Additional receptor
	39167NEI11660	39.386712	-81.517476	Additional receptor
	39167NEI11660	39.373718	-81.532765	Additional receptor
	39167NEI11660	39.36754	-81.535303	Additional receptor
	54053NEIWV053FELMAN	38.948407	-81.923071	Additional receptor
	54053NEIWV053FELMAN	38.960334	-81.939735	Additional receptor

Appendix 9 – Draft Protocol for Site-Specific Multipathway Risk Assessment

Protocol for Developing a TRIM.FaTE Model Scenario to Support a Site-Specific Risk Assessment in the RTR Program

WORKING DRAFT

February 2014

Prepared For:

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711
Contract No. EP-W-12-010

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CONTENTS

TABLES

1. Introduction

This document presents a protocol for developing TRIM.FaTE scenarios in support of site-specific risk assessments conducted within the RTR program using the TRIM.FaTE environmental fate and transport model.

This section describes the regulatory context, intended purpose of the protocol, the scope and limitations of the protocol, and some caveats to its use. It also presents a road-map to the content and structure of this document.

1.1 Regulatory Context and Approach to Risk Assessment for PB-HAPs

Section 112 of the Clean Air Act (CAA) directs the U.S. Environmental Protection Agency (EPA) to assess the risk remaining (i.e., residual risk) from emissions of persistent and bioaccumulative hazardous air pollutants (PB-HAPs) following the implementation of maximum achievable control technology (MACT) standards for emission sources. Such risk assessments for various emission source categories are a major component of EPA's Risk and Technology Review (RTR) program.

To evaluate ingestion exposures and human health risks for RTR on a source category basis, an iterative approach is currently employed. The approach enables EPA to confidently screen out PB-HAP emissions unlikely to pose health risks above levels of concern (i.e., a cancer risk exceeding 1-in-one million or a non-cancer hazard quotient exceeding 1[1]) and to focus additional resources on sources of greater concern within the category.

Two models are used to estimate ingestion exposure and ingestion risk in the RTR program:

- The Fate, Transport, and Ecological Exposure module of EPA's Total Risk Integrated Methodology (TRIM.FaTE) is used to model the fate and transport of pollutants released to the environment; and
- The Multimedia Ingestion Risk Calculator (MIRC) is used to estimate transfer and uptake into the food chain and exposure to receptors consuming contaminated food products and soil. A subset of media concentration estimates from TRIM.FaTE serve as inputs to MIRC, which also depends on other exposure and biotransfer-related input parameters.

The RTR approach is divided into three steps of increasing refinement:

1. Tier 1 of the approach identifies facility-level emissions of PB-HAPs within a source category and compares them to risk-based emission thresholds.

2. Tier 2 uses the actual location of the facility emitting PB-HAPs to refine a subset of the assumptions associated with the modeled Tier 1 environmental scenario while maintaining the Tier 1 ingestion exposure scenario assumptions; and

3. The final step, for facilities that cannot be ruled out based on the Tier 1 and Tier 2 screening process, is to conduct a more refined assessment, up to and sometimes including site-specific multipathway risk assessment. A site-specific risk assessment is intended to incorporate location- or facility-specific characteristics regarding the environment to which PB-HAPs are emitted, relevant exposure pathways, ingestion rates or other exposure factors, and other parameters. Site-specific risk assessments undertaken in the past as part of the RTR process have involved extensive literature searches for model parameters and required more time and resources to complete than the Tier 1 and Tier 2 screening analyses.

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[1] EPA considers "cancer risks exceeding 1-in-one million" to refer to risks of at least 1.5-in-one million, and "non-cancer hazard quotients exceeding 1" to refer to hazard quotients of at least 1.5.

1.2 Purpose of this Protocol

The site-specific protocol presented in this document is intended to serve as a guiding framework to set up and parameterize scenarios in TRIM.FaTE that support accurate and cost-effective site-specific risk assessments as part of the RTR framework.

The purpose of the protocol is to develop a standard set of guidelines and recommendations for conducting site-specific assessments, providing a streamlined and replicable framework for configuring and parameterizing the TRIM.FaTE model. The protocol aims to balance modeling accuracy with cost-effectiveness in implementation, and to facilitate consistency and transparency across diverse assessments. This protocol is also intended to function as part of the technical documentation for future site-specific residual risk assessments by providing a clear and transparent description of the approach to parameterization and some of the relevant sources. Deviations from this protocol would need to be documented on a case-by-case basis. This document also provides guidance on ICF's FaTEmaster Scenario Builder tool and discusses how that tool can be used to support site-specific risk assessments using the TRIM.FaTE model.

1.3 Scope and Limitations

The site-specific protocol presented in this document focuses on the fundamental aspects of setting up a scenario in TRIM.FaTE from an RTR perspective. While the TRIM.FaTE User's Guide (U.S. EPA 2005) provides guidance on the mechanistic aspects of designing a simulation, the protocol focuses on identifying best practices that optimize model set-up efficiency while maintaining a high level of model precision in the RTR context.

These best practices have been developed with a focus on the impact of alternative model configuration and parameterization approaches on ingestion risk in the RTR process. Thus, if two alternative model configuration approaches are estimated to have similar impacts on risk estimates in the RTR process, the protocol will recommend the less effort-intensive approach where appropriate. For instance, the protocol identifies only a limited set of TRIM.FaTE model properties as requiring site-specific parameterization, while proposing land use-specific or nationally representative or health protective values for others based on the finding that relatively few model parameters substantially influence risk in the RTR context.

However, the protocol is not driven exclusively by considerations of cost-effectiveness. In some instances, the protocol aims to provide superior methods of model configuration based on model accuracy and scientific considerations that were previously not clearly articulated in available TRIM.FaTE guidance, and that have a focus on the RTR program.

This protocol is not intended to serve as a substitute for the TRIM.FaTE User's Guide (U.S. EPA 2005) or the TRIM.FaTE Technical Support Document (U.S. EPA 2002). It is not step-by-step guide to running the model. It is recommended that the protocol be read in conjunction with the User's Guide and the Technical Support Documentation to provide a holistic perspective on how the model should be used in site-specific RTR applications.

1.4 Caveats

The findings and recommendations presented in this document are subject to several caveats:

- Some of the conclusions presented in this protocol are based on a combination of available empirical evidence, theoretical considerations, and expert judgment. A "brute-force" empirical approach to test an extensive range of scenarios and parameters was not feasible.
- For some model parameters, ICF relied on sensitivity analyses performed on previous configurations of the model. It is possible that the results of previous sensitivity analyses differ slightly from the current Tier 1 model configuration.
- ICF did not test the sensitivity of model parameters in alternative model configurations; and

- ICF did not research and identify land use-specific parameter values for soil properties values as part of this protocol, although it recommends their use.

Despite these limitations, the current recommendations are expected to meet the objectives of providing a cost-effective and accurate approach to site-specific risk assessment in the RTR program. However, users are encouraged to extend site-specific model design and parameterization beyond the levels proposed here as circumstances permit.

1.5 Protocol Road Map

This protocol contains the following types of information:

- best practices for TRIM.FaTE model configuration for use in site-specific RTR applications;
- documentation of the rationale for best practice recommendations;
- nationally representative or health protective model parameter values for site-specific applications of TRIM.FaTE; and
- a guide to the FaTEmaster Scenario Builder tool to create input files for TRIM.FaTE.

These distinct elements are woven together in the following structure:

- Section 2 sets the context with a summary of TRIM.FaTE input files and their content;
- Section 3 discusses the model's meteorological data requirements, potential data sources, approaches to address missing data, data processing requirements, and the issue of plume rise;
- Section 4 presents recommendations and rationale for best practices for designing air and surface parcels in TRIM.FaTE;
- Section 5 presents recommendations and rationale for best practices for defining surface hydrology and erosion parameters required by TRIM.FaTE;
- Section 6 identifies parameters recommended for site-specific parameterization;
- Section 7 identifies parameters recommended for land-use specific parameterization;
- Section 8 identifies parameters recommended for national default parameterization;
- Section 9 presents a guide to using ICF's FaTEmaster Scenario Builder tool in site-specific RTR applications; and
- Section 10 discusses potential future improvements and enhancements to the protocol.

2. A Brief Introduction to TRIM.FaTE Input Requirements

TRIM.FaTE is a spatially and temporally explicit multimedia environmental fate and transport model that estimates the concentrations of emitted chemicals in biotic and abiotic environmental media. The model uses a compartmental box model approach to track the movement of chemicals in environmental media. The model is based on representing environmental media as compartments, moving chemical mass between interacting compartments consistent with a set of governing mathematical algorithms that describe environmental physical and chemical processes, and assuming instantaneous mixing within each compartment.

2.1 TRIM.FaTE Input Files and Contents

TRIM.FaTE requires a variety of inputs from users to define the modeled environment and to quantify the various environmental mass transfer processes. These inputs are provided to the model in the form of the following files:

- A "volume elements" file defines the spatial layout of the modeled domain in terms of three-dimensional abiotic compartments. Each volume element provides a frame of reference for one or more biotic compartments within it.
- A "compartments" file places biotic and abiotic compartments (modeling unit containing chemical mass) within the volume elements.
- A library file contains all the model algorithms, properties, and emission source information. Examples of the kinds of properties that are defined in the library file include:
  - scenario characteristics (e.g., start/stop time, modeling time parameters, output options);
  - source characteristics (e.g., chemicals emitted, location, emission rate);
  - chemical-specific properties, including physical-chemical (e.g., molecular weight, K_{ow}) and abiotic chemical-specific (e.g., degradation half-life);
  - non-chemical-specific characteristics of biota (e.g., body weight, food intake rate);
  - site-specific ecological setting data and characteristics of biota (e.g., type of species present, population and density information, food web relationships); and
  - abiotic environmental setting data such as abiotic media characteristics (e.g., air/water content of soil, pH of surface water, suspended sediment density), runoff/erosion fractions for adjacent surface soil compartments, and water flow between connected surface water compartments.
- A properties file typically contains: (i) simulation- and site-specific property values that are used to overwrite default library values, and (ii) the location of time-varying input files for parameters such as meteorological and vegetation parameters.

These input files must be developed using syntax that is consistent with TRIM.FaTE requirements. ICF's FaTEmaster Scenario Builder tool, discussed further in Section 9, provides a spreadsheet-based interface that facilitates the automated generation of syntactically accurate TRIM.FaTE input files from user-specified inputs. Further detail on the required syntax of the input files, and the process of setting up and running the model using these input files, is available in the TRIM.FaTE User's Guide (U.S. EPA, 2005).

Much of the challenge in a site-specific TRIM.FaTE application lies in designing a spatial layout that is consistent with the nature of the governing algorithms and that reflects the environmental dynamics of the modeled domain, researching and estimating numerous environmental properties that serve as inputs into the model, finding and preparing appropriate meteorological and climate-related data, and setting up the input files. The following sections will discuss the optimal methods of performing these tasks from the perspective of a site-specific RTR application.

2.2 Recommended Sequence of Activities for TRIM.FaTE Set Up

The following sections of this document focus on various aspects of TRIM.FaTE set up as discrete elements in the model configuration process. There are, however, interconnections between the research required to guide various components of the set up process. Although there are no firm rules governing the order in which the model's input files must be developed, this protocol recommends a sequence of activities as a means to enhance efficiency and accuracy in the model configuration process:

1. Perform qualitative spatial analyses of topography, hydrography (boundaries of watersheds, flow lines), and land cover around the site. This will aid in identifying meteorology data, identifying modeled lakes and farms or potential farmland, and shaping the model domain;

2. Identify meteorological data based on RTR considerations (e.g., what meteorology did the RTR inhalation risk assessment use for the site?), data availability, data quality, and the representativeness of the data and instrument siting with respect to the modeled facility. Further,

create the meteorological file and use the meteorological data and emission source parameters to estimate plume rise where necessary;

3. Identify lakes to model based on lake size and a preliminary assessment of risk potential and data availability;

4. Identify farms or potential farmland to model based on a preliminary assessment of risk potential and data availability;

5. Create spatial layout;

6. Estimate and define surface hydrology and erosion dynamics within the layout;

7. Gather data on site-specific properties per the protocol;

8. Enter input property data into FaTEmaster Scenario Builder tool;

9. Generate TRIM.FaTE input files; and

10. Run TRIM.FaTE.

3. Meteorological Data Development

3.1 The Role of Meteorological Data in TRIM.FaTE

The algorithms that simulate the advection of chemicals between the air compartments and the simultaneous deposition of chemicals to the underlying surface compartments depend on numerous meteorological parameters such as wind speed, wind direction, mixing height, and rainfall rate, amongst others. Sensitivity analyses have indicated that meteorological parameters are among the most risk influential parameters in the TRIM.FaTE model (U.S. EPA 2009). Previous evaluations have also suggested that the effects of these parameters are important in TRIM.FaTE, favoring the use of time-varying meteorological data at the temporal resolution at which the measurements are reported, rather than data averaged over longer time periods.

For these reasons, it is recommended that all meteorological parameters be site-specific. This accounts for the potential interactive effects between meteorological parameters. The meteorology data should also be hourly, where possible—averaging to coarser time steps can obscure real trends in the data.

This section discusses best practices in incorporating site-specific meteorological parameters in TRIM.FaTE applications.

3.2 Summary of Meteorological Parameterization in TRIM.FaTE

The following steps, discussed in greater detail in subsequent sections, serve as a general guide to generating TRIM.FaTE meteorology input data in RTR site-specific applications:

1. Determine the meteorology time step to be used (e.g., hourly, *n* hours per day, daily, etc.). Surface meteorology data available from federal agencies is typically hourly. Longer time steps reduce model run time but can obscure real and significant trends in the data. Hourly values are recommended;

2. If it is appropriate to use the same meteorology data used in RTR inhalation risk assessments, obtain those data. Otherwise, identify the source(s) of meteorology data that meet the following criteria:

The data contain all the meteorology fields required by TRIM.FaTE. Note that upper-air radiosonde data do not contain mixing height values. Mixing height values must be calculated, typically using a combination of surface and upper-air data (see Bullet 3 below);.

  a. The data have no more than 10 percent missing data for any of the meteorology fields required by TRIM.FaTE; and

  b. The data are as representative as possible of the area being modeled.

3. If necessary, use a meteorological preprocessor or other method of estimating mixing heights at the desired time step (upper-air data is typically measured twice daily with a radiosonde and does not include mixing heights);

4. Replace all missing data with values that are as reasonable as possible;

5. If desired (although not recommended), aggregate the meteorology data to larger time steps. Then, replicate the data as needed to create a meteorology input file that covers the entire period of modeling; and

6. The combination of emission source characteristics (e.g., exit gas temperatures and velocities) and meteorological characteristics (e.g., stability, ambient temperature) might lead to significant emission plume rise during some time steps. In these cases, the user may use the emission source characteristics and meteorology data to estimate plume rise values.

3.3 Required Meteorological Parameters and Data Time Steps

TRIM.FaTE meteorology data must include the fields in Table 3-1. Mixing heights are not part of observed surface meteorology data. Mixing heights can be manually estimated using a vertical profile plot of upper-air data from radiosondes, though the typical method of calculating mixing heights relies on using surface and upper-air observed data in a meteorological processor such as AERMOD's meteorological processor (AERMET) or the U.S. EPA mixing height program. These meteorological processors, sources of surface and upper-air data, and sources of pre-calculated mixing heights are discussed in Section 3.4.

Surface meteorology data are typically available in hourly time steps, with some wind data available at smaller time steps. Upper-air data from radiosondes are typically available twice per day. These data time steps (hourly for surface data, twice-daily for upper-air data) are typically required by meteorological processors to estimate hourly mixing height values. The TRIM.FaTE meteorology data file does not require hourly time steps, although hourly data are typically used in site-specific assessments. Larger time steps will shorten model run time. The aggregation of data into larger time steps (although not recommended) should take place *after* mixing height values are determined.

Table 3-1. Meteorological Parameters Required for Meteorology Input File for TRIM.FaTE

Parameter	Format	Units	Further Description and Notes
Date	M/D/YYYY	NA	NA
Hour	Numeric	NA	NA
Time Zone	e.g., "EST"	NA	NA
Horizontal Wind Speed	Numeric	m/s	NA

Parameter	Format	Units	Further Description and Notes
Wind Direction	Numeric degrees	degrees clockwise from north; blowing from	e.g., from north is 360 degrees; from east is 90 degrees; from south is 180 degrees; and so on. 0 degrees is reserved for calm winds (e.g., wind speed = 0 m/s)
Air Temperature	Numeric	K	NA
Mixing Height	Numeric	m	Not an observed parameter. Must be calculated, typically using a meteorology processor with surface and upper-air data inputs.
Rain Rate	Numeric	m/day	NA
Cumulative Rain	Numeric	m	Total precipitation in a precipitation event. A multi-hour event will have equal cumulative rainfall values for each hour.
Is Day	Boolean (i.e., 1 or 0)	NA	Daytime (value of 1; after sunrise) or nighttime (value of 0; after sunset). Calculated using U.S. EPA's SR-SS.exe program, available with TRIM.FaTE.

3.4 Selecting Appropriate Surface and Upper-air Data

RTR inhalation risk assessments match a facility with the Automated Surface Observing Station that is closest to the facility and that has relatively complete data for one recent year (that year is currently 2011). That surface station is coupled with its closest, regularly reporting upper-air station. Unless meteorology data were measured at the facility itself, it is usually appropriate to use those same meteorology stations for RTR ingestion risk assessments, subject to EPA discretion and the availability of good quality data for multiple recent years.

Surface and upper-air radiosonde data can be obtained from the National Climatic Data Center (NCDC), regional climate centers, and third party vendors. Some sources of hourly surface meteorological data across the United States are shown in Table 3-2. These data sources are shown with generally the more current and more spatially dense data (i.e., the large and freely available Integrated Surface Hourly data) listed first. Some state agencies also maintain their own station networks and might be good sources of meteorology data.

Twice-daily upper-air radiosonde data from stations operated by federal agencies can be obtained for free from the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) in Forecast Systems Laboratory (FSL) format for over 100 U.S. stations and for 1994 through present, where available (ESRL 2011). ESRL also has archived FSL-formatted upper-air data going back to 1946, available for purchase on disc. Mixing heights are not part of observational data. Hourly mixing heights can be manually estimated or they can be calculated using a combination of surface and upper-air data. Typically, these hourly mixing height calculations are performed in a meteorology data preprocessor such as AERMET (U.S. EPA 2012a). AERMET accepts some of the surface meteorology data formats presented in Table 3-2 and FSL-formatted upper-air data. Pre-calculated, twice-daily mixing height data also are available from U.S. EPA for over 70 U.S. stations for 1984 through 1991 (U.S. EPA 2010a) and can be used in the computer version of the meteorological processor for the Regulatory Air Model (PCRAMMET; U.S. EPA 2012c).

The user should select appropriate data based on proximity of the station to the modeling site and on the station site's representativeness of the modeling site (e.g., elevation, land use, and wind flow). Evaluating the representativeness of the site and data is subjective. The surface and upper-air stations closest to the modeling site often will be the best choices. Because the upper-air station network is much sparser than the surface network, proximity might be a less restrictive criterion in choosing upper-air stations compared to choosing surface stations. Instead, it might be more important to choose an upper-air site that experiences boundary layer characteristics that are similar to those of the modeling site. For example, if the modeling site is well inland, it might not be appropriate to use an upper-air station on the coast.

The availability and quality of the data must also be considered. It is typically recommended that no more than 10 percent of the data be missing, and the data values should be within expected bounds. The user should also note that some meteorological data are archived in UTC, or Zulu time, which is functionally the same as Greenwich Mean Time and equivalent to Eastern Standard Time plus five hours. The data should be converted to local standard time for use in TRIM.FaTE, and standard time must be used throughout the year (most archived meteorology data are in standard time).

One year of data might be sufficient, as long as the data on average are representative of recent climatological averages at the site. NCDC 30-year climate normals are recommended for comparison (NCDC 2011). When data from a single year are found to be significantly different from typical conditions, the user can use several consecutive years that, together on average, are closer to typical conditions.

3.5 Replacing Missing Data

TRIM.FaTE requires that there be no missing data in its meteorology fields. U.S. EPA's recommended guidance for replacing missing meteorology data (U.S. EPA 1992) has a series of objective data replacement steps as a first pass, but those steps might not fill in all missing data. The guidance suggests some subjective procedures for filling in remaining missing data; however, these are manual steps and do not cover all possible cases of missing data (e.g., if more than a few contiguous hours of data are missing). A meteorologist or experienced air quality modeler should perform these subjective data fill procedures. The user should expect that the quality of substituted values will be worse for longer contiguous periods of missing data versus only a few contiguous hours of missing data. However, as long as the amount of data originally missing is no more than 10 percent, and as long as the substituted values are not out of normal bounds, then substituted data will have only a small impact on modeling results—especially for TRIM.FaTE assessments where the desired outputs are final accumulated media concentrations after several decades of modeling.

ICF developed a tool (AERMET2TRIM), based in Microsoft Access, that fills in missing data in all meteorology fields needed by TRIM.FaTE. The procedures are based on those provided in U.S. EPA (1992). AERMET2TRIM requires first that AERMET be run on the surface and upper-air data in order to estimate hourly mixing heights. AERMET2TRIM then reformats the data into the format required by TRIM.FaTE.

Table 3-2. Potential Sources of Hourly Surface Meteorological Data (not all-inclusive)

Name	Notes on Measured Data	Years Available	Spatial Coverage	Source	Other Notes
Integrated Surface Hourly (ISH) Data	NA	Over 100 years to today, where available	Thousands of stations worldwide	NCDC (2008)	Available in two formats -- abbreviated and full. AERMET requires the full format. The availability and structure of the formats have changed through the years and through the different available data storage media. Free via online download.
Quality Controlled Local Climatological Data (QCLCD)	NA	2005 to today	Approx. 1,600 U.S. stations	NCDC (2013)	Free via online download.
U.S. EPA AERMOD-formatted data for the Human Exposure Model (HEM-3)	Not strictly observational data – processed observational data through AERMOD's preprocessors to produce AERMOD-ready format.	2011 only	Over 800 U.S. stations	U.S. EPA (2013)	Free from EPA.
Solar and Meteorological Surface Observation Network (SAMSON)	NA	1961 through 1990, where available	Approx. 237 U.S. stations	NCDC (2012)	File formats changed after approx. 2007. Available for purchase on disc.
U.S. EPA Support Center for Regulatory Atmospheric Modeling (SCRAM)	No precipitation data (request DSI-3240 format precipitation data from NCDC)	1984 through 1992, where available	Approx. 250 U.S. stations	U.S. EPA (2010b)	DSI-1440 format. Free via online download.

3.6 Aggregate and Duplicate

If desired (though not recommended), the user should aggregate the data to conform to the modeling time step being used. Values of wind speed, air temperature, mixing height, and rain rates should be averaged. For wind direction, the hourly values of wind speed and wind direction should be used to calculate the vector components of the wind (i.e., u and v values), those vector components should be averaged, and the averaged vectors should be used to calculate the average wind direction. Calculate new cumulative rain values after averaging the rain rates. Use professional judgment to determine appropriate values for the “Is Day” parameter.

Previous site-specific assessments conducted using TRIM.FaTE typically have used 50-year modeling periods. The meteorology data in TRIM.FaTE format should be duplicated as necessary to produce a 50-year data period (or other appropriate time period that matches the facility lifetime/emissions period selected during the initial assessment planning stage). For example, if the meteorology data represent years 2008 through 2011, the user should copy-and-paste that four-year period to create 50 years of data (e.g., 2000 through 2049). The user should make sure that the year values are changed appropriately, and that leap years contain data for February 29. If the user’s original meteorology data do not contain a leap day, simply duplicate data from February 28 and label as February 29.

3.7 Plume Rise

Emission plumes in nature usually have a vertical component to their dispersion pattern (i.e., plume rise). Multiple forces can affect vertical dispersion, including the temperature of the plume compared to the ambient air temperature, the wind speed at the release point, the ambient vertical temperature gradient, atmospheric stability, the diameter of the release point, and the temperature and velocity of the emissions as they exit the release point.

TRIM.FaTE does not calculate plume rise. Instead, emitted chemicals are advected horizontally through fully mixed air compartments whose dimensions are defined by the user. This advection occurs in one of two air volume compartments—the mixing layer compartment (where people, plants, animals, soil, and water are exposed to the chemicals) or the upper-air compartment above the mixing layer (where the chemicals are removed from ground-level exposure; i.e., a sink). Because an emission source’s release height is static, the mixing height for a given modeling time step determines which air layer the chemicals are emitted into in that time step.

AERMET2TRIM has a function that estimates hourly plume rise given the physical parameters of an emission source (i.e., latitude-longitude coordinates, release point height and diameter, and exit gas temperature and velocity), the horizontal distance from the source at which to estimate the plume rise (i.e., the radius of the modeled source parcel), and the meteorology data being used for the TRIM.FaTE analysis. Because AERMET output data do not contain cloud ceiling heights, the AERMET2TRIM plume rise calculations require a supplementary file containing those data (such ceiling data are available in ISH and SAMSON data, for example). These plume rise estimations are based on methods summarized by Seinfeld and Pandis (1998). The output from this function is a text file with hourly values for effective release height, which is the actual release height plus the hourly plume rise value. If desired, the user can then aggregate the data to the time step being modeled.

Including hourly effective release heights will increase model runtime. In previous TRIM.FaTE site-specific assessments, a 5% rule has been used to judge whether or not to use hourly heights; that is, if the effective release height was above the mixing height less than 5% of the time, hourly heights were not used (i.e., the static, physical stack height was used). The user also has the option to estimate an average effective release height for the entire modeling period, and simply use that average height as the release height for all modeling times.

4. Air and Surface Parcel Design

4.1 The Role of Spatial Layouts in TRIM.FaTE

One of the primary inputs required by the TRIM.FaTE model is the specification of a spatial layout using Cartesian coordinates to define the vertices of surface and air parcels and volume elements. This information is input into the model via the “volume elements” input file. To construct the volume elements input file, users are required to divide the modeled domain into two-dimensional air parcels and surface parcels. Air and surface parcels need not line up in all cases. Each parcel is also associated with a height, which may vary in time. The parcel coordinates and height are combined to define three-dimensional abiotic volume elements that contain biotic and abiotic compartments used to model the movement of chemical mass in TRIM.FaTE.

In a site-specific assessment, the spatial layout should capture the features of interest (e.g., farms or lakes) at the surface level and also specify how the overlying air domain is to be divided to produce accurate and informative estimates. Although the TRIM.FaTE User’s Guide (U.S. EPA 2005) provides useful mechanistic guidelines and rules of thumb on the design of air and surface parcels, those recommendations are not specific to the RTR context and are not based on an ingestion risk perspective. The following guidelines, as noted in the introduction to this document, are intended to support site-specific risk assessments in the RTR program and should be considered in addition to the instructions and recommendations provided in the User’s Guide and Technical Support Document (U.S. EPA 2002).

4.2 Theoretical Considerations Influencing Parcel Design

Discussed below are the theoretical considerations related to the TRIM.FaTE model that were used to inform the air and surface parcel design recommendations presented later in this section.

4.2.1 Cross-Wind Dispersion

TRIM.FaTE models the movement of chemical mass based on first-order differential equations. Consequently, the model does not account for dispersive processes in air that carry mass in a cross-wind direction. Air parcel design must be conscious of, and attempt to compensate for, this limitation of the TRIM.FaTE model. For instance, using a square grid for air parcels may result in “pipeline flow” with the bulk of the emitted chemical concentrated in a compartment directly downwind. The concentration estimates based on such a design would not align well with empirical evidence or with theoretical Gaussian plume models that are based on the second-order advection dispersion equation.

Although a compartmental model with instantaneous mixing (such as TRIM.FaTE) could never produce identical spatial results to a Gaussian plume model, air parcel design in TRIM.FaTE must attempt to ensure that an appropriate amount of lateral dispersion is permitted to occur. The Pasquill-Gifford estimates of cross-wind dispersion are commonly applied as parameters in air dispersion models for alternative atmospheric conditions (U.S. EPA 1995). These cross-wind dispersion estimates are in the form of graphs which plot cross-wind dispersion as a function of downwind distance. The Turner equations are mathematical representations of these plots. A plot of the Turner equations, which numerically approximate the Pasquill-Gifford estimates of cross-wind dispersion, suggests that 99% of the emitted mass in neutral atmospheric conditions is likely to be contained within a cone subtending an angle of 20 degrees from the source, assuming a constant wind direction through the centerline. This provides a guideline about the ideal breadth of air parcels, especially those downwind of features of interest.

4.2.2 Numerical Diffusion

All compartmental models potentially experience the issue of “numerical diffusion,” which refers, in the context of an air dispersion model, to the propagation of mass further downwind at a given point in time than is physically possible given the wind speed. Maintaining a fixed relationship between the size of the time step used in the simulation, the length of compartments, and the wind speed helps prevent issues of numerical diffusion. Users interested in strict time accuracy are advised to ensure that compartment lengths are shorter than the wind speed multiplied by the model time-step. For RTR purposes, however, average annual values in the 50th year are of primary interest, and strict restraints on parcel length for a given time-step are considered less important but still good practice to implement.

4.2.3 Shape of the Deposition Profile with Distance from Source

The TRIM.FaTE model produces a deposition profile that has the largest values in the source compartment and decreases with increasing distance in a pattern similar to an exponential curve. Theoretical and empirical evidence suggests, however, that the maximum deposition rate would not be experienced at the point of emission, but further downwind. At a wind speed of 5 m/s, the point of maximum deposition for fine particulates and gases was estimated to be between 1 and 5 km (Overcamp 1976). Users of the TRIM.FaTE model should therefore be conscious of potential overestimation of deposition in surface parcels adjacent to the source and a potential for bias in the deposition profile.

4.3 Empirical Evidence Relating to TRIM.FaTE Parcel Design

A limited number of TRIM.FaTE scenarios were modeled to provide empirical data about the impact on risks (in the RTR context) from air and surface parcel layout design. Most of these scenarios were based on simple variations of the Tier 1 screening scenario layout. The main findings are summarized here:

- Extending an air parcel beyond the outer boundary of the underlying surface parcel (i.e., having an air parcel “overhang” the surface parcel beneath it) reduces deposition over the surface parcel compared to air parcels that are co-terminus with surface parcels (i.e., having the air parcel directly overlay the surface parcel);
- The number of air parcels that precede the air parcel overlying the surface feature of interest (i.e., the number of air parcels between the source parcel and an air parcel of interest) does not materially impact deposition over that surface parcel;
- Soil concentrations in the surface compartment adjacent to the source are considerably higher than if the same surface compartment is set back by a short distance of approximately 400m (i.e., a 400-m buffer parcel between the source and the parcel of interest). This is consistent with TRIM.FaTE’s exponential deposition gradient; and
- Increasing the length and/or breadth of a surface compartment might substantially reduce surface soil concentrations

More detailed results from these scenarios are documented in Appendix A.

4.4 Recommended Best Practices for Air and Surface Parcel Design

The following recommendations for air and surface parcel design are intended to maintain a high degree of modeling accuracy while reducing design effort and potentially optimizing computer run time. While these guidelines are intended to facilitate optimal parcel design, every scenario is unique and might require site-specific adjustments beyond the suggested approach provide here. Any adjustments or improvements to the proposed approach should aim to be consistent with the governing principles and empirical evidence discussed earlier in Section 4.

Step 1: Identify Features of Interest

Several steps are recommended for identifying features of interest:

- Use geospatial data (e.g., aerial imagery, data on watersheds and water bodies, and remotely-sensed land cover and crop growth) to identify features of potential interest from the RTR perspective, such as farms and lakes;

  - Geospatial data can include Google Earth (Google 2013), the National Hydrography Dataset (USGS 2013), the National Land Cover Database (MRLC 2013), and the Cropland Data Layer (USDA 2013).
- Consider only lakes that are at least as large as 25 acres (approx. 10 hectares)[2] and that research suggests are fishable; and
- Use the following guidance to finalize the selection of lakes and farms for modeling:
  - Limit farms to those within roughly 5 km of the source;
  - Do not select multiple farms in the same direction from the source;
  - Do not select farms adjacent to the source parcel. Choose a buffer distance of at least 400 m;
  - Prefer farms and lakes closer to the emission source versus those farther away;
  - Prefer lakes for which preliminary research suggests good availability of modeling data (e.g., flush rates, depth, pH, total phosphorus levels, suspended sediment concentration);
  - Prefer lakes and farms that are frequently downwind from the emission source, if they exist, based on the meteorology data selected for modeling; and
  - Prefer the lake(s) selected in the Tier 2 screening analysis.

Step 2: Breadth of Air Parcels (Air Parcel Radials)

Several steps are recommended for defining the breath of air parcels:

1. Emissions center point: Identify the center point of what will later become the emission source parcel. It should roughly be the centroid of all the actual emission sources of concern at the facility;

2. Draw 20-degree radials: Manually or using geospatial software, overlay radials that intersect at the source center point, are 20 degrees apart. These radials roughly create triangles and represent preliminary breadth boundaries of air parcels;

3. Adjust the radial grid: Rotate the radial grid so that the maximum number of surface features of interest (e.g., farms and lakes) falls within single triangles;

4. Smaller features of interest: For features that fall within a single triangle, use the boundaries of the triangle to define the breadth dimension of the air parcel overlying the surface feature;

5. Larger features of interest: For features that fall within multiple triangles, merge and adjust the multiple triangles into a single triangle that fully contains the feature. For instance, if a lake subtends an angle of 50 degrees with respect to the source, three 20 degree triangles should be merged and adjusted to form a 50 degree triangle to define the breadth of the overlying air parcel. This process will distort the shape of the surrounding triangles (i.e., they will be greater than the suggested 20 degrees), but that is acceptable; and

6. Areas not overlying features of interest: For air parcels not overlying any features of interest, less resolution is required. Merge three 20 degree triangles to create a 60 degree triangle to define the breadth dimension of the overlying air parcel.

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[2] Based on available data, for RTR multipathway emission screening analyses, EPA defines potentially fishable lakes as those larger than 100 acres, without exceeding 100,000 acres. Even a 100-acre lake is unlikely to be large enough to sustain harvesting the number of piscivorous fish required for the current screening ingestion rate (i.e., 373 g ww fillet/day). This is discussed in Section B.3.1 of Attachment B in Appendix 4 to the Risk Report. However, EPA includes smaller lakes (as small as 25 acres) in site-specific RTR multipathway analyses to be health protective and to ensure that small lakes that might be more highly contaminated than estimated by the screening analyses are not eliminated.

Step 3: Define the Outer Boundaries of the Domain

Draw the outer boundaries of the domain approximately 5 km beyond the farthest feature of interest (in relation to the emission source), using the remaining parcel radials as the design template. This 5-km buffer is flexible depending on the characteristics of the nearby watersheds and how they might impact the runoff and erosion of chemical into the features of interest. Truncate the outer boundary of the domain in areas without features of interest, provided that these areas contribute much less significantly than other areas toward chemical runoff or erosion towards the features of interest.

Step 4: Complete Air and Surface Parcels for Features of Interest

Within the triangle overlying the feature (defined in Step 2), encase the feature within a trapezoid (⏢) by drawing straight lines at an angle to the sides of the triangle to define the inside boundary (the side closest to the source) and outside boundary of the feature. The trapezoid should be perpendicular to an imaginary radial originating at the emission source center point; put another way, these new lines should be parallel to each other and perpendicular to an imaginary radial bisecting the triangle, thus creating a trapezoid.

Where possible, the surface parcel representing the feature of interest should coincide with the air parcel trapezoid described above. This might require slightly distorting the dimensions of the surface feature of interest, but that is a permissible approach when the shape of the feature of interest is not very different from the overlying air parcel trapezoid.

For irregular surface features (i.e., those whose shapes are very different from the overlying air parcel trapezoid), create additional surface parcels as required to fill the space between the actual boundaries of the feature of interest and the boundaries of the overlying air parcel trapezoid. The additional surface parcels adjacent to the features of interest should be constructed subject to the consistency of land cover, terrain patterns, and/or hydrography. A single adjacent parcel should never surround another parcel entirely. Instead, two adjacent parcels should bound the irregularly shaped feature on either side.

Step 5: Draw Air and Surface Parcels for the Emission Source

The air and surface parcels for the emission source should line up. The source parcel should be centered on the center point identified in Step 2 above and should accurately reflect where chemicals of concern are actually being emitted at the facility (i.e., it should fully contain all of the actual emission sources of concern). It should be a polygon where each side connects the sides of each air parcel triangle, and each side is perpendicular to an imaginary radial bisecting the triangle. For example, if the air parcel triangles each subtend exactly 60 degrees, and if the real emission sources span a 500-m distance, then the source parcel would be a perfect hexagon that is centered on the emission source center point and has a diameter of 500 m.

Step 6: Complete Air and Surface Parcels Upwind of the Features of Interest

Within the two radials that bound a feature of interest, create a single air parcel between the feature and the source parcel (i.e., upwind of the feature of interest). Like the air parcel above the feature itself, this upwind air parcel will be a trapezoid bounded by two lines that define the inside and outside boundaries (parallel to the inside and outside lines of the feature, relative to the emission source) and by the radials.

There should be a corresponding surface parcel that lines up with the upwind air parcel. If the upwind region contains several different regimes of land cover, terrain, and/or hydrography that are large relative to the region, then divide the surface parcel into separate parcels for each of those different, major regimes. For example, for an upwind surface parcel oriented north-south, if the northern half contains urban land cover and the southern half is a deciduous forest, then it might be reasonable to divide the parcel into a northern parcel (with no vegetation) and a southern parcel (with deciduous forest). On the other hand, if the region is a scattered mix of forested and pasture/hay land cover, it would not be reasonable or efficient to create many very small parcels for each small area of forest or pasture/hay.

Step 7: Air and Surface Parcels Downwind of the Features of Interest

Create an air parcel downwind of the feature of interest (i.e., on the side of the feature opposite the emission source) with a length dimension no larger than 5 km. The relative small size of this downwind parcel increases the accuracy of chemical transfer via runoff and erosion.

There should be a corresponding surface parcel that lines up with the downwind air parcel. If the downwind region contains several different regimes of land cover, terrain, and/or hydrography that are large relative to the region, then divide the surface parcel into separate parcels for each of those different, major regimes.

Step 8: Complete Air and Surface Parcels Crosswind of the Features of Interest

Several considerations are recommended for defining air parcels crosswind of features of interest (i.e., parcels to the “left” and “right” of the feature, relative to the emission source):

- The outside boundary of an air parcel immediately crosswind of a feature of interest should not extend beyond the outside boundary of the feature itself (i.e., the outside boundaries of the feature parcel and the crosswind parcel, relative to the emission source, should connect). This is to increase the accuracy of chemical transfer via runoff and erosion;
- The breadth dimensions of a crosswind air parcel should be defined by the radial grid. That is, the “left” and “right” sides of the crosswind parcels (relative to the emission source) should be defined by the radial grid developed in Step 2 above;
- The inside boundary is the source parcel, unless there is already a parcel drawn between the source and the crosswind parcel (i.e., a parcel related to a different feature of interest); and
- There should be a corresponding surface parcel that lines up with the crosswind air parcel. If the crosswind region contains several different regimes of land cover, terrain, and/or hydrography that are large relative to the region, divide the surface parcel into separate parcels for each of those different, major regimes.

Step 9: All Other Air and Surface Parcels

All other air and surface parcels should be fitted within the boundaries defined by: (i) the air parcel radials (Step 2); (ii) the boundaries of the features of interest and their upwind, downwind, and crosswind neighbors (Steps 6-8); and (iii) the outer boundaries of the domain (Step 3). These other air and surface parcels are subject to continuity of land cover, terrain, and/or hydrography, as discussed in the above steps.

5. Surface Hydrology and Erosion Property Definitions

5.1 Surface Parcel Chemical Transfer Dynamics in TRIM.FaTE

The TRIM.FaTE model incorporates the ability to account for chemical transfers between adjacent surface parcels via runoff and erosion. The algorithms that model surface runoff and erosion in TRIM.FaTE simulate the advective chemical transfer dynamics between surface parcels without requiring spatial elevation information or land-cover details as inputs. Instead, the algorithms depend on inputs explicitly specifying the destination of erosion and runoff from a specific parcel. In other words, for each surface parcel, users must specify the proportion of the erosion and runoff originating in that parcel that reaches specific adjacent parcels. These inputs are known as link properties in TRIM.FaTE and are typically specified in the TRIM.FaTE “properties” file discussed in Section 2. Users must also separately specify the average runoff and erosion rate for each surface parcel. These inputs are combined internally with estimates of the chemical concentration in surface soil and soil water to estimate mass transfers that occur in conjunction with erosion and runoff processes.

The inter-parcel runoff and erosion parameter inputs in TRIM.FaTE are inherently site-specific because there is no logical default value for the percentage of runoff and erosion from one parcel that reaches an adjacent parcel. Simulations indicate that ingestion risk in the RTR process is sensitive to the choice of these values (refer to Appendix A). This section discusses options for parameterizing these inputs in site-specific TRIM.FaTE applications for RTR.

For users not having access to (or expertise in using) geographical information systems (GIS) software with features to quantitatively analyze surface hydrology and erosion, the recommended method of estimating parcel-to-parcel runoff/erosion fractions is summarized in Section 5.2. If sophisticated GIS software with features to analyze surface hydrology and erosion based on elevation is to be used, the recommended method is summarized in Section 5.3.

5.2 Estimating Runoff and Erosion Fractions without Sophisticated GIS Software

Without a license for sophisticated GIS software, the user can still obtain free GIS viewing tools that allow the user to display multiple layers of geospatial data and that have limited interaction with the data, including querying the data and measuring distances. With such viewing software, the method for estimating runoff/erosion fractions provided in Module 11 of the TRIM.FaTE User's Guide (U.S. EPA 2005) is appropriate. This method is summarized briefly here, with some additional tips not provided in the User's Guide.

Step 1: Assemble Hydrological and Elevation Data

The user should obtain geospatial data indicating boundaries of hydrological units relevant to the modeling domain. These hydrological data are available from the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD; USGS 2013). These hydrography data should already have been obtained and used to inform the design of the modeling parcels. The NHD offers several levels of hydrological units, typically from regions (the most spatially coarse) to subwatersheds (typically the highest spatial resolution). Considering that the typical site-specific TRIM.FaTE modeling domain has a radius less than 50 km and is divided into several surface parcels, subbasins or watersheds will usually offer the most appropriate resolution for use in configuring parcels and estimating runoff/erosion fractions. The NHD also offers directional flow lines of streams, rivers, and other hydrographic features.

The user should also obtain elevation data for the modeling domain. High resolution data are available from the USGS National Elevation Dataset (NED; USGS 2006). These elevation data should already have been obtained and used to help construct the modeling parcels. The data with the highest spatial resolution are not necessary; 30-m resolution usually is appropriate.

Step 2: Relate Surface Modeling Parcels to Each Other and to Hydrological Units

The user should display the modeling surface parcels along with the appropriate hydrologic unit boundaries from the NHD. For each parcel ("sending parcel"), do the following:

- For each hydrologic unit that occupies at least part of the sending parcel, estimate (or calculate, if able) the ratio [surface area of the part of the hydrologic unit that is inside the sending parcel] to [surface area of the sending parcel];
- Identify each neighboring parcel ("receiving parcel"), including sinks where appropriate for the sides of the sending parcel that lie along the outer boundary of the modeling;
- For each hydrologic unit that occupies at least part of the sending parcel, estimate or calculate the length of each interface between the hydrologic unit and each receiving parcel (not discussed in the TRIM.FaTE User's Guide); and
- Estimate or calculate the fraction of the sending parcel's perimeter that interfaces with each receiving parcel (not discussed in the TRIM.FaTE User's Guide).

Step 3: Estimate Fraction of Runoff and Erosion

For each hydrologic unit that occupies at least part of a sending parcel, one should use NED elevation data and NHD flow lines to estimate the fraction of runoff that will flow from the hydrologic unit into each receiving parcel and, where appropriate, into sinks outside the modeling domain. A fraction might be 0 if the elevation and flow lines suggest that all water in the hydrologic unit flows away from a receiving parcel.

The User's Guide (U.S. EPA 2005) Section A.5 discusses runoff/erosion fractions. Although not discussed there, the NHD flow lines can help estimate the relative distribution of runoff from a sending parcel to its receiving parcels, or from a hydrologic unit in the sending parcel to a receiving parcel. One can examine the flow lines along each sending-receiving boundary to get a sense how much of the boundary has flows from the sending area to the receiving area. This information can be combined with information on how much of the sending area's perimeter interfaces with the receiving area in question, aiding the user in developing runoff/erosion fractions.

As discussed in the User's Guide Sections A.5 and A.6—separately for each hydrologic unit in a sending parcel, multiply [the fraction of sending parcel's area covered by the hydrologic unit] by [the runoff/erosion fraction from the hydrologic unit to the receiving parcel] for each of the sending parcel's receiving parcels. Then, for each of these receiving parcels, sum this product across the hydrologic units. This sum provides the final fraction of runoff/erosion from each sending parcel to each receiving parcel. For each sending parcel, the fractions will sum to 1 when sinks are included as appropriate.

Another option is to estimate the runoff and erosion fractions based on visual inspection. This approach does not explicitly relate the area of each hydrologic unit to each sending parcel. Therefore, it does not explicitly assume that water cannot cross the boundaries of hydrologic units. Like the methods described above, this option uses flow lines and the interfacial length between adjacent parcels. In this option, for each sending parcel, the user visually examines the NHD flow lines to see where (if at all) flow lines cross each interfacial boundary and *into* the receiving parcels. For each sending-receiving pair of parcels, the user should estimate (or measure, if possible) the length of the part of the interfacial boundary that has flow lines crossing into the receiving parcel. Then, divide that length by the total perimeter length of the sending parcel. This ratio provides the fraction of runoff/erosion from the sending parcel into the receiving parcel. Some professional judgment is required to subjectively adjust these fractions based on the relative magnitude of runoff across the various interfacial boundaries. These relative magnitudes can consider the overall terrain and flow patterns throughout the sending parcel (i.e., a flow into the receiving parcel with a relatively small fetch will likely carry less chemical into the receiving parcel than a flow with a relatively long fetch).

5.3 Estimating Runoff and Erosion Fractions with Sophisticated GIS Software

The method discussed in this section requires the use of ESRI® ArcGIS™ software. The software license must enable the "Spatial Analyst" extension. ICF is currently developing an ArcGIS™ model, coupled with a Microsoft® Excel™ post-processing tool, that largely automates the below procedures.

In ArcGIS, select the "Flow Direction" tool of the "Spatial Analyst" extension. Given a raster elevation dataset (such as the NED), this tool will determine the flow direction of each raster cell to the steepest downhill neighboring raster cell. The output of this tool will be a raster, where the value of each raster cell will indicate the flow direction.

Then, select the "Flow Accumulation" tool of the "Spatial Analyst" extension. The input to the "Flow Accumulation" tool is the output of the "Flow Direction" tool described above. Separately for each input raster cell, the "Flow Accumulation" tool will follow the flow direction into the appropriate neighboring cell, and continue following the flow direction of that cell into a third cell, and so on, "connecting the dots" of the flow vectors until an endpoint is reached. This creates flow lines across the raster. Then, the tool calculates the number of these flow lines that cross each raster cell. This is the "flow accumulation" number produced by this tool. The flow accumulation is unitless, as it does not represent an actual amount of water or chemical flowing from one place to another; the accumulation values should be viewed relative to each other.

For each sending parcel, the user would use the combination of flow direction and flow accumulation data from the above tools to calculate the total flow (unitless) from the sending parcel to each receiving parcel. The runoff/erosion fraction from the sending parcel into receiving parcel "A" would be the accumulated flow from the sending parcel to receiving parcel "A" divided by the total accumulated flow from the sending parcel to all its receiving parcels.

6. Compartment Properties Recommended for Site-Specific Parameterization

6.1 The Role of Properties in TRIM.FaTE

The TRIM.FaTE model is dependent on hundreds of user-specified properties that describe the biotic and abiotic environments being modeled. Properties in TRIM.FaTE can be broadly divided into the following types:

- non-chemical specific properties that define biotic compartments (e.g., biomass of game fish in a lake, the length of a leaf on a deciduous plant),
- non-chemical specific properties that define abiotic compartments (e.g., porosity of surface soil, the total suspended solids concentration in a lake),
- chemical-specific properties (including system-wide chemical properties such as the Henry's Law constant, the octanol-water partition coefficient, and compartment-specific chemical properties such as reaction and degradation rate constants in various environmental media), and
- simulation-specific properties (e.g., model run-time, model time step).

All user-defined (e.g., non-formula) properties in a TRIM.FaTE scenario can be assigned simulation- or site-specific values. In theory, the more properties that are assigned site-specific values, the more accurately the simulation will represent chemical fate and transport at that location. Following this logic, the user should try to find site-specific values for as many properties as possible. However, although each model property is potentially important in defining a particular environmental fate and transport process, it is apparent based on theoretical considerations and empirical evidence (i.e., analysis of model results and model evaluations) that there is a subset of model properties that more significantly influences the environmental concentrations that drive the risks of importance in the exposure scenarios evaluated in RTR assessments. The fact that some parameters are more influential on results is true for complex models in general. This is the focus of sensitivity analyses.

In previous site-specific risk assessments using TRIM.FaTE, which were conducted for RTR and in other regulatory applications, a substantial portion of the level of effort required to perform the assessments was directed towards site-specific property parameterization. One of the specific objectives of this protocol is to take advantage of the results of sensitivity analyses and model evaluations conducted of TRIM.FaTE. Based on these results, we have identified those compartment properties that are a high priority for site-specific parameterization, those that can be adequately represented by regional or land-use-specific default values, and those for which nationally representative or health-protective values are adequate. This classification scheme is intended to reduce the level of effort required to adequately parameterize site-specific assessments while maintaining a high level of accuracy in risk estimates for RTR.

6.2 Approach to Prioritizing Properties for Site-Specific Parameterization

ICF relied on a combination of theoretical reasoning and empirical evidence to prioritize TRIM.FaTE properties for the purposes of this protocol. In this way, ICF was able to limit the need for "brute-force" empirical evaluations (e.g., comprehensive sensitivity analyses that systematically vary all or most of the user-defined inputs, such as those conducted prior to the 2009 SAB review (U.S. EPA 2009)) and additional resource-intensive literature searches. ICF's justification for determining that properties were ***not*** high priority was based on three lines of evidence:

1. ICF followed a **"process"-based approach** to rule out a large subset of TRIM.FaTE properties from the need for site-specific parameterization. This approach was founded on the idea that the TRIM.FaTE model produces greater than necessary resolution (in terms of the number of concentrations that are calculated for different environmental media types) when viewed from the RTR perspective. The individual human ingestion exposure scenarios evaluated for RTR rely most directly on results from TRIM.FaTE for surface soil compartments at the location of a farm and fish compartments in a lake of interest. All fate and transport processes—and the properties that exclusively define those processes—that do not strongly influence these concentrations can reasonably be ruled out from requiring site-specific parameterization. The implications of this approach will be discussed in greater detail below.

2. ICF also used practical considerations regarding **data availability** to rule out certain properties from site-specific parameterization. Over the course of numerous site-specific assessments and the parameterization of the screening scenarios, ICF has conducted literature searches on numerous TRIM.FaTE properties. ICF used the insight gained from these exercises to identify certain sets of parameters as being too data-scarce to parameterize on a site-specific basis at this time without expending a substantial amount of time and money (for possibly uncertain results).

3. **Physical constants and physicochemical properties** of the modeled PB-HAPs were also ruled out from site-specific parameterization based on their largely unchanging nature in the environment for the chemicals considered for RTR.

ICF evaluated the parameters not eliminated by the above considerations to determine which properties should be the focus of data collection efforts during site-specific TRIM.FaTE modeling for RTR. ICF conducted a limited number of evaluations and used the results of previous sensitivity analyses to decide which of these shortlisted parameters should be prioritized for site-specific parameterization, for land-use-based parameterization, or for regional parameterization.

Other scenario properties such as emission period and the model's numerical integration time-step are typically not varied between site-specific assessments. These properties are not discussed further in this protocol, but are documented in Appendix B.

6.3 Elimination of Properties from Site-Specific Parameterization

6.3.1 Process-based Elimination of Parameters

The operative principle in the process-based elimination of parameters is that fate and transport processes that do not substantially influence concentrations of interest from an RTR perspective are less important to parameterize. ICF used theoretical considerations based on the evaluation of the underlying TRIM.FaTE algorithms, combined with empirical evidence from TRIM.FaTE simulations, to identify the less important fate and transport processes and eliminate the need to parameterize those processes on a site-specific basis. The specific processes identified as being of less importance in the RTR context and the underlying justification for ruling them out from site-specific consideration are listed below:

- Chemical transport via water percolation through the sub-surface soil layers (not including surface soil) does not affect farm soil or lake water concentrations. Theoretical considerations suggest that chemical, once transported into the lower soil layers, will not substantially make its way back to the surface compartments of interest;
- Chemical transport via sub-surface soil diffusive processes, although having the potential to transfer mass upwards, are not sizeable in comparison to advective transfer processes. An evaluation of relative mass flux in the Tier 1 screening scenario supports this assertion for all the chemicals evaluated; and

- Chemical transport to the lake via horizontal groundwater flow and recharge is negligibly small compared to other advective chemical inputs into the lake. The relative mass flux for this process compared to other advective transfer processes carrying chemical into the lake in the Tier 1 screening scenario supports this assertion for all chemicals evaluated.

Because the RTR user has no intrinsic interest in the concentrations prevailing in the lower soil layers, all of the above processes have been ruled out from consideration for site-specific parameterization. As a consequence, it is possible to rule out all sub-surface soil compartment properties from requiring site-specific parameterization.

6.3.2 Data Availability-based Elimination of Parameters

Chemical-Specific Aquatic Biota Properties: The aquatic biota compartments in TRIM.FaTE—currently including benthic invertebrates and five types of fish—are characterized by several potentially site-specific properties that control algorithms influencing the uptake, degradation, and elimination of chemicals in the aquatic organisms. These chemical-specific properties include the absorption rates of chemical into each type of fish from surface water, elimination rates from fish digestive systems, degradation rates within the fish, and other parameters. In the course of parameterizing TRIM.FaTE for the screening scenario and conducting extensive evaluations of parameter sensitivity, it has become apparent that only a limited number of studies are available for several of these properties for most combinations of chemicals and organisms.

Although these properties may potentially differ in alternative climates and conditions, it appears unlikely that additional literature searches and evaluations would yield better, more appropriate site-specific values than the current defaults. Until such time as more studies on these properties are available, practical considerations suggest that these chemical-specific aquatic biota properties be ruled out from site-specific parameterization.

Chemical-Specific Abiotic Compartment Properties: TRIM.FaTE algorithms model chemical reaction and degradation processes in several abiotic compartments (e.g., surface soil). These algorithms depend on chemical-specific parameters such as degradation rates (or half-lives), transformation rates, and other properties. Literature searches conducted during previous site-specific assessments in the RTR process and other regulatory applications using TRIM.FaTE have suggested that data are limited for these properties.

These chemical properties (with the exception of oxidation, reduction, and methylation and demethylation rates influencing mercury) therefore are currently ruled out from site-specific consideration. The mercury transformation properties have been shown to be highly risk-influential as well as variable across different ecosystem types and conditions, and these properties are reserved for site- or land-use-specific parameterization in the future, subject to greater data availability and the results of additional evaluations.

6.3.3 Combination of Data- and Sensitivity-based Elimination of Parameters

Terrestrial Vegetation: The terrestrial vegetation compartments in TRIM.FaTE—currently including grass, coniferous forest, deciduous forest, wetland grass, and wetland forest—are not directly part of the RTR risk assessment calculations (i.e., chemical concentrations in these compartments are not used as inputs to the MIRC ingestion exposure model). However, these compartments act as sinks for chemicals and also transfer chemicals from air to soil via litterfall. In this way, the choice of terrestrial vegetation influences surface soil concentrations and, ultimately, risk.

The terrestrial vegetation compartments depend on properties such as the lipid content of leaves, wet density of leaves, area indices of leaves, etc. Although it is possible that these properties differ on a site-specific basis—for instance, the characteristics of coniferous trees in Oregon are different from those of coniferous trees in North Carolina—these differences are not expected to have a substantial influence on risk. ICF's simulations indicate that the impact on risk of alternative vegetation scenarios is limited after accounting for differences in erosion regimes specific to land-use type (see Appendix A). It is expected that site-specific differences within a single vegetation type would be even lower.

Literature searches during previous site-specific assessments in the RTR process have indicated that highly intensive literature search would be required to parameterize the full range of terrestrial vegetation parameters required by the TRIM.FaTE algorithms. Based on the limited risk impact of terrestrial vegetation properties, and limited data availability at the site-specific level, these properties are currently ruled out from site-specific parameterization.

6.3.4 Elimination of Physical and Chemical Characteristics

Algorithms in the TRIM.FaTE model frequently depend on physical and chemical parameters, such as the Henry's Law constant and the octanol-water partition coefficient, to partition chemicals between phases within a compartment. These properties are, by their nature, relatively unchanging across most standard environmental conditions for the non-ionic organic compounds currently evaluated (i.e., dioxins and PAHs)[3]. These properties are thus ruled out from requiring site-specific parameterization for the time being.

6.4 Properties Recommended for Site-Specific Parameterization

Following the elimination process described above, ICF identified a set of parameters for further evaluation based theoretical considerations as well as higher sensitivity potential displayed in previous sensitivity analyses (e.g., U.S. EPA 2009). To estimate the risk influence of these parameters, ICF performed a limited set of additional sensitivity analyses. The evaluated parameters are listed below, grouped by compartment type:

- Air: dust load, fraction of organic matter.
- Surface Soil: unit soil loss, inter-compartment drainage and erosion fractions, soil particle density, soil air fraction, soil organic content, soil pH, soil water content.
- Surface Water and Sediment: suspended solids concentration, bed sediment density, suspended solids density, bed sediment porosity.
- Aquatic Biota: biomass of various aquatic biota compartments.
- Terrestrial Vegetation: "Allow exchange" and "litterfall" file inputs.

Unlike previous analyses, these sensitivity analyses were not based on fixed perturbations from the default values but instead used reasonable high and/or low bounds approximately corresponding to the range found in the environment. The impacts on risk were computed with respect to the Tier 1 screening scenario results at equivalent emission rates.

ICF extended the scope of the current analyses by also using the results of TRIM.FaTE sensitivity analyses conducted in previous regulatory applications and pertaining to air, surface soil, and surface water and sediment. Although these analyses were performed on a different version of the Tier 1 screening scenario set up, the results are considered informative.

The specific details of the analyses conducted as part of this protocol development are reported in Appendix A, while other supporting evidence has been drawn from previous reports (e.g., U.S. EPA 2009). Based on the results of these analyses, Table 6-1 contains TRIM.FaTE properties recommended for site-specific parameterization in the RTR process. These properties have been further classified as high, medium, and low priority to facilitate an appropriate allocation of available resources in the parameterization process.

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[3] For mercury, some analogous properties, such as the partition coefficient for mercury in the aqueous phase, do vary according to pH; these relationships are incorporated into the model as formula properties.

Table 6-1. TRIM.FaTE Properties Recommended for Site-Specific Parameterization

Compartment	Property	Priority	Remark
Surface Water	Depth	High	Having depth as well as flush rate helps serve as a check on surface hydrology assumptions.
	Flush Rate	High	
	Suspended Solids Concentration	High	Attempt to find a column-averaged value.
	pH	Moderate	Important for metals.
	Algae Density	Moderate	May be estimated from total phosphorus concentrations in the absence of measured values.
	Organic Carbon Fraction	Moderate	Important for TCDD (U.S. EPA 2009). Data availability may be limited.
	Water Temperature	Moderate	Sensitive but unlikely to manifest wide range.
Aquatic Biota	Biomass	Moderate	May be estimated from total phosphorus concentrations in absence of measured values.
Surface Soil	pH	Moderate	Important for metals.
Terrestrial Biota	“Allow Exchange” and “Litterfall” data files	Low	These files govern how long leaves remain open for stomatal exchange during different times of the year and also when the leaves fall off the trees onto the surface soil. Although the impact of these properties has not been empirically tested, theoretical considerations suggest they will have a low impact when estimating average annual risks.

In addition to these values, meteorology parameters, surface hydrology and erosion-related parameters, and the spatial layout are fundamentally site-specific elements of a TRIM.FaTE simulation, as noted in the previous sections.

7. Properties Recommended for Land Use-Based Values

In addition to the properties identified in Section 6 as desirable for site-specific parameterization, we identified properties that also influence risk substantially but for which the impacts on risk are expected to be largely captured by land use-specific parameters. In other words, for these properties, accounting for variations that correspond to land use is expected to adequately account for any variation in these parameters (to the extent that they influence risk). Additional variation in parameter values resulting from site-specific variations within a particular land use category is not expected to be significant. For example, differences in surface soil erosion (as expressed by the unit soil loss rate property in TRIM.FaTE) are expected to be larger between the average deciduous forest and the average parcel of tilled soil than between different types of deciduous forest or between different types of tilled soil. The use of land use-specific values for such properties is expected, therefore, to adequately capture their impact on risk estimates in the RTR process.

The rationale for identifying properties as land use-based in this protocol is a combination of risk sensitivity analysis (Appendix A and U.S. EPA 2009), professional judgment about the range exhibited in the environment, and expected data availability at the site-specific level. For land use-specific properties, users performing a site-specific assessment should identify the land use type of each surface parcel in the FaTEmaster Scenario Builder tool. The tool would then automatically assign the appropriate land use-specific property values. It should be noted, however, that the tool is not currently parameterized with land-use specific property values.

Table 7-1 lists the TRIM.FaTE parameters that are recommended for land use-specific parameterization. These parameters are all related to the surface soil parcel and assume distinct values for each of the land use types modeled in TRIM.FaTE. These land use types currently include deciduous forest, coniferous forest, grass, agricultural soil, untilled soil, forested wetlands, and grassy wetlands. Other land use types may also be defined using the FaTEmaster Scenario Builder tool. Land use type is not an explicit input in TRIM.FaTE but is implicitly reflected in the TRIM.FaTE property values corresponding to each surface parcel.

Table 7-1. TRIM.FaTE Properties Recommended for Land use-Specific Parameterization

Property	Remark
Organic carbon fraction	Fraction of dry soil solids that is organic in origin.
Water content	The sum of the water and air content fractions of a soil determines its porosity.
Air content	
Particle density	Refers to the dry density of the average soil particle.
Rainfall/erosivity index	Universal Soil Loss Equation (USLE) properties used in FaTEmaster Scenario Builder Tool to compute each surface soil compartment's average erosion rate.
Soil erodibility index	
Topographical (LS) factor	
Cover/management factor	
Supporting practices factor	
Fraction of precipitation that evapotranspires	Water balance-related property used in FaTEmaster Scenario Builder Tool to compute each surface soil compartment's average runoff rate.
Fraction of precipitation subject to overland runoff	

8. Properties Recommended for National Values

Nationally-representative or health-protective values are recommended for all TRIM.FaTE properties that are not identified for site-specific or land use-based parameterization in Sections 6 and 7 above. These properties are expected either to (1) not substantially influence risk in the RTR process, (2) not have adequate data to support site-specific parameterization, or (3) be relatively constant in the environment, as discussed in greater detail in the approach described in Section 6. These properties have been previously characterized in the RTR Tier 1 and Tier 2 screening threshold derivation analyses by either nationally-representative values or health-protective values. The same values are recommended for these properties in site-specific analyses and are listed with references in Appendix B.

9. The FaTEmaster Scenario Builder

All user inputs can be provided to TRIM.FaTE via text-based or delimited data input files. The files must be defined in syntax specific to TRIM.FaTE; a full description of syntax requirements is provided in the TRIM.FaTE User's Guide (U.S. EPA 2005)

ICF's FaTEmaster Scenario Builder tool provides a Microsoft® Excel™-based environment that facilitates translation of user inputs into appropriately formatted TRIM.FaTE input files that can be used to set up and run site-specific scenarios. The FaTEmaster Scenario Builder tool does not, however, create the TRIM.FaTE Master Library file, which contains library properties and can be used to set property values that are not expected to vary between scenarios. The recommendations for the use of site-specific properties made earlier in this document are not envisaged to require changes to the TRIM.FaTE Master Library file. The FaTEmaster Scenario Builder tool is further documented in Appendix C.

10. Potential Future Improvements

This protocol represents a first attempt at documenting the current state of knowledge related to conducting site-specific environmental modeling in support of RTR multipathway risk assessments. The protocol could be enhanced in the future by documenting best practices and developing recommendations regarding the following issues (among others):

- Identification of land use-specific parameters for the identified soil properties based on literature review;
- Application of enhanced technical approaches, such as the use of a sensitivity score approach, to identify the most influential model properties;
- Potential development of regional parameters for a subset of model properties based on the results of further sensitivity analysis and data availability assessments;
- Greater use of graphics and figures to illustrate model set-up concepts;
- Enhanced technical editing to help the protocol be more self-explanatory and independent of other TRIM.FaTE support documents in its scope;
- Researching the potential for geographically variable biotransfer factors and other parameters in MIRC; and
- Further research and development of GIS-based approaches to surface hydrology and erosion property parameterization.

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Appendix A. Documentation of Empirical Analyses Used to Prioritize TRIM.FaTE Properties

A.1. Introduction

ICF performed a series of empirical analyses to prioritize TRIM.FaTE model properties for site-specific parameterization. These analyses were based on changing the value of one or more model properties relative to the Tier 1 screening scenario and measuring the relative impact on risk. Unlike in a traditional sensitivity analysis, this analysis changed property values to approximate high and low-end values within the environmental range of the property of interest, instead of using a fixed perturbation. The measured impacts on risk, the expected range in the environment, and data availability were considered in prioritizing model properties for site-specific parameterization, as discussed in Sections 6 and 7.

Table A-1 summarizes the various empirical analyses that were conducted, the risk impact of the scenario modifications, and conclusions from the analyses.

Table A-1. Results and Conclusions from Empirical Analyses Used to Prioritize TRIM.FaTE Properties

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
Tier 1 SS	Tier 1 Screening Scenario.	1.00	1.00	1.00	1.00	Designed to produce most conservative risk estimate.	All relative risks for modified scenarios are measured relative to the Tier 1 screening scenario.
WF1	Reduce watershed flows (erosion and runoff) to half screening scenario levels. Redirect remainder to sink. Maintain same flow directions as screening scenario.	0.56	0.69	0.21	0.38	Reducing the quantity of runoff and erosion reaching receiving compartments reduces chemical inputs into those compartments, including the lake, and reduces risk.	Surface hydrology and erosion flows (where and how much of the erosion and runoff from a compartment reaches) are potentially highly sensitive properties in the model (influencing risk by up to a factor of 10) and are recommended for site-specific parameterization.
WF2	Reduce watershed flows (erosion and runoff) to 1/10 screening scenario levels. Redirect remainder to sink. Maintain same flow directions as screening scenario.	0.34	0.68	0.11	0.25		
ER0	Switch off erosion.	0.39	1.02	1.10	0.43	Turning off erosion reduces chemical inputs into the lake and reduces chemical removal off the farm.	Although erosion is a relatively important process, its maximum impact on risk is less than a factor of 3, even when

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
ER1	Double erosion rates.	1.09	0.99	0.86	0.86	Increasing erosion produces competing effects: while it increases chemical inputs into the lake, it also increases the burial rate of sediment and increases chemical removal from the farm.	accounting for variable runoff rates. A land-use specific parameterization approach is recommended for the average erosion rates of surface soil compartments.
ER-RUN1	Double erosion and runoff rates (same flush rate; higher lake depth).	0.94	0.96	0.74	0.89	Increasing the runoff rate increases the input of soluble chemicals into the lake and decreases the removal of those chemicals from the farm.	
ER-RUN2	Double erosion and runoff rates (higher flush rate; same lake depth).	1.09	0.99	0.74	0.85	Increased runoff rates can be accommodated by means of increased lake depths or increased flush rates.	
RUN1	Switch off runoff; maintain flush rate and depth.	0.99	1.00	0.70	0.96	Nullifying chemical transfer through runoff reduces chemical input into the lake and reduces chemical removal from the farm.	Runoff rates have a limited impact on risk. A land-use specific parameterization approach is recommended for average runoff rates from surface soil compartments.
RUN2	Implement cumulative runoff regime.	1.02	1.00	1.14	1.10	Assumes runoff from one compartment does not evaporate but contributes to runoff from the receiving compartment.	

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
FR1	Double lake depth, half flush rate, same rainfall, and same runoff fraction.	0.71	0.96	1.00	1.15	Doubling depth reduces concentrations but halving the flush rate reduces chemical output from the lake.	Lake depth and flush rate have a modest impact on risk. However, knowledge of both these parameters can help guide the surface hydrology and erosion direction flows in the watershed which can more substantially influence risk. Site-specific parameterization is recommended for lake depth and flush rate.
FR2	Half lake depth, double flush rate, same rainfall, and same runoff fraction.	1.28	1.07	1.00	0.92	Halving depth increases concentrations but doubling the flush rate increases chemical output from the lake.	
FR3	Double depth, same flush rate, same rainfall, same runoff fraction (violate water balance in screening scenario).	0.69	0.96	0.58	1.02	Doubling depth reduces lake concentrations for most chemicals.	
FR4	Double flush rate, same depth, same rainfall, and same runoff fraction (violate water balance in screening scenario).	0.95	1.00	0.58	0.89	Doubling flush rate reduces lake concentrations.	
PERC1	Implement balanced percolation regime.	0.99	1.00	0.62	0.99	Assumes runoff from one compartment does not evaporate but percolates in the receiving compartment.	Percolation rate (the fraction of rainfall that is subject to percolation into the sub-surface) has a modest impact on risk. Land use-based parameterization is recommended for this property.

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
R1	Reduce rainfall down to 1/3rd SS value; same lake depth; runoff rates and flush rate down to 1/3rd.	0.64	0.59	0.92	0.58	Reducing rainfall reduces chemical washout from air.	This run, when combined with earlier runs focusing on the impacts of flush rate, suggests that the chemical washout impact of rainfall has more influence on risk than the impact of rainfall levels on hydrological properties like flush rate. This reinforces the argument for site-specific meteorological parameters.
V_C	Set all surface compartments except farm to coniferous forests.	0.79	0.75	0.40	0.87	The choice of vegetation in surface soil compartments impacts risk by absorbing chemicals from air and soil and then redepositing them onto the surface soil via litterfall.	Land use-type has a limited impact on risk. Based on these results, terrestrial vegetation parameters are recommended for land-use specific parameterization. In interpreting these results, it is important to note that these runs have not been normalized for erosion rates. Therefore, the impacts on risk presented here are from a combination of impacts from differential erosion rates and vegetation types.
V_D	Set all surface compartments except farm to deciduous forests.	0.34	0.92	0.49	0.39		
V_G	Set all surface compartments except farm to grassland.	0.88	0.82	0.45	0.92		
V_U	Set all surface compartments except farm to untilled soil.	0.42	0.73	0.37	0.81		
V_WW	Set all surface compartments except farm to forested wetlands.	0.36	0.92	0.49	0.47		

Scenario Name	**Scenario Description (with respect to Tier 1 Screening Scenario)**	**Normalized Risk Relative to Tier 1 Screening Scenario**				**Risk Impact of Scenario Modification**	**Conclusions**
		TetraCDD, 2,3,7,8-	**Benzo(A) pyrene**	**Cadmium**	**Methyl Mercury**		
V_WG	Set all surface compartments except farm to grassy wetlands.	0.86	0.83	0.46	0.94		
BM1	Increase aquatic biomass uniformly by a factor of 10.	0.84	0.39	0.90	0.99	Increasing aquatic biomass reduces chemical concentration in biomass as the same amount of chemical is distributed in a higher amount of biomass.	Risk is sensitive to the aquatic biomass levels. These properties are therefore recommended for site-specific parameterization. In interpreting the results of these runs, it may be noted that all biomass levels were uniformly raised. In real applications, the biomass levels of the upper trophic levels may constitute a lower percentage of the total biomass as total biomass increases, suggesting slightly lower risk sensitivity than apparent here.
BM2	Increase aquatic biomass uniformly by a factor of 100.	0.35	0.32	0.29	0.79		
Air_DL1	Increase air dust load by a factor of 10.	2.34	2.31	0.50	0.98	Increasing the dust load in air increases	Although these runs indicate that air dust load

Scenario Name	**Scenario Description (with respect to Tier 1 Screening Scenario)**	**Normalized Risk Relative to Tier 1 Screening Scenario**				**Risk Impact of Scenario Modification**	**Conclusions**
		TetraCDD, 2,3,7,8-	**Benzo(A) pyrene**	**Cadmium**	**Methyl Mercury**		
Air_DL2	Increase air dust load by a factor of 100.	4.14	2.71	0.50	0.90	particulate deposition to the surface.	moderately influences risk, literature search indicated that the range manifested by this property is relatively small and the default value used is already in the high end of the observed range in the U.S. Therefore, this property is not recommended for site-specific parameterization.
Air_FOM1	Halve the fraction of organic matter in air solids.	0.87	0.66	0.50	1.00	The organic content of air solids can differentially influence chemical adherence to the solid phase.	Although these runs indicate that the fraction of organic matter in air solids moderately influences risk, literature search indicated that site-specific data may be difficult to obtain. This property is not recommended for site-specific parameterization.
Air_FOM2	Double the fraction of organic matter in air solids.	1.23	1.43	0.50	1.00		
Soil_Air	Double the soil air content.	1.21	1.29	0.50	1.14	Increasing the soil air fraction reduces soil solids, which distributes the same amount of chemical over a lower solids content, thereby increasing soil concentrations.	Although these runs indicate that air dust load moderately influences risk, literature search indicated that the range manifested by this property is relatively small and the default value used is already in the high end of the observed range in the U.S. Therefore, this property is not recommended for site-
Soil_FOC	Increase the soil organic fraction content by a factor of 10.	1.04	1.01	0.60	1.00	Increasing soil organic content increases chemical adherence to soil for some chemicals.	

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
Soil_pH1	Set soil pH at 4.	1.00	1.00	0.39	1.00	Soil pH can influence chemical adherence to soil solids for some chemicals.	specific parameterization.
Soil_pH2	Set soil pH at 10.	1.00	1.00	0.66	1.00		
Soil_Rho	Set soil solids density at 1000 kg/m^3.	1.41	1.43	0.50	1.16	Decreasing soil particle density increases soil concentrations when normalized by soil weight.	
Soil_Water	Double the soil water content.	1.00	1.00	0.50	1.00	Increasing soil water content increases chemical removal by percolation for some chemicals.	
SusSed_TSS1	Increase lake suspended solids concentration by a factor of 2.	0.73	0.98	1.01	0.74	Increasing suspended solids in water causes more chemical to be deposited to sediment.	Suspended solids concentration in lakes has a moderate influence on risk. Due to the wide range potentially exhibited by this property, it has been recommended for site-specific parameterization.
SusSed_TSS2	Increase lake suspended solids concentration by a factor of 10.	0.33	0.98	0.46	0.38		
Sed_Bur	Halve sediment burial rate; same erosion rate (violate solids balance in screening scenario).	1.11	1.00	1.12	1.31	Decreasing the burial rate reduces the removal of chemicals from the sediment layer.	Sediment properties have a moderate impact on risk, given the limited range of values assumed by them in the environment.

Scenario Name	Scenario Description (with respect to Tier 1 Screening Scenario)	Normalized Risk Relative to Tier 1 Screening Scenario				Risk Impact of Scenario Modification	Conclusions
		TetraCDD, 2,3,7,8-	Benzo(A) pyrene	Cadmium	Methyl Mercury		
Sed_Rho	Decrease bed sediment particle density to 1000 kg/m^3.	1.36	1.00	0.63	2.74	The lower the sediment particle density, the lower the volumetric resuspension rate from sediment and the higher the volumetric burial rate.	
Sed_Por	Halve sediment bed porosity.	0.85	1.00	0.42	0.78	The lower the sediment porosity, the lower the volumetric resuspension rate from sediment and the lower the volumetric burial rate.	

Appendix B. TRIM.FaTE National Property Values

B.1. Introduction

This protocol recommends the use of nationally representative or health protective values (referred to as national values) for TRIM.FaTE model properties that have not been identified for site-specific or land use-based parameterization.

These national values are readily accessible in the FaTEmaster Scenario Builder tool, with references. This tool is included with the protocol and is documented in Appendix C. The national values are also documented in Appendix 4 of the Risk Report (see its Attachment A, Addendum 1).

Appendix C. The FaTEmaster Scenario Builder Tool

C.1. Introduction

A TRIM.FaTE scenario requires a variety of inputs from users to define the modeled environment and to parameterize the algorithms for physical, chemical, and biological processes that transfer and transform chemical mass between and within environmental media. These inputs are provided to the TRIM.FaTE model in the form of the following files:

- A “volume elements” file, which defines the spatial layout of the modeled domain in terms of three-dimensional abiotic compartments. Each volume element provides a frame of reference for one or more biotic compartments within it.
- A “compartments” file, which places biotic and abiotic compartments (modeling units containing chemical mass) within the volume elements.
- A Master Library file, which contains all the model algorithms, properties, and emission source information.
- A properties file, which typically contains (i) simulation- and scenario-specific properties that overwrite default values specified in the Master Library and (ii) the location of time-varying input files for parameters such as meteorological and vegetation parameters.

These input files must be constructed in syntax consistent with TRIM.FaTE requirements, as described in Module 3 of the TRIM.FaTE User’s Guide.

ICF’s FaTEmaster Scenario Builder tool provides an MS-Excel spreadsheet-based interface that facilitates the automated generation of syntactically accurate TRIM.FaTE input files derived from user-specified inputs. The tool does not output the TRIM.FaTE Master Library file.

This appendix describes how the FaTEmaster Scenario Builder tool can be used to construct input files for the TRIM.FaTE model for use in site-specific risk assessments in the RTR process. While this document discusses the principal steps required to operate the tool, it does not provide line-by-line guidance for each of the hundreds of inputs contained within it. The tool already incorporates comments and guidance for each input cell and is largely self-explanatory. This overview of the tool is intended to facilitate an enhanced understanding of the scope of the tool and its operational structure. This document is not intended to serve as a guide to running the TRIM.FaTE model itself.

C.1.1. Output Files from the FaTEmaster Scenario Builder Tool

The FaTEmaster Scenario Builder Tool produces five text output files, which serve in turn as input files to the TRIM.FaTE model. The filenames, contents, and purpose of the output files generated by the tool are described in Table C-1.

C.1.2. Summary Worksheets in the FaTEmaster Scenario Builder Tool

The FaTEmaster Scenario Builder Tool consists of 15 worksheets. The names, contents, and purpose of these worksheets are described in Table C-2, which has been color-coded in an identical manner to the worksheet “tabs” in the tool.

Table C-1. Output Files Generated by the FaTEmaster Scenario Builder Tool

File Name	Contents	Purpose
Sources.txt	Coordinates specifying the location of the emission sources and the chemical emission rates.	This file facilitates the creation of a unique scenario-specific TRIM.FaTE Sources Library. This file must be manually imported through the TRIM.FaTE graphical interface and saved as a library. This Sources Library must then be loaded to the site-specific TRIM.FaTE scenario together with the TRIM.FaTE Master Library.
Volume Elements.txt	Coordinates specifying the spatial dimensions of the volume elements and specification of the primary abiotic compartment within each volume element.	This file serves as a TRIM.FaTE input file to define the spatial layout of the modeled domain in terms of three-dimensional abiotic compartments, each of which can contain other biotic and abiotic compartments.
Compartments.txt	The names of biotic and non-primary abiotic compartments located within each primary abiotic compartment defined by the Volume Elements file.	This file serves as a TRIM.FaTE input file to situate user-specified biotic and abiotic compartments within each volume element. These compartments are the discrete units that contain chemical mass in TRIM.FaTE.
Properties.txt	Values defining site-specific properties relating to the scenario, biotic and abiotic compartments, and user-specified link properties.	This files serve as a TRIM.FaTE input file to define the values of various properties that define the scenario. It overwrites default values for these properties specified in the TRIM.FaTE Master Library file.
Other Properties.txt	Values defining properties that are not included amongst the standard sections of the tool for user-specification. This is a discretionary or optional file that may be useful when overwriting library properties that are not redefined by the standard elements of the tool.	This file serves as a TRIM.FaTE input file to define the values of any of the various properties that define the scenario. It overwrites default values for these properties specified in the TRIM.FaTE Master Library file.

Table C-2. Summary of Worksheets Generated by the FaTEmaster Scenario Builder Tool

Worksheet Name	Contents	Purpose
Tracking	• Command button • Documentation of version changes.	Contains “Export All” button that generates TRIM.FaTE input files based on values specified in other worksheets. Also serves as a documentation sheet for tool software developers only.
Parameters	• User-specified property values for several TRIM.FaTE model properties.	Provides a user-friendly interface for the definition of site-specific model properties. Adds the properties defined here to the Properties file.
Layout	• Coordinates of the vertices of the parcels that define the spatial layout. • Coordinates of the location of the emission sources. • Emission rates of each chemical species from each source.	Serves as a basis for the creation of the Volume Elements and the Sources output files.
Land	• User-specified parameter values for the USLE equation for different land use types.	Computes average erosion rates based on the USLE equation for surface soil compartments and adds those estimates to the Properties file. Also contains elements used to construct the Compartments file.
Soil	• User-specified property values for all soil layers differentiated by land use types.	Computes average runoff and percolation rates, and adds these estimates and other soil-related properties to the Properties file. Also contains elements used to construct the Compartments file.
Plants	• User-specified vegetation types and vegetation components for each land use category.	Places the appropriate vegetation composite compartments within soil compartments based on user-specified land use. This is used to construct the Compartments file.
Watersheds	• User-specified inter-compartment erosion and runoff directions and percentages.	Defines inter-compartmental link properties for runoff and erosion and adds them to the Properties file.
Lakes	• User-specified lake and sediment properties. • Equations to compute lake flush rates/depth and sediment resuspension velocity based on watershed flows.	Adds lake and sediment related properties, and computed lake and sediment hydrodynamic parameters, to the Properties file.
Fish	• User-specified aquatic food web and biomass levels.	Adds aquatic food web and biomass properties to the Properties file. These elements are also used to construct the Compartments file.

Worksheet Name	Contents	Purpose
Soil Data	- User-specified soil properties differentiated by land use type.	Serves as an input sheet for soil properties that is called by the "Soil" worksheet. May potentially be parameterized on a regional basis.
Sources	No user inputs are required on these worksheets. They are constructed from the inputs specified in the previous tabs and contain the content of the output files that will later be generated by the tool as text files.	
Volume		
Cmpts		
Props		
OtherProps	User may enter supplementary properties into this worksheet consistent with TRIM.FaTE syntax. This worksheet can be used to overwrite properties that are defined in the Master Library file or to define properties that are not previously defined either in the library file or other input files.	

C.1.3. Additional Salient Features of Worksheets in the FaTEmaster Scenario Builder Tool

This section provides a limited description of the features of the various worksheets within the FaTEmaster Scenario Builder, with a focus on the most salient operational aspects from the user perspective.

A general rule when working with the tool, also mentioned clearly at the top of each worksheet, is that only cells color-coded green may be modified by users. Blue and white color-coded cells are not to be modified by users.

(i) The *Tracking* Worksheet

- Users should click the "Export All" command button after they have made all the necessary input modifications to the other worksheets. This will be the final step in operating the tool.
- The remainder of the worksheet is intended for software developers only to document version changes in the tool.

(ii) The *Parameters* Worksheet

- Specify a "set up" file directory in cell D9.
    - Model output will be directed to this directory into a sub-folder named "Output".
    - This directory will also be the destination to which the tool will write its five output files.
    - This directory should contain the time-varying meteorological values file, leaf "allow exchange" file, and litterfall data file later referenced in the worksheet.
- In cell D48, enter the average annual precipitation based on the average from the time-varying site-specific meteorological file. This averaging must be performed manually offline.
- In cell D49, update the formula reference with the name of the applicable meteorological values file if they have changed.
- In cells D80, D92 and D103 update the formula with the names of the leaf allow exchange data files if they have changed.
- In cells D84, D96 and D107 update the formula with the names of the litterfall data files if they have changed.
- Note: Cells commented as "Reported Value" will be reported in the tables for documentation purposes but will not be used in TRIM.FaTE input files.

- Note: All other input cells may be updated as required. Cell comments have been provided for guidance.

(iii) The *Layout* Worksheet

- Based on the spatial layout for air and surface parcels developed in GIS or through manual mapping, enter the Cartesian coordinates of each vertex point in columns C and D. The center of the emissions source (or facility) parcel should be defined as the origin of the system.
- Specify offset coordinates in cells E9 and F9 to situate the layout spatially, consistent with the specified map projection system in cell D4. (This is similar to a latitude and longitude specification. It does not affect TRIM.FaTE results, however.)
- Specify the name of each parcel in the spatial layout and the vertex points that define the parcel in a clockwise or anticlockwise direction around the perimeter of the parcel in columns H and K.
- Specify the parcel category from the available options in column I.
- Specify the land use corresponding to each parcel in column J.
- Specify the source name, source parcel location, and source elevation in column U.
- Specify the chemical emission rates in column U.

(iv) The *Land* Worksheet

- In columns E through L, enter the USLE parameters that are used to compute average erosion rates for each land use type.
- Enter the vegetation type within each land use type.

(v) The *Soil* Worksheet

- This worksheet requires no user inputs. It draws inputs from other worksheets and calculates average runoff and percolation rates based on those values.

(vi) The *Plants* Worksheet

- Specify the vegetation components corresponding to each land use type.
- Note: If new types of vegetation components are being defined, their corresponding properties and algorithms should be defined in the Master Library or separately within property files.

(vii) The *Watersheds* Worksheet

- For each parcel, specify which of its adjoining parcels receive the runoff and erosion originating from that parcel and in what amounts (specified in percentages).
- Click on the “Refresh” button after updating the worksheet.

(viii) The *Lakes* Worksheet

- Specify lake and sediment properties in column K.
- Specify one of either lake depth or flush rate in cells K18 and K19.
- Note: The worksheet will compute the unspecified property (either lake depth or flush rate) using a water balance. The water balance assumes that runoff entering the lake is the sum of runoff entering the lake from adjacent soil compartments and cumulative runoff from the larger watershed.
- Note: The worksheet also computes sediment resuspension velocity and sediment burial rate using principles discussed in the TRIM.FaTE Technical Support Document (Section 4.2.2).

(ix) The *Fish* Worksheet

- Define the aquatic food web by specifying the diet fraction for each aquatic organism.
- Specify the total biomass of each organism type and the single body weight of each organism.

(x) The *Soil Data* Worksheet

- For each land-use type, specify properties for all soil layers.
- (Note: The tool has the capacity to accommodate region-specific definitions of soil parameters too but this functionality has not currently been parameterized.)

C.1.4. Generating Output Files from the FaTEmaster Scenario Builder Tool

After entering site-specific inputs into the various worksheets within the tool as required, the following steps should be used to complete the generation of output files:

- Navigate to the “Layout” tab, and click “Refresh”.
- Navigate to the “Watersheds” tab, and click “Refresh”.
- Navigate to the “Tracking” tab, and click “Export All”.

The five output files generated by the tool can then be used as input files to set up the site-specific TRIM.FaTE scenario. (It is reiterated that the tool does not generate the TRIM.FaTE Master Library file, the contents of which are largely invariable between applications.

Appendix 10 – Ferroalloys Multipathway Site-Specific Assessment

Technical Support Document: Human Health Multipathway Residual Risk Assessment for the Ferroalloys Production Source Category

DRAFT

February 21, 2014

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CONTENTS

TABLES

FIGURES

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1. Introduction

This report provides the details and results of an assessment of human health risks, via the ingestion pathway, from exposure to persistent and bioaccumulative hazardous air pollutants (PB-HAPs) emitted to the air from a ferroalloys production facility. Cadmium, dioxins, mercury, and polycyclic aromatic hydrocarbons (PAHs) were the evaluated PB-HAP groups,[1] selected from a larger list of PB-HAPs, based in part on ranking their toxicity-weighted air emissions across all source categories (explained further in Appendix 4 of the Risk Report). As detailed in Appendix 4 of the Risk Report, the risks evaluated were chronic cancer risks (for PAHs and dioxins) and chronic non-cancer hazards (for cadmium and mercury). This assessment was conducted to show an example of the differences in risk estimates between the multipathway “tiered” screening results and those of a site-specific multipathway analysis.

As described in Section 4 of this document and Appendix 4 of the Risk Report, EPA uses the TRIM.FaTE[2] model to evaluate the environmental transport, transfer, and fate of PB-HAP emissions. The MIRC[3] program then calculates farm food chain (FFC) chemical uptake, human exposure, and human health risk. For the assessment described in this report, these models were used to conduct one site-specific case study for a ferroalloys production facility with emissions that might elevate risks to human health from ingestion of food products and soil contaminated with PB-HAPs from the facility. This facility is the Eramet facility near Marietta in Washington County, Ohio (NEI11660 in the National Emissions Inventory [NEI]; approx. 39.37°N, 81.52°W).

Two ferroalloys production facilities make up the source category: NEI11660 and NEIWV053FELMAN. In the iterative (“tiered”) screening-level ingestion analysis discussed in greater detail in Section 2 of this document, both facilities exceeded the Tier 1 and Tier 2 emission screening thresholds for at least one of the PB-HAP groups evaluated. NEI11660 exceeded the Tier 2 thresholds of cadmium, mercury, and PAHs by larger margins than the other facility in the source category (the New Haven facility), making it the highest facility in the source category for Tier 2 screening. NEI11660 was selected based on its Tier 2 screening results and based on the feasibility, with respect to the modeling framework, of parameterizing the region surrounding the facility. The ingestion exposure scenarios assessed for the selected facility do not necessarily represent the *highest* potential ingestion exposures and risks for all humans living in the vicinity of ferroalloys production facilities, but the exposure and risk estimates should be among the highest possible for this source category.

The approach, data, assumptions, and results of the site-specific assessment are presented in this report. Beyond the description and discussion of this site-specific assessment presented in this document, the *Protocol for Developing a TRIM.FaTE Model Scenario to Support a Site-specific Risk Assessment in the RTR Program* (which is Appendix 9 to the Risk Report) provides additional considerations, suggested guidelines, and justifications for developing a site-specific assessment (not specific to this source category). EPA generally followed this protocol

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[1] The phrase “PB-HAP group” is used to distinguish the individual PB-HAP chemicals and congeners from the overall family (grouping) of those chemicals. For example, EPA’s ingestion risk methods in its Risk and Technology Review (RTR) program evaluate emissions of 17 individual congeners of chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans in the “dioxin” PB-HAP group.

[2] TRIM.FaTE stands for the Fate, Transport, and Ecological Exposure module of the Total Risk Integrated Methodology modeling system. Additional TRIM.FaTE information can be found at: http://www.epa.gov/ttn/fera/trim_gen.html.

[3] MIRC stands for the Multimedia Ingestion Risk Calculator.

in developing this site-specific assessment. The *Technical Support Document for the TRIM-Based Multipathway Tiered Screening Methodology for RTR*, which is Appendix 4 to the Risk Report, provides a more comprehensive description of the iterative approach (focusing especially on Tiers 1 and 2) that EPA uses to evaluate the potential for ingestion risks resulting from PB-HAP emissions.

2. Screening-level Assessments

As described in more detail in Appendix 4 to the Risk Report, EPA developed an iterative screening approach for evaluating the potential for human health risks above levels of concern resulting from non-inhalation exposures (i.e., via the ingestion pathway) to selected PB-HAPs in air emissions. In the screening approach, PB-HAP emissions are “screened out” if they are unlikely to pose human health ingestion risks above levels of concern, therefore enabling EPA to focus additional resources on emission sources of greater concern. The levels of concern are an incremental lifetime human cancer risk exceeding 1-in-one million (for PAHs and dioxins) and a chronic non-cancer hazard quotient (HQ) exceeding 1 (for cadmium and mercury).[4] The Tiers 1 and 2 screening assessments and results are discussed in Section 2.1 and Section 2.2.

2.1 Tier 1 Emission Screening Analysis

As described in more detail in Appendix 4 of the Risk Report (Sections 1 and 2, and Attachment A), the objective of the Tier 1 emission screening analysis is to rank PB-HAP emission sources within a source category (or across source categories), enabling EPA to screen out emission sources unlikely to pose human health ingestion risks above levels of concern. The confidence in screening out emission sources is achieved by avoiding the underestimation of media concentrations and human exposure resulting from the emissions.

The Tier 1 emission screening thresholds are intended to apply to any U.S. facility; that is, they are designed to be applicable to every facility regardless of the facility’s characteristics and surrounding environment and the population exposed in its vicinity (see Attachment A of Appendix 4 of the Risk Report for a discussion of development of the screening thresholds). Each evaluated PB-HAP group has a single Tier 1 screening threshold, as shown in Table 2-1. For Tier 1, the emissions of all dioxin congeners are normalized to 2,3,7,8-tetrachlorodibenzo-p-dioxin-equivalent emissions, and the emissions of all PAH congeners are normalized to benzo(a)pyrene-equivalent emissions.[5] The equivalency factors used to relate individual compounds to the surrogates are based on oral toxicity factors and factors related to the congeners’ environmental fate and transport characteristics as analyzed in the TRIM.FaTE model (explained further in Appendix 4 to the Risk Report: Section A.2.7 of Attachment A). For mercury, emissions of divalent mercury are evaluated, but the Tier 1 emissions screening threshold reflects ingestion of methyl mercury from contaminated fish, only because ingestion of fish is the dominant exposure medium for mercury and methyl mercury (formed from the methylation of divalent mercury) represents 95 percent or more of the total mercury concentration in fish.

As shown in Table 2-1, the emissions from both ferroalloys production facilities exceeded the Tier 1 emission screening threshold for mercury, dioxins, and PAHs, and from one facility

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[4] EPA considers “cancer risks exceeding 1-in-one million” to refer to risks of at least 1.5-in-one million, and “non-cancer HQs exceeding 1” to refer to HQs of at least 1.5.

[5] 2,3,7,8-TCDD and BaP are sometimes used in this report as shorthand terms for 2,3,7,8-tetrachlorodibenzo-p-dioxin and benzo(a)pyrene, respectively.

(NEI11660) for cadmium. Tier 1 screening quotients were calculated as the ratio of a facility's emissions to the Tier 1 emission screening threshold. Where a facility's PB-HAP-specific emission rate exceeds the Tier 1 screening threshold emission rate, the screening quotient exceeds 1. The highest screening quotients estimated in the source category varied by PB-HAP, with NEI11660 being the highest emitter for mercury, cadmium, and PAHs:

- mercury – 100 at NEI11660 (meaning the highest emitting facility exceeded the Tier 1 emission screening threshold by a factor of 100),
- cadmium – 10 at NEI11660,
- PAHs – 200 at NEI11660, and
- dioxins – 100 at NEIWV053FELMAN (80 at NEI11660).

When the Tier 1 screening quotients are summed across the four PB-HAP groups, NEI11660 ranked first in the source category.

Table 2-1. Tier 1 Screening Results for the Ferroalloys Production Source Category

Facility		Tier 1 Emission Screening Analysis		
Facility	**PB-HAP Group**	**(a) Emission Screening Threshold (TPY)[a]**	**(b) Facility-level Emissions (TPY)[b]**	**(c) Screening Quotient [(b)/(a)][c]**
NEI11660	Mercury[d] (non-cancer)	3.16E-04	3.43E-02	100
	Cadmium (non-cancer)	1.18E-02	1.20E-01	10
	PAHs as BaP (cancer)	2.58E-03	5.67E-01	200
	Dioxins as 2,3,7,8-TCDD (cancer)	2.81E-09	2.34E-07	80
NEIWV053FELMAN	Mercury[d] (non-cancer)	3.16E-04	3.52E-03	10
	Cadmium (non-cancer)	1.18E-02	2.27E-03	0.2
	PAHs as BaP (cancer)	2.58E-03	6.50E-02	30
	Dioxins as 2,3,7,8-TCDD (cancer)	2.81E-09	3.89E-07	100

[a] TPY = tons per year

[b] PAH and dioxin emissions in this column were normalized to BaP and 2,3,7,8-TCDD, respectively, for oral toxicity and Tier 1 modeled environmental fate and transport.

[c] Red highlights indicate screening quotients that are greater than 1 (i.e., 2 or larger when rounded; screening quotients rounded to one significant figure).

[d] The emission screening threshold for mercury applies to emissions of divalent mercury, although it was derived based on hazards associated with ingestion of fish contaminated with methyl mercury (i.e., emissions of divalent mercury, which transforms to methyl mercury within the environment and accumulates in fish tissue).

2.2 Tier 2 Emission Screening Analysis

The generic site characteristics used in the Tier 1 screening analysis can differ from those actually present at many facilities. In a Tier 2 screening analysis, as described in more detail in Appendix 4 to the Risk Report (Sections 1 and 3, and Attachment B), some site-specific characteristics are taken into account when developing Tier 2 emission screening thresholds. Meteorological conditions (temperature, wind speed and direction, mixing height, and precipitation totals) and locations of potentially fishable lakes are the site-specific characteristics used to adjust the emission screening thresholds in Tier 2. These characteristics were selected because sensitivity analyses have shown them to influence modeled media concentrations substantially. Moreover, their use to adjust the emission screening thresholds does not require significant re-modeling (discussed further in Attachment B in Appendix 4 to the Risk Report). Meteorological conditions at a specific facility can differ significantly from those used for all facilities in Tier 1 and can impact modeled media concentrations significantly. The locations of lakes near a specific facility also can differ from the location of the lake used for all facilities in Tier 1 (assumed to be very close to the facility), which can significantly affect chemical deposition to the lake.

For Tier 2 assessments, a matrix of meteorological characteristics and lake locations was developed, representing ranges of wind speed, mixing height, precipitation amount, and lake distance expected to be found at most U.S. locations. Several hundred runs of TRIM.FaTE and MIRC then were performed using those characteristics to develop chemical exposure factors and Tier 2 emission screening thresholds for each possible combination of meteorology and lake location. All other modeled site characteristics remained unchanged from Tier 1, although the spatial layout was modified to accommodate the different lake locations (discussed further in Attachment B of Appendix 4 to the Risk Report). For a facility undergoing a Tier 2 analysis, the typical meteorological conditions and the locations of potentially fishable lakes are analyzed. Wind and lake data are subset by the eight cardinal directions ("octants," i.e., north, northeast, east, etc.), while mixing height and precipitation data do not differ by direction. For each octant, the facility's combination of meteorology and lake information is matched to the most similar modeled combination, the frequency of winds blowing into the octant is accounted for, and the facility emissions are evaluated against the respective Tier 2 emission screening thresholds. For a given PB-HAP group, the octant having the largest (among all octants) Tier 2 screening quotient is selected to avoid underestimating exposure and risk. As with the Tier 1 analysis, the Tier 2 screening methods enable EPA to rank emissions from facilities and confidently screen out those unlikely to pose human health risks above levels of concern (by avoiding underestimating exposure and risk).

Summary-level Tier 2 screening results for the ferroalloys production facilities are shown in Table 2-2.

Table 2-2. Tier 2 Screening Results for the Ferroalloys Production Source Category

Facility		Tier 2 Emission Screening Analysis		
Facility	**PB-HAP Group**	**(a)Emission Screening Threshold (TPY)[a]**	**(b)Facility-level Emissions (TPY)[b]**	**(c)Screening Quotient[(b)/(a)][c]**
NEI11660	Mercury[d] (non-cancer)	3.74E-03	3.43E-02	9
	Cadmium (non-cancer)	1.40E-01	1.20E-01	0.9
	PAHs as BaP (cancer)	6.92E-03	1.48E-01	20
	Dioxins as 2,3,7,8-TCDD (cancer)	3.46E-08	2.32E-07	7
NEIWV053FELMAN	Mercury[d] (non-cancer)	3.18E-03	3.52E-03	1
	Cadmium (non-cancer)	1.00E-01	2.27E-03	0.02
	PAHs as BaP (cancer)	7.78E-03	2.05E-02	3
	Dioxins as 2,3,7,8-TCDD (cancer)	2.75E-08	4.48E-07	20

[a] TPY = tons per year

[b] Emissions of PAHs and dioxins in this column were normalized to BaP and 2,3,7,8-TCDD, respectively for oral toxicity and Tier 2 modeled environmental fate and transport.

[c] Red highlights indicate screening quotients that are greater than 1 (i.e., 2 or larger when rounded; screening quotients rounded to one significant figure).

[d] The emission screening threshold for mercury applies to emissions of divalent mercury, although it was derived based on hazards associated with ingestion of fish contaminated with methyl mercury (i.e., emissions of divalent mercury, which transforms to methyl mercury within the environment and accumulates in fish tissue).

Table 2-3 contains both Tier 1 and Tier 2 screening results for NEI11660 for each chemical (i.e., for emissions of cadmium compounds, divalent mercury, 17 congeners of dioxins, and 18 congeners of PAHs) and chemical group. At NEI11660, emissions of cadmium exceeded the Tier 1 emission screening threshold but screened out in the Tier 2 analysis, and the same is true for mercury emissions from NEIWV053FELMAN.

For NEI11660 in Tier 2:

- For mercury, the screening quotient (9) was much smaller than in Tier 1 (100) and was the largest in the source category (same rank as in Tier 1).
- Cadmium emissions screened out, although the screening quotient (0.9, down from 10 in Tier 1) was the largest in the source category (same rank as in Tier 1).
- For PAHs, the screening quotient (20) was much smaller than in Tier 1 (200) and was the largest in the source category (same rank as in Tier 1), driven primarily by benzo(b)fluoranthene and, to a lesser extent, benzo(k)fluoranthene and benzo(e)pyrene.
- For dioxins, the screening quotient (7) was much smaller than in Tier 1 (80), and was the second largest in the source category (same rank as in in Tier 1), driven primarily by 1,2,3,7,8-PCDD and, to a lesser extent, 2,3,7,8-TCDD.
- When the Tier 2 screening quotients are summed across the four PB-HAP groups, the facility ranked first in the source category (same ranking as in Tier 1).

In the Tier 2 analysis for NEI11660, the meteorological statistics (shown in Table 2-4) were derived from the Mid-Ohio Valley Regional Airport surface station (Weather Bureau Army Navy [WBAN] ID 03804; 8 km east-southeast of NEI11660) and from the Pittsburgh International Airport upper-air station (WBAN ID 94823). This pair of surface and upper-air stations is the same as that used in the Risk and Technology Review (RTR) inhalation analysis for this facility. Concentrations of cadmium, mercury, and dioxins were highest in one lake (Veto Lake; 12 km west-southwest of the facility, was matched with the 10-km lake scenario in Tier 2); therefore, this lake was analyzed for consumption of fish contaminated by emissions of these chemicals. Veto Lake was farther from the facility than the generic lake in Tier 1 (which was approx. 1.4 km from the facility), which reduces modeled chemical deposition to the lake in Tier 2 if all other parameters are held constant. For PAHs, chemical exposure via fish ingestion was largest with Wolf Run Lake in the north octant (48 km from the facility, which matched to the 40-km lake scenario in Tier 2); therefore, this lake was used to assess risk from PAH exposure via fish ingestion.

The modeled meteorological conditions for NEI11660 (in the west octant for cadmium, mercury, and dioxins and the north octant for PAHs) are also shown in Table 2-4, along with the values used for all facilities in Tier 1. Annual precipitation and average mixing height are not modeled by compass direction, and the modeled Tier 2 mixing height remained unchanged from the Tier 1 analysis, while the modeled Tier 2 precipitation was smaller than in Tier 1. Tier 2 modeled wind speeds were also unchanged from Tier 1. Winds blew into each Tier 2 octant much less frequently than into the Tier 1 domain, decreasing modeled chemical deposition to the domain.

Table 2-3. Tiers 1 and 2 Screening Results for NEI11660, by PB-HAP Chemical and PB-HAP Group Total[a]

Chemical Information			Tier 1 Emission Screening Analysis				Tier 2 Emission Screening Analysis			
PB-HAP Group	**PB-HAP Chemical**	**Raw Emissions (lbs)**	**Adjusted Emissions (lbs)[b]**	**Emission Screening Threshold (lbs)**	**Screening Quotient (by Chem.)[b]**	**Screening Quotient (by PB-HAP Group)[b,c]**	**Adjusted Emissions (lbs)[b]**	**Emission Screening Threshold (lbs)**	**Screening Quotient (by Chemical)[b]**	**Screening Quotient (by PB-HAP Group)[b,c]**
Mercury[d]	Divalent mercury	3.43E-02	3.43E-02	3.16E-04	100	100	3.43E-02	3.74E-03	9	9
Cadmium	Cadmium compounds	1.20E-01	1.20E-01	1.18E-02	10	10	1.20E-01	1.40E-01	0.9	0.9
PAHs	2-Methyl-naphthalene	6.98E-01	7.64E-04	2.58E-03	0.30	200	4.65E-05	6.92E-03	0.0067	20
	Acenaphthene	2.89E-01	4.76E-04		0.18		6.22E-05		0.0090	
	Acenaphthylene	9.71E-01	2.51E-03		0.97		1.41E-04		0.020	
	Anthracene	3.75E-01	0		0		0		0	
	Benz(a)anthracene	1.52E-01	2.16E-03		0.84		1.77E-03		0.26	
	Benzo(a)pyrene	2.58E-02	2.58E-02		10		2.58E-02		3.7	
	Benzo(b)fluoranthene	1.61E-01	3.01E-01		120		4.70E-02		6.8	
	Benzo(e)pyrene[e]	2.08E-01	6.37E-02		25		3.20E-02		4.6	
	Benzo(g,h,i)perylene	1.58E-02	4.68E-03		1.8		2.53E-03		0.37	
	Benzo(k)fluoranthene	4.75E-02	1.40E-01		54		2.71E-02		3.9	
	Chrysene	4.30E-01	1.76E-03		0.68		1.11E-03		0.16	
	Dibenzo(a,h)anthracene	2.72E-03	1.23E-02		4.8		4.95E-03		0.72	
	Fluoranthene	1.33E+00	3.42E-03		1.3		1.14E-03		0.16	
	Fluorene	3.82E-01	7.95E-04		0.31		4.87E-05		0.0070	
	Indeno(1,2,3-c,d)pyrene	1.01E-02	7.51E-03		2.9		4.24E-03		0.61	
	Perylene[e]	2.79E-03	2.24E-04		0.087		7.07E-05		0.010	
	Phenanthrene	2.11E+00	0		0		0		0	
	Pyrene	9.89E-01	0		0		0		0	
Dioxins	HeptaCDD, 1,2,3,4,6,7,8-	5.96E-08	5.94E-10	2.81E-09	0.21	80	6.46E-10	3.46E-08	0.019	7
	HeptaCDF, 1,2,3,4,6,7,8-	7.82E-08	1.25E-10		0.044		2.53E-10		0.0073	
	HeptaCDF, 1,2,3,4,7,8,9-	3.29E-08	6.19E-11		0.022		9.45E-11		0.0027	
	HexaCDD, 1,2,3,4,7,8-	3.21E-08	4.99E-09		1.8		5.03E-09		0.15	

Chemical Information			**Tier 1 Emission Screening Analysis**				**Tier 2 Emission Screening Analysis**			
PB-HAP Group	**PB-HAP Chemical**	**Raw Emissions (lbs)**	**Adjusted Emissions (lbs)[b]**	**Emission Screening Threshold (lbs)**	**Screening Quotient (by Chem.)[b]**	**Screening Quotient (by PB-HAP Group)[b,c]**	**Adjusted Emissions (lbs)[b]**	**Emission Screening Threshold (lbs)**	**Screening Quotient (by Chemical)[b]**	**Screening Quotient (by PB-HAP Group)[b,c]**
	HexaCDD, 1,2,3,6,7,8-	3.11E-08	3.17E-09		1.1		3.23E-09		0.093	
	HexaCDD, 1,2,3,7,8,9 -	3.22E-08	1.36E-09		0.48		1.38E-09		0.040	
	HexaCDF, 1,2,3,4,7,8-	3.69E-08	1.17E-09		0.41		1.46E-09		0.042	
	HexaCDF, 1,2,3,6,7,8-	2.84E-08	1.33E-09		0.47		1.69E-09		0.049	
	HexaCDF, 1,2,3,7,8,9-	3.41E-08	1.65E-09		0.59		2.09E-09		0.060	
	HexaCDF, 2,3,4,6,7,8-	4.14E-08	8.14E-10		0.29		1.03E-09		0.030	
	OctaCDD, 1,2,3,4,6,7,8,9-	5.02E-07	1.65E-10		0.059		3.11E-10		0.0090	
	OctaCDF, 1,2,3,4,6,7,8,9-	8.66E-08	4.35E-12		0.0015		9.57E-12		0.00028	
	PentaCDD, 1,2,3,7,8-	4.60E-08	1.76E-07		63		1.69E-07		4.9	
	PentaCDF, 1,2,3,7,8-	3.68E-08	4.68E-10		0.17		6.44E-10		0.019	
	PentaCDF, 2,3,4,7,8-	5.60E-08	6.15E-09		2.2		7.97E-09		0.23	
	TetraCDD, 2,3,7,8-	3.57E-08	3.57E-08		13		3.57E-08		1.0	
	TetraCDF, 2,3,7,8-	5.09E-08	6.47E-10		0.23		7.21E-10		0.021	

[a] Emissions and emission thresholds in this table are in units of pounds, whereas the units in Table 2-1 and Table 2-2 are in short tons (pounds/2000). All values in the "Screening Quotient (by PB-HAP Group)" columns, and values for mercury and cadmium in the "Screening Quotient (by Chem.)" columns, are rounded to one significant figure.

[b] "Adjusted Emissions" of PAHs and dioxins were normalized to BaP and 2,3,7,8-TCDD, respectively, to account for differences in oral toxicity (using toxic equivalency factors) and Tier 1 (or Tier 2) modeled environmental fate and transport (i.e., exposure equivalency factors).

[c] Red highlights indicate PB-HAP group screening quotients that are greater than 1 (i.e., 2 or larger when rounded; see table footnote (a) regarding rounding). Gray font indicates screening quotients of 1 or smaller (i.e., not 2 or larger when rounded). Green highlights indicate emissions that screened out in Tier 2 but not in Tier 1. Mercury and cadmium are evaluated for non-cancer effects, while PAHs and dioxins are evaluated for cancer effects.

[d] The emission screening threshold for mercury applies to emissions of divalent mercury, although it was derived based on hazards associated with ingestion of fish contaminated with methyl mercury (i.e., emissions of divalent mercury that transforms to methyl mercury within the environment and accumulates in fish tissue).

[e] These PAH congeners are not currently fully parameterized in TRIM.FaTE to evaluate their specific fate, transport, and transformation properties. Their exposure equivalency factors (to relate them to the benzo(a)pyrene surrogate used in screening) were based on how their K_{ow} values related to the K_{ow} values of the fully parameterized congeners. See Attachment 4 to the Risk Report (specifically, Section A.2.7.1) for more information.

Table 2-4. Meteorological and Lake Location Information Used in Tier 1 (all facilities) and in Tier 2 (specific to NEI11660)

Parameter (As Modeled)	Tier 1	Tier 2	
	All Chemicals	Cadmium, Mercury, Dioxins	PAHs
Octant Analyzed	–	W	N
Wind Speed (m/s)	2.8	2.8	2.8
Frequency of Winds Blowing into Modeled Domain (fraction)	0.43	0.07	0.19
Annual Precipitation (mm), site-wide (same for all octants)	1,500	1,187	1,187
Mixing Height (m), site-wide (same for all octants)	710	710	710
Distance to Lake (km)	1.4	10 (Veto Lake)	40 (Wolf Run Lake)

3. Scope of Site-specific Risk Assessment

This site-specific risk assessment evaluated the emissions of four PB-HAP groups (mercury, cadmium, dioxins, and PAHs) emitted from the selected ferroalloys production facility. This section describes the conceptual exposure model and overall scope of the site-specific assessment.

For an inhalation risk assessment, the risk can be approximated (taking into account a range of assumptions) using modeled long-term average air concentrations associated with a source and information on where people reside. For an evaluation of non-inhalation exposures, however, estimating the risk to the “most exposed” individual can be more difficult because chemical concentrations in environmental media to which people are exposed *and* individual exposure patterns associated with ingestion can vary greatly, depending on location, timing, and other factors. For example, people can be exposed to chemicals that accumulate in the FFC by consuming a variety of fruits and vegetables, each of which might or might not be grown in the vicinity of the source. The amount of each type of produce consumed can vary widely among the individuals in a population, as can the fraction of each type of produce that is actually impacted by emissions from a source.

To simplify the exposure and risk assessment of PB-HAPs for the selected facility for this risk assessment, a scenario approach was employed. This approach involved evaluating a combination of exposure media by which an individual is most likely to be exposed to elevated concentrations of PB-HAPs (i.e., a set of “exposure scenarios”). The scenario approach provides a systematic method for evaluating the relative importance of exposure media (e.g., consumption of farm food products versus consumption of fish) that are of potential concern for different chemicals and locations. Typically, only scenarios that are plausible for the situation of interest are evaluated, and the assessment usually focuses on those scenarios that are assumed a priori to lead to the highest individual exposure and risks. Risk metrics such as incremental lifetime cancer risk and chronic non-cancer HQ are calculated as appropriate for each scenario. If warranted, information regarding the likelihood of a specific exposure scenario actually occurring could be used to develop estimates of uncertainty for each scenario and the variations thereof.

For this site-specific residual risk assessment, exposure estimates and corresponding risks were calculated for two basic exposure scenarios:

- A **subsistence farmer scenario**, involving an individual living for a 70-year lifetime on a farm homestead in the vicinity of the source and consuming produce grown on, and meat and animal products raised on, the farm. The individual also incidentally ingests surface soil at the location of the farm homestead.

- An **angler scenario**, involving an individual who regularly consumes fish caught in a freshwater lake in the vicinity of the source of interest over the course of a 70-year lifetime.

Variations of these two scenarios were evaluated using different assumptions regarding food source (i.e., location of the farm homestead or the water body from which fish are obtained), the age of the individual exposed (for non-cancer hazards), the assumed ingestion rate of each food type, and other factors. In particular, a range of fish ingestion rates was evaluated to determine the possible health risks associated with that important medium.

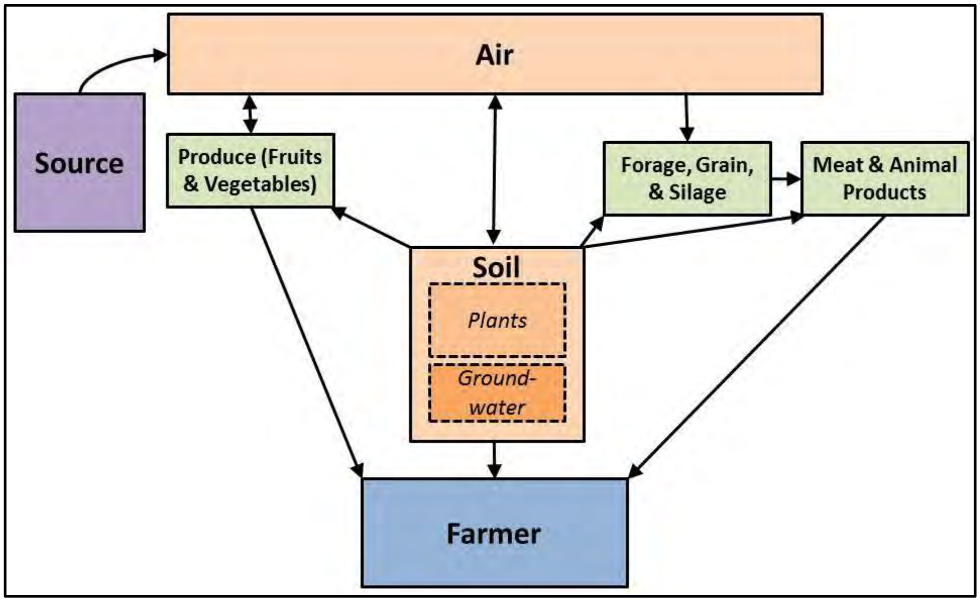
In addition, exposure estimates and risks for **infants consuming contaminated breast milk** were evaluated in the case of dioxins, with the assumption that the nursing mother was exposed to chemicals via one of the two basic scenarios listed above.

The conceptual exposure model for the subsistence farmer scenario is presented in Figure 3-1. The arrows represent the movement of the chemical of concern through the environment and FFC. In this exposure scenario, the hypothetical receptors consume produce, meat, animal products, and incidentally ingested soil. The conceptual exposure model for the angler scenario is presented in Figure 3-2. The hypothetical receptor consumes fish from a contaminated water body. Note that the groundwater parts of these conceptual models were not used in this analysis of the ferroalloys production facility. Chemical transport into a modeled lake via horizontal groundwater flow and recharge is negligibly small compared to other chemical inputs into the lake. The vadose soil zone also was not used in this analysis because theoretical considerations (and sensitivity runs with TRIM.FaTE) suggest that chemical transported into lower soil layers will not substantially move back into the surface soil. Removing the vadose soil zone and groundwater compartments improves model runtime and have no appreciable impact on human chemical exposure in the TRIM.FaTE modeled environment.

These scenarios are expected to cover the highest possible long-term exposures and risks for the chemicals evaluated. In addition to ingestion, non-inhalation exposure to PB-HAPs also can occur by the dermal pathway. Risk from dermal exposure, however, was expected to be a small fraction of the risk from inhalation exposure or ingestion exposure (see Attachment A, Addendum 3 to Appendix 4 to the Risk Report for more detail). Therefore, the risk from dermal exposure was not calculated for this site.

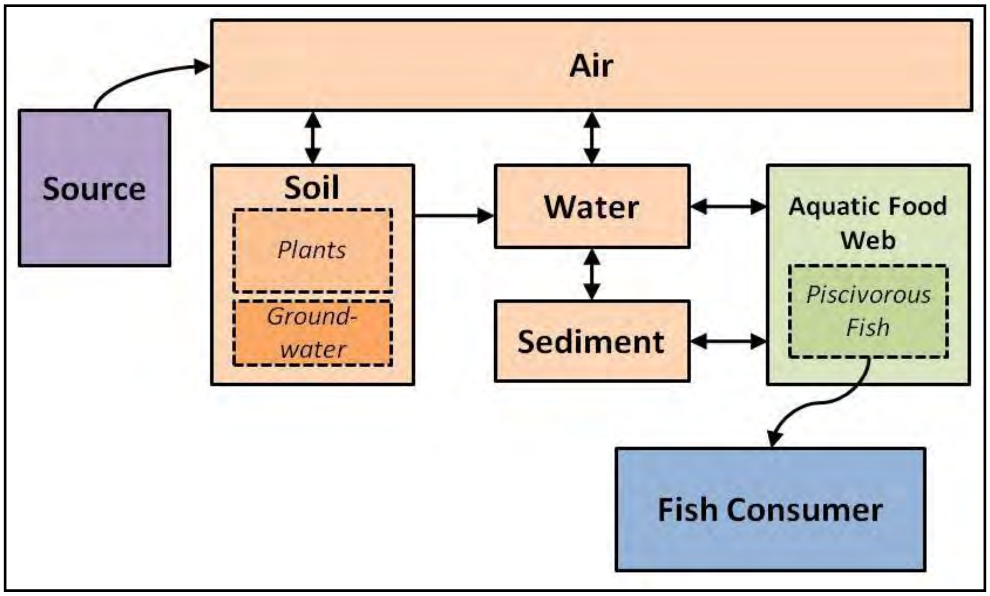
These three exposure scenarios (subsistence farmer, angler, and infant consuming breast milk) were evaluated for each of the four PB-HAP groups as appropriate (note, for example, that for methyl mercury, only the angler scenario is relevant). As described in Sections 1 and 2 of this report, the facility evaluated was the Eramet facility near Marietta, Ohio (NEI ID NEI11660). NEI11660 was selected for this site-specific assessment based on its Tier 2 screening results and based on the feasibility of parameterizing the environment surrounding the facility for the TRIM.FaTE and MIRC models. EPA anticipates that the results for this facility and these scenarios are among the highest that might be encountered for the ferroalloys production source category.

Figure 3-1. Conceptual Exposure Model for Subsistence Farmer Scenario[a]



[a] The soil vadose zone and groundwater compartments were not modeled in this analysis, which had no noticeable impact on modeled human chemical exposure.

Figure 3-2. Conceptual Exposure Model for Angler Scenario[a]

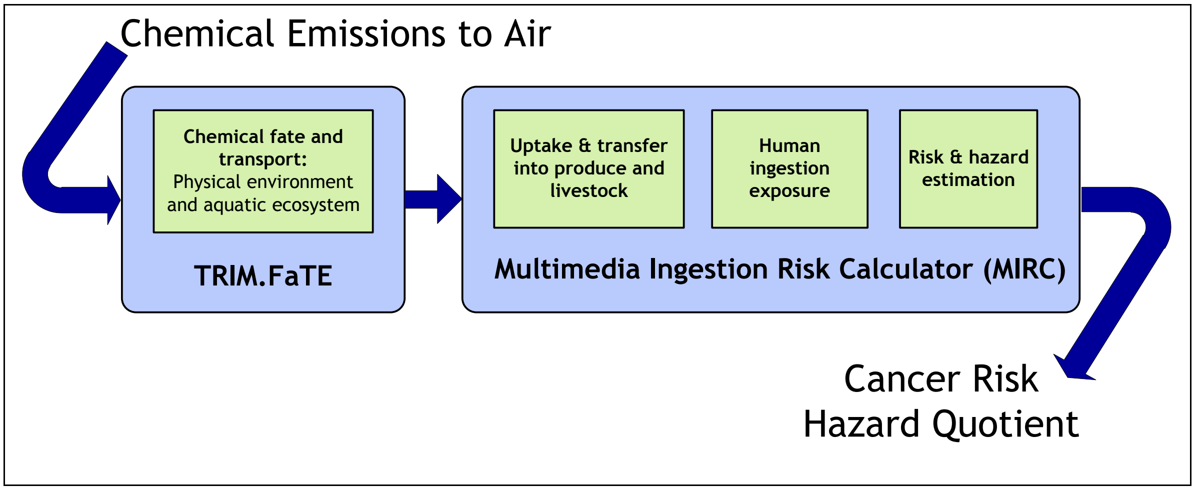


[a] The soil vadose zone and groundwater compartments were not modeled in this analysis, which had no noticeable impact on modeled human chemical exposure.

4. Analysis Methods

An overview of the processes analyzed by TRIM.FaTE and MIRC for assessing site-specific multipathway risks from the assessed ferroalloys production facility is shown in Figure 4-1. The approach can be divided into the following four steps, which correspond to the green boxes in Figure 4-1.

Figure 4-1. Overview of Ingestion Exposure and Risk Screening Evaluation Methods



1. TRIM.FaTE: Fate and transport modeling of PB-HAPs that are emitted to air by the source and partition into soil, water, and other environmental media (including fish).
2. MIRC: Modeling of transfer and uptake of PB-HAPs into FFC media (produce, livestock, and dairy products) from soil and air.
3. MIRC: Estimating ingestion exposures (i.e., average daily ingestion rates) resulting from contact by a hypothetical human receptor with the various selected media.
4. MIRC: Calculating incremental lifetime cancer risk estimates or chronic non-cancer HQs, as appropriate, for each PB-HAP and comparing these metrics to health effect levels of concern used in the RTR.

Site-specific aspects of the fate and transport modeling for this facility are discussed in Section 4.1. The methods used for the exposure and risk modeling are presented in Section 4.2. Further discussion of TRIM.FaTE and MIRC and their implementation for RTR screening analyses can be found in Appendix 4 to the Risk Report.[6]

4.1 Fate and Transport Modeling

This section describes the TRIM.FaTE modeling conducted for this assessment. Most of the material presented here describes the assumptions and data sources used to develop TRIM.FaTE inputs and settings related to meteorological inputs used by the model, the spatial aspects of the modeled region, the characteristics of abiotic environmental compartments and plants included in the scenario, and the aquatic ecosystems set up in each water body of interest.

4.1.1 Overview of the Area Surrounding the Facility

Figure 4-2 shows the location of NEI11660, along with satellite imagery, water bodies, terrain, and land cover in the larger region around the facility. The facility is located in Washington

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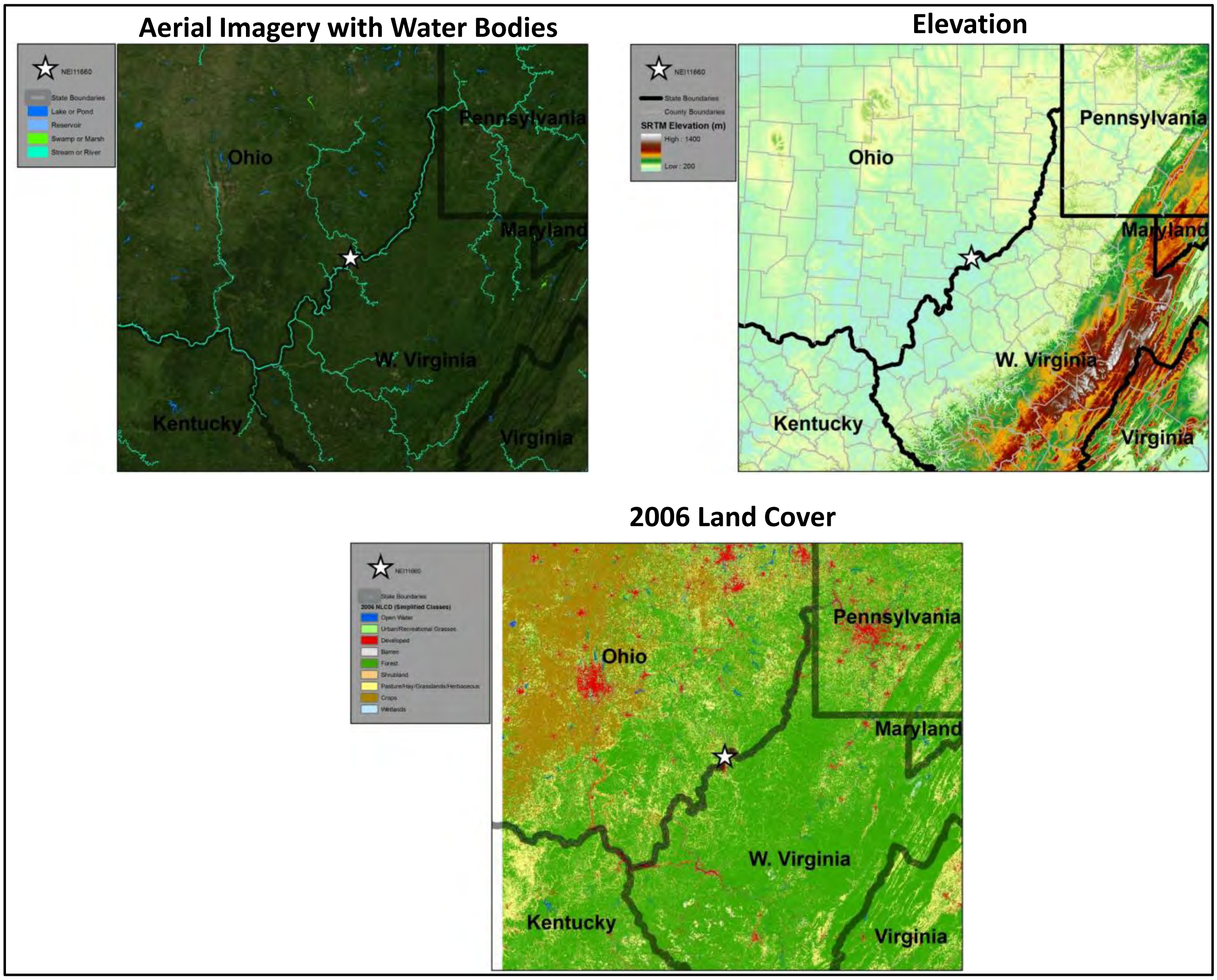
[6] TRIM.FaTE in Appendix 4 to the Risk Report: Section 2.2.1; Section A.2.5 of Attachment A. MIRC in Appendix 4: Sections 2.2.2–2.2.4; Section A.2.6 and Addendum 2 of Attachment A. Note: Appendix 4 focuses on development of Tiers 1 and 2 of the multipathway screening analysis, although general descriptions of TRIM.FaTE and MIRC and their components and purposes still apply to this site-specific assessment.

County, OH—approximately 8 km southwest of Marietta, OH and 5 km northeast of Vienna, WV. The area around the facility is generally forested with relatively small areas of pasture and farmland. Some industrial and other development is located along the Ohio River, generally running northeast to southwest directly past the facility. Most crop farming activities are related to soybeans and corn (not shown in Figure 4-2) and occur on the Ohio side of the river (northwest of the facility). The elevation in most nearby areas is between 200 and 300 m above sea level, with areas farther north in Ohio, northeast in Pennsylvania, and east/southeast in West Virginia exceeding 300 m. The number of people in Washington County, OH is relatively small (approx. 62,000 people in 2010; U.S. Census Bureau 2013; not shown in Figure 4-2). Wood County, WV, directly across the river from the facility, also has a relatively small population (approx. 87,000 people in 2010). The modeling domain for the facility occupies parts of seven counties for which the 2010 total population exceeded 236,000 (all of the counties, not just the parts inside the modeling domain).

Figure 4-2. Location of the Assessed Facility (NEI11660)[a]



[a] Top Left Panel: Basemap: ESRI World Imagery (ESRI 2013); Foreground: ESRI Water Body Types (Specifically, the geospatial file in the ESRI Data & Maps 2009 Data Update for ArcGIS version 9.3.1; derived by USGS, EPA, and ESRI from the USGS National Hydrography Dataset (USGS 2012). Top Right Panel: Shuttle Radar Topography Mission elevation data (see: http://www.esri.com/news/arcnews/spring07articles/global-elevation.html). Bottom Panel: 2006 National Land Cover Dataset (MLRC 2006).

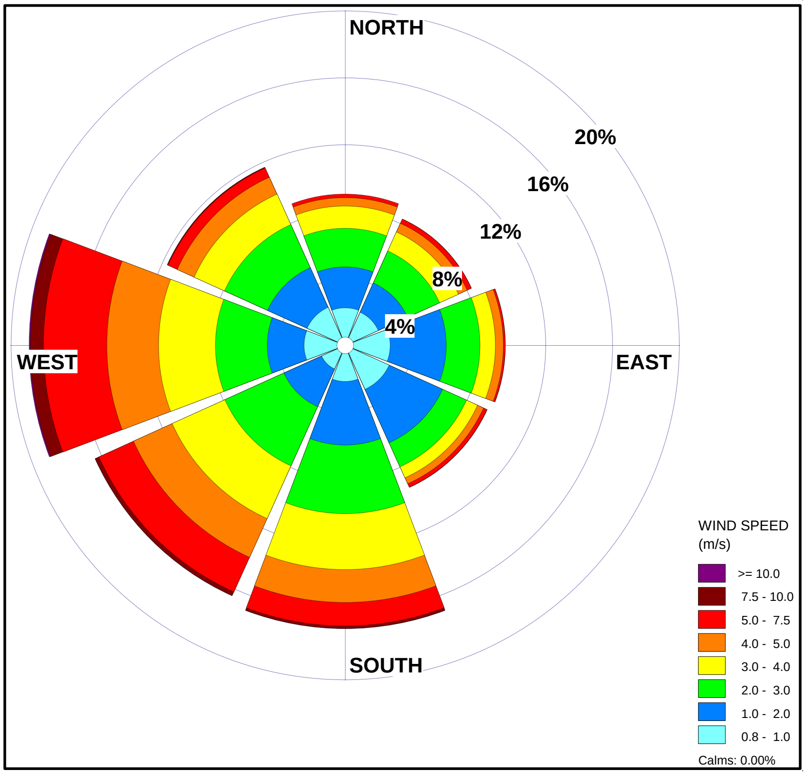
4.1.2 Meteorological Data for Modeling

In the RTR assessments of inhalation risk and Tier 2 ingestion screening (Section 2.2), NEI11660 was matched to the surface station (WBAN 03804) at the Mid-Ohio Valley Regional Airport because it was the closest Automated Surface Observing Station (8 km east-southeast of NEI11660) with relatively few missing data in the data period used in these assessments (2011). That surface station was matched to the upper-air observing station closest to it—Pittsburgh International Airport (WBAN ID 94823; approx. 160 km northeast of the surface station, approx. 175 km northeast of NEI11660).

EPA followed the suggested meteorological data development steps described in Section 3 of the site-specific assessment protocol provided in Appendix 9 to the Risk Report. For this site-specific analysis, the same surface and upper-air stations were selected. A recent 4-year period (2008 through 2011) was used after ensuring that the period-averaged annual precipitation total was not much larger or much smaller than the 30-year average. Multiple years of meteorological data often are used in chemical dispersion and advection models to sample a wider range of meteorological conditions and to reduce the impact of individual extreme weather events on long-term exposure estimations. For this assessment, TRIM.FaTE was run for 50 years on hourly data to allow the emitted chemical to bioaccumulate and persist in the environment. Obtaining, analyzing, and processing 50 years of meteorological data are impractical (based on cost and availability of such a long period of record). Consequently, 4 years of meteorological data were used because repeating it over and over to create a 50-year meteorological dataset is simpler while still representing long-term meteorological patterns on the whole.

TRIM.FaTE requires five meteorological parameters: temperature, wind speed, wind direction, mixing height, and precipitation amount. EPA obtained hourly mixing height values for the site-specific assessment by running AERMOD’s meteorology processor (AERMET; version 12345, with modifications to reduce the impact of a known error with friction velocity calculations; includes processing of 1-minute winds with EPA’s AERMINUTE processor) on the surface data, upper-air data, and the 1992 National Land Cover Dataset (EPA’s AERSURFACE tool accepts only 1992 land cover data, which did not change significantly by 2006, which is the latest data available from the National Land Cover Database). Approximately 7 percent of the meteorological data was missing, so EPA used automated methods to replace all missing data based on reasonable surrounding values. The methods of replacing missing data were based in part on EPA’s guidance for substituting missing meteorological data for regulatory air quality models (Atkinson and Lee 1992; see also Section 3.5 of the site-specific protocol, Appendix 9 to the Risk Report). EPA also substituted all calm winds (which occurred 6 percent of the time) and winds speeds less than 0.75 m/s (which occurred 7 percent of the time) with a wind speed value of 0.75 m/s, and replaced all mixing heights less than 20 m (which occurred less than 1 percent of the time) with a value of 20 m. As evident from Figure 4-3 and Table 4-1, winds most often blew toward the east (19 percent frequency) during the analysis period, and winds blowing toward the north or northeast also were common (17 and 16 percent frequency, respectively). Winds with a strong westward or southward wind component were least frequent (8 percent toward the southwest; 9 percent each toward the south and northwest; 10 percent toward the west). The average wind speed was 2.7 m/s, although that average varied by ±0.9 m/s depending on wind direction.

Figure 4-3. Wind Rose for the Meteorological Data Used in this Site-specific Assessment[a]



[a]Winds are shown “blowing from.” That is, the cone in the northeastern quadrant indicates that winds blow toward the southwest approximately 8 percent of the time.

Table 4-1. Wind and Precipitation Statistics for the Meteorological Data Used in this Site-specific Assessment

Directional Octant	All Times			When Precipitating (9% of the time)		When Not Precipitating (91% of the time)	
	Wind Frequency Toward Octant (%)	**Average Wind Speed (m/s)**	**Average Annual Precipitation Total (mm)[a]**	**Wind Frequency Toward Octant (%)**	**Average Wind Speed (m/s)**	**Wind Frequency Toward Octant (%)**	**Average Wind Speed (m/s)**
N	17%	2.8	204	18%	3.4	17%	2.7
NE	16%	3.2	169	16%	3.8	16%	3.2
E	19%	3.6	157	17%	4.0	19%	3.6
SE	12%	2.4	108	10%	3.0	12%	2.4
S	9%	2.1	100	9%	2.7	9%	2.0
SW	8%	2.2	75	8%	2.9	8%	2.1
W	10%	1.8	124	11%	2.5	9%	1.8
NW	9%	1.8	101	11%	2.7	9%	1.7
Average Regardless of Octant	–	2.7	1,038	–	3.2	–	2.6
Calm	Calm winds (<0.75 m/s) occurred 6% of the time in the raw meteorological data. For TRIM.FaTE, calm values and values less than 0.75 m/s (occurred 7% of the time) were replaced with 0.75 m/s.						
Missing	Missing wind data occurred 1% of the time. For TRIM.FaTE, missing values were replaced with averages of surrounding values.						

[a]The average annual precipitation totals in the individual octant rows represent only the precipitation that fell when winds were blowing into that octant. The “Average Regardless of Octant” value is the total precipitation without regard to wind direction.

Precipitation occurred 9 percent of the time and was usually associated with stronger winds than times without precipitation. Approximately 46 percent of the annual precipitation occurred when winds had a northward component. The average annual precipitation total was 1,038 mm (Table 4-1), which was approximately equal to the 1981–2010 30-year average (not shown).

Hourly mixing heights typically were less than 1,000 m, and more than 64 percent of hours modeled had mixing heights smaller than 500 m (Table 4-2). The average of the maximum daily mixing heights was approximately 1,254 m, and the average of the minimum daily mixing heights was approximately 67 m (not shown).

Table 4-2. Mixing Height Statistics for the Meteorological Data

Range of Hourly Mixing Heights (exclusive − inclusive) (m)	Frequency
= 20[a]	0.1%
20−418	58%
418−816	21%
816−1214	11%
1214−1612	7%
1612−2010	3%
2010−2408	1%
2408−2806	0.2%
2806−3204	0.1%
3204−3602	0.04%
3602−4000	0.03%

[a] Mixing heights of less than 20 m are set equal to 20 m.

4.1.3 Characteristics of the Modeled Emission Source Compartment

For TRIM.FaTE, the modeled emissions location, amounts, and release heights were derived from the same NEI emissions data used for the RTR inhalation assessment for the ferroalloys production source category. The emission source compartment in TRIM.FaTE was approximately centered on the facility and generally encompassed the locations of all of its 16 PB-HAP-emitting sources.

The height of the source compartment represents the chemical release height, and the release height's only impact in TRIM.FaTE is to determine whether the emissions are released within the mixing layer or above it. Chemicals released above the mixing layer are not available for ground-level exposure (i.e., they are emitted to an upper-air sink). When determining whether emissions are within the mixing layer, one must consider not only the physical release height of the emission source but also the buoyancy and vertical momentum of the emission. TRIM.FaTE does not explicitly model the buoyancy and vertical momentum characteristics related to the emissions' exit gas temperatures and velocities, which have the real-world effect of ejecting the chemical vertically beyond exiting the source (i.e., plume rise). The effect of plume rise, however, can be represented in TRIM.FaTE by varying the release height with time to account for plume-rise effects appropriately. The use of time-varying release heights can increase model runtime, so this adjustment was implemented only when plume-rise estimations indicated that more than 5 percent of the modeled chemical emissions would be lost to the upper-air sink.

Among the 16 PB-HAP-emitting sources at NEI11660 were 5 unique release height values ranging from 13 m to 38 m. Other physical stack parameters (exit diameter, exit gas temperature, and exit gas velocity) also had widely varying values, leading to seven unique combinations of release height, exit diameter, exit gas temperature, and exit gas velocity. EPA examined these seven unique combinations at NEI11660 and reduced the data to three modeled sources generally representing three unique combinations of physical characteristics. These groups, and their emission amounts, are shown in Table 4-3. Plume-rise values were estimated for each emission source for each hour of modeling, using the hourly meteorology developed for this site-specific assessment and using methods summarized by Seinfeld and Pandis (1998) (see also Section 3.7 of the site-specific protocol, Appendix 9 to the Risk Report).

Table 4-3. Modeled Emissions Amounts for Each Grouped Emission Source

Modeled PB-HAP Group	Modeled Chemical	Emissions (tons per year)			
		Stack A	Stack B	Stack C	Total
		Release Ht.: 28.8 m	Release Ht.: Varies by Hour for Plume-rise Purposes		
Mercury	Divalent Mercury	1.58E-03	1.05E-05	3.27E-02	3.43E-02
	Elemental Mercury[a]	6.30E-03	4.20E-05	1.31E-01	1.37E-01
Cadmium	Cadmium	8.94E-02	4.82E-05	3.06E-02	1.20E-01
PAHs	2-Methylnaphthalene	5.98E-01	8.11E-03	9.22E-02	6.98E-01
	Acenaphthene	2.42E-01	3.18E-03	4.37E-02	2.89E-01
	Acenaphthylene	6.62E-01	6.55E-03	3.02E-01	9.71E-01
	Benz(a)anthracene	7.93E-02	2.01E-04	7.20E-02	1.52E-01
	Benzo(a)pyrene[b]	2.11E-02	7.69E-05	1.91E-02	4.03E-02
	Benzo(b)fluoranthene	7.82E-02	1.66E-04	8.22E-02	1.61E-01
	Benzo(g,h,i)perylene	9.23E-03	9.20E-05	6.48E-03	1.58E-02
	Benzo(k)fluoranthene	2.37E-02	8.32E-05	2.37E-02	4.75E-02
	Chrysene	2.15E-01	3.42E-04	2.15E-01	4.30E-01
	Dibenzo(a,h)anthracene	1.43E-03	1.31E-05	1.27E-03	2.72E-03
	Fluoranthene	7.04E-01	2.42E-03	6.24E-01	1.33E+00
	Fluorene	2.85E-01	3.66E-03	9.34E-02	3.82E-01
	Indeno(1,2,3-c,d)pyrene	4.88E-03	3.94E-05	5.16E-03	1.01E-02
Dioxins	HeptaCDD, 1,2,3,4,6,7,8-	5.24E-08	1.05E-09	6.12E-09	5.96E-08
	HeptaCDF, 1,2,3,4,6,7,8-	7.40E-08	1.53E-09	2.70E-09	7.82E-08
	HeptaCDF, 1,2,3,4,7,8,9-	2.91E-08	5.74E-10	3.22E-09	3.29E-08
	HexaCDD, 1,2,3,4,7,8-	2.88E-08	5.74E-10	2.73E-09	3.21E-08
	HexaCDD, 1,2,3,6,7,8-	2.79E-08	5.56E-10	2.69E-09	3.11E-08
	HexaCDD, 1,2,3,7,8,9 -	2.84E-08	5.65E-10	3.20E-09	3.22E-08
	HexaCDF, 1,2,3,4,7,8-	3.36E-08	6.75E-10	2.66E-09	3.69E-08
	HexaCDF, 1,2,3,6,7,8-	2.59E-08	5.21E-10	2.05E-09	2.84E-08
	HexaCDF, 1,2,3,7,8,9-	3.08E-08	6.18E-10	2.65E-09	3.41E-08

Modeled PB-HAP Group	Modeled Chemical	Emissions (tons per year)			
		Stack A	Stack B	Stack C	Total
		Release Ht.: 28.8 m	Release Ht.: Varies by Hour for Plume-rise Purposes		
	HexaCDF, 2,3,4,6,7,8-	3.84E-08	7.84E-10	2.23E-09	4.14E-08
	OctaCDD, 1,2,3,4,6,7,8,9-	4.29E-07	8.72E-09	6.41E-08	5.02E-07
	OctaCDF, 1,2,3,4,6,7,8,9-	7.76E-08	1.54E-09	7.50E-09	8.66E-08
	PentaCDD, 1,2,3,7,8-	4.20E-08	8.45E-10	3.24E-09	4.60E-08
	PentaCDF, 1,2,3,7,8-	3.36E-08	6.79E-10	2.53E-09	3.68E-08
	PentaCDF, 2,3,4,7,8-	5.22E-08	1.07E-09	2.74E-09	5.60E-08
	TetraCDD, 2,3,7,8-	3.16E-08	6.18E-10	3.53E-09	3.57E-08
	TetraCDF, 2,3,7,8-	4.56E-08	9.02E-10	4.42E-09	5.09E-08

[a] Emissions of elemental mercury are included in site-specific modeling because it can transform in the environment to other forms of mercury.

[b] Modeled emissions of BaP shown here include emissions of benzo(e)pyrene and perylene, which are not currently fully parameterized in TRIM.FaTE to evaluate their specific fate, transport, and transformation properties. Emissions of benzo(e)pyrene and perylene respectively make up 35.37% and <1% of the modeled emissions of BaP.

Two of the source groups (Sources B and C) had physical release heights, exit gas temperatures, and exit gas velocities that were large enough to produce large plume-rise values during some meteorological conditions. Stacks B and C were estimated to emit chemical into the upper-air sink 17 percent and 31 percent of the time, respectively, so they were modeled with hourly varying release heights in TRIM.FaTE. The median plume-rise value above the physical release points was 34 m for Stack B and 101 m for Stack C. Chemical emissions from Stack A rarely had enough buoyancy or vertical momentum to release into the upper-air sink, so they were modeled with a static release height of approximately 29 m.

As is evident in Table 4-3, most of the mercury emissions (95 percent) came from Stack C, with nearly all the remainder coming from Stack A, so approximately 30 percent of total mercury emissions was released into the upper-air sink and was unavailable for human exposure. Most of the cadmium emissions (75 percent) came from modeled Stack A, with nearly all the remainder coming from Stack C, so approximately 8 percent of total cadmium emissions was released into the upper-air sink and was unavailable for human exposure. The PAH (BaP-equivalent emissions) were split evenly between Stacks A and C, with less than 1 percent emitted from Stack B, so approximately 15 percent of total BaP-equivalent PAH emissions was released into the upper-air sink and was unavailable for human exposure. Nearly all of the dioxin (2,3,7,8-TCDD-equivalent) emissions (91 percent) came from Stack A, with 2 and 7 percent respectively from Stacks B and C, so approximately 3 percent of total 2,3,7,8-TCDD-equivalent emissions was released into the upper-air sink and was unavailable for human exposure. These BaP- and 2,3,7,8-TCDD-equivalent emissions are not shown in Table 4-3.

Two PAH compounds emitted from NEI11660 (benzo(e)pyrene—BeP for simplicity—and perylene) are not currently parameterized in TRIM.FaTE. Surrogate compounds were selected to approximate their environmental fate, transport, and transformation characteristics in the modeling. To select an appropriate surrogate chemical, a brief literature search was conducted to obtain information on physicochemical and environmental fate properties of these congeners. These properties included number of benzene rings, molecular weight, K_{ow}, K_{oc}, Henry's Law Constant, solubility in water, vapor pressure, biotransformation half-life in fish, and environmental partitioning and persistence. Data sources included the National Institutes of Health's TOXNET (U.S. NIH 2013b) and ChemID (U.S. NIH 2013a) and British Columbia's Ministry of Environment (B.C. MOELP 1993), among others. These properties were compared to those of congeners already parameterized in TRIM.FaTE. The number of benzene rings and molecular weight were the priority properties; a reasonable surrogate for a chemical would usually have the same number of benzene rings and a similar molecular weight. For the other properties, similarity between chemicals was quantified by grouping chemicals with similar values for each property and noting roughly the number of times each TRIM-parameterized chemical was grouped with the chemical requiring a surrogate. Additional considerations included the number and types of additional groups (e.g., methyl, chlorine) attached to one or more benzene rings and overall configuration of the molecule (e.g., planar, bent). The weight of evidence, considered along with professional judgment, suggested that BaP was an appropriate surrogate for both congeners. The compound-to-surrogate ratio of oral pathway toxicities (i.e., the oral toxic equivalency factor) was 0.0685 for both congeners. That is, emissions of BeP and perylene were multiplied by 0.0685 and added to the emissions of BaP. The emissions of BaP shown in Table 4-3 reflect this process. BeP and perylene emissions make up approximately 35 and less than 1 percent, respectively, of the modeled emissions of BaP.

The properties of the modeled chemicals are shown in various tables in Appendix A to this report. These properties include diffusivity, Henry's Law Constant, molecular weight, K_{ow}, deposition velocity, transformation rates, and half-lives, and various assimilation, absorption, and elimination rates in aquatic species.

4.1.4 Modeling Domain and Parcel Design

The spatial configurations of the TRIM.FaTE surface and air parcels are described below. These parcels subdivide the surface and air modeling domains in two dimensions. The modeling compartments associated with a parcel have well-mixed chemical concentrations and are where chemical transformations and transport take place. The parcels were designed step-by-step, generally following the design recommendations provided in Section 4 of the site-specific protocol (Appendix 9 to the Risk Report). These steps first considered the locations of the modeled features of interest (i.e., farms and lakes), and then considered other parcels adjacent to (including upwind and downwind from) those features. Finally, the spaces were methodically filled in between the source, those features of interest, and the desired outer domain of the modeling, considering important land cover, elevation, soil type, and watershed qualities where appropriate. Air and surface parcels were generally collocated, except for the features of interest and areas directly crosswind of those features, and except where important land characteristics changed significantly beneath a single air parcel. For the parcel design overall, runtime also was considered because each additional air or surface parcel introduces additional runtime. Model runtime also increases with increasing number of points (i.e., vertices) used to draw a parcel, so parcels for features of interest were drawn with as few points as was reasonable to represent the modeled area. The rationale for this system of parcel designed is described in Section 4 of the site-specific protocol (Appendix 9 to the Risk Report).

4.1.4.1 Surface Parcels

The surface parcel design for NEI11660 is shown in Figure 4-4. The name of each modeled water body is shown, and each of the other parcels is labeled based roughly on its location relative to the source parcel (e.g., “NW1,” “SE3,” and so on). The parcel shading generally corresponds to the type of vegetation used in the modeling (or the tilled or untilled nature of the soil, in the case of modeled farms and other parcels with heavy farm use). The selection of the water bodies and farms and the assignment of vegetation and soil types are described below. This design process is described below. Figure 4-5, Figure 4-6, and Figure 4-7, respectively, show the surface parcels with land cover, elevation, and county boundary base maps. Figure 4-8 is similar to Figure 4-4 but is zoomed in on farms and lakes near the facility to show additional resolution.

The characteristics of all potentially fishable lakes[7] within approximately 50 km of the facility were analyzed. Lakes identified included those used in the Tier 2 analysis, plus a small number of other lakes. Most of the potential lakes, upon examination using satellite data and Internet searches, appeared unlikely to be fishable or were close to a much larger lake that was more likely to be open to fishing and to support the larger fish populations that are more likely to be supportive of a subsistence angler.

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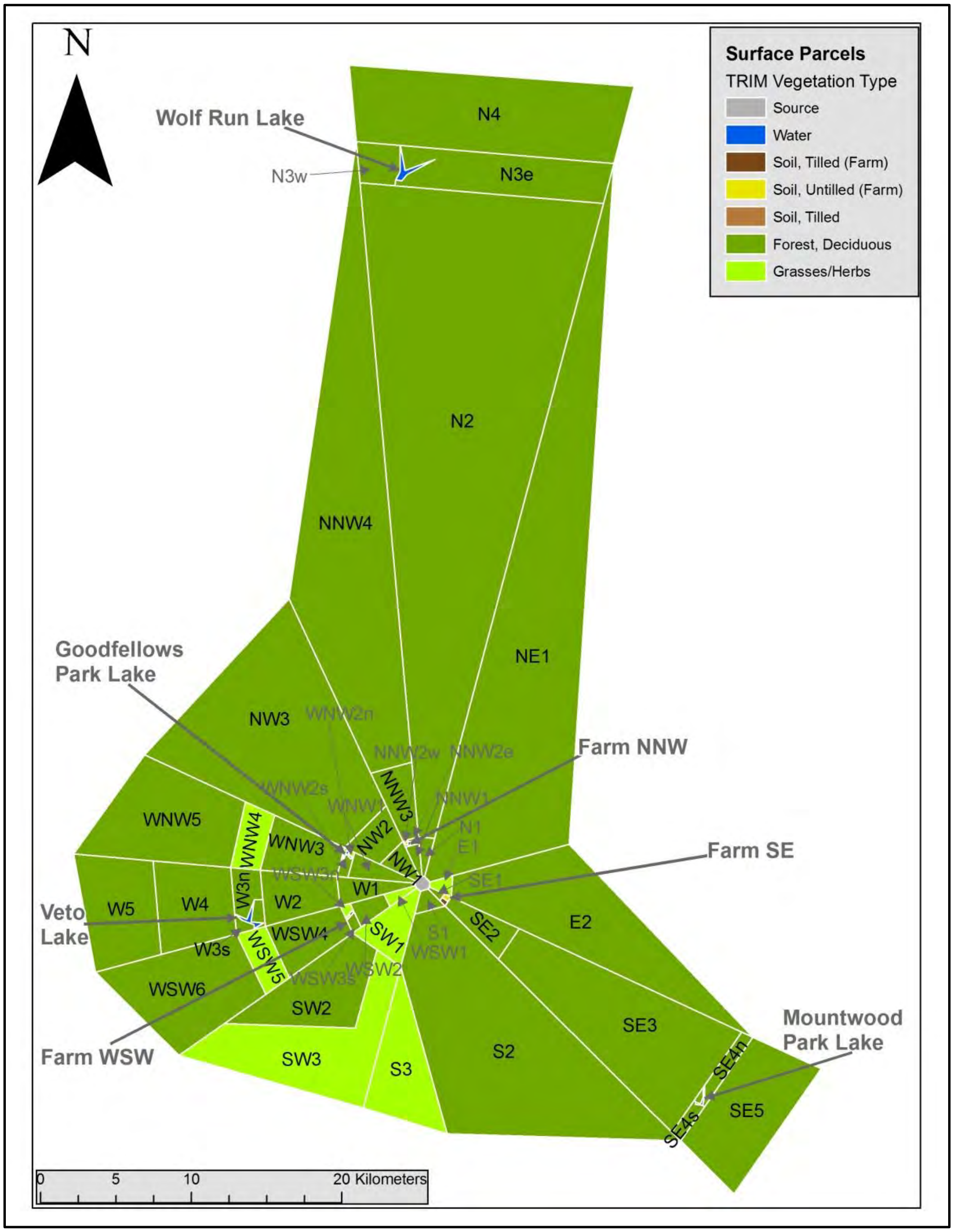
[7] Based on available data, for RTR multipathway emission screening analyses, EPA defines potentially fishable lakes as those larger than 100 acres, without exceeding 100,000 acres. Even a 100-acre lake is unlikely to be large enough to sustain harvesting the number of piscivorous fish required for the current screening ingestion rate (i.e., 373 g ww fillet/day). This is discussed in Section B.3.1 of Attachment B in Appendix 4 to the Risk Report. However, EPA includes smaller lakes (as small as 25 acres) in site-specific RTR multipathway analyses to be health protective and to ensure that small lakes that might be more highly contaminated than estimated by the screening analyses are not eliminated.

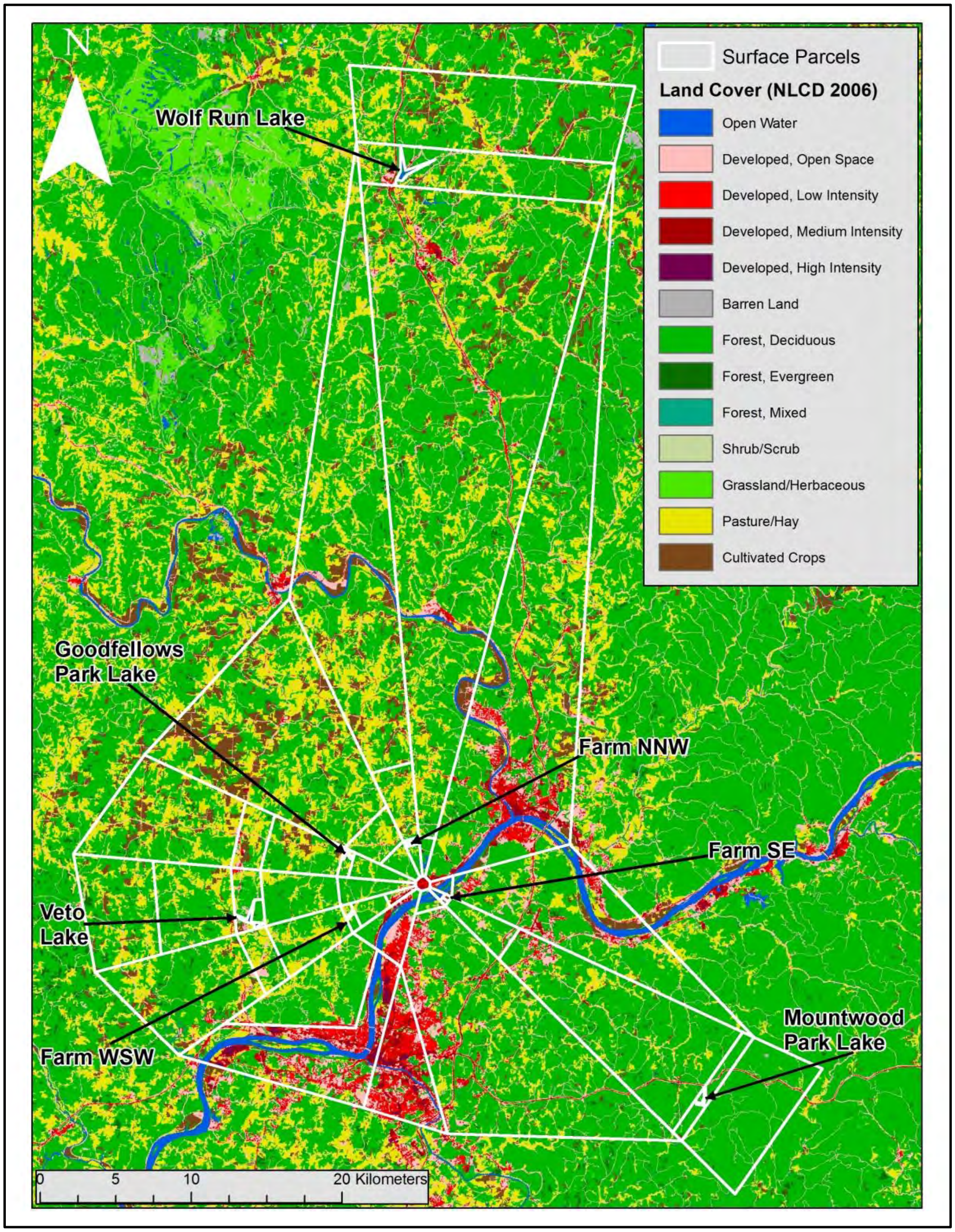
Figure 4-4. Modeled Surface Parcels for NEI11660 and Their Modeled Vegetation or Soil Types[a,b]



[a] Parcel shadings correspond to modeled vegetation or soil types.

[b] As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

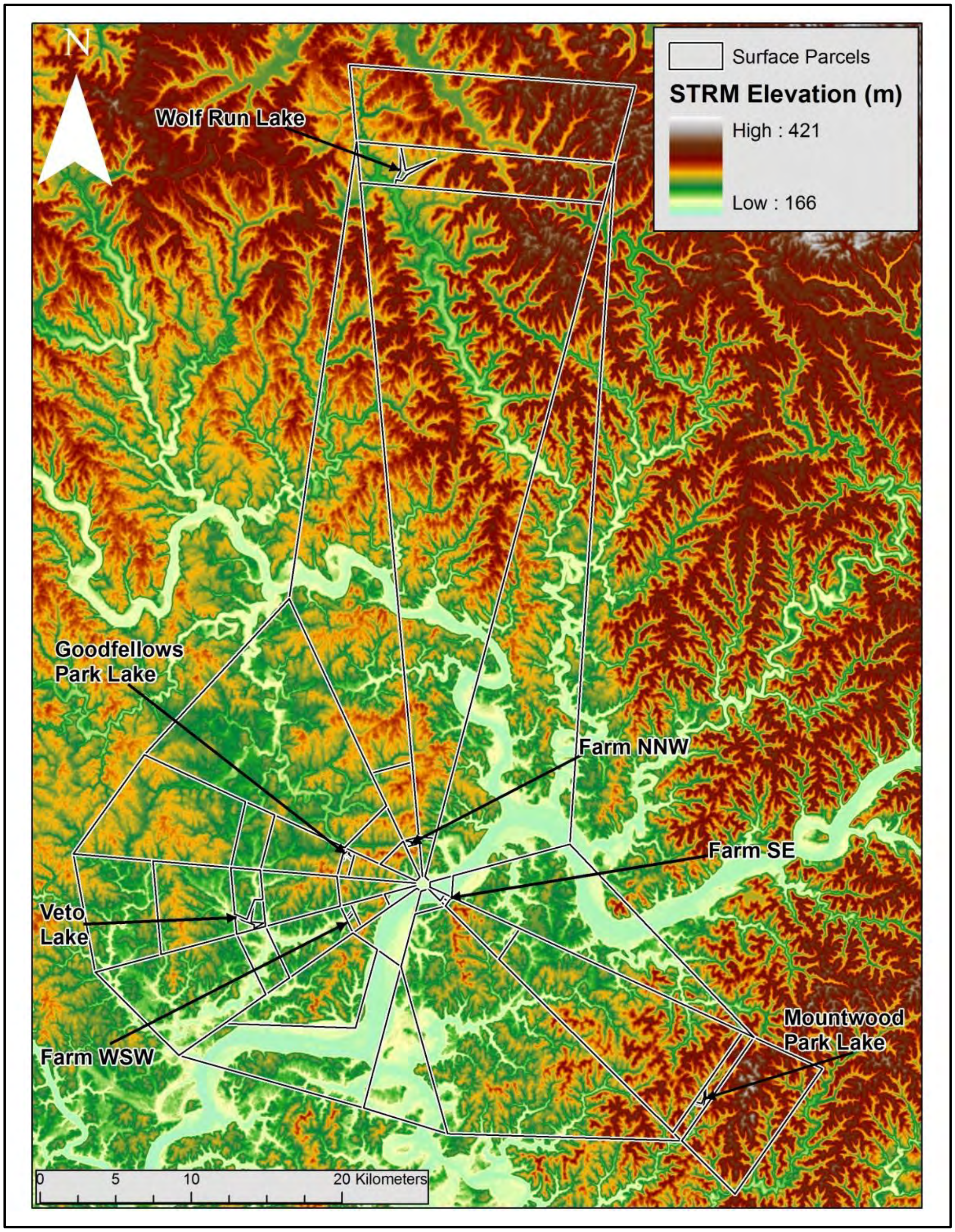
Figure 4-5. Modeled Surface Parcels for NEI11660 and Land Cover Base Map[a,b]



[a] MLRC (2006)

[b] As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

Figure 4-6. Modeled Surface Parcels for NEI11660 and Terrain Base Map[a,b]



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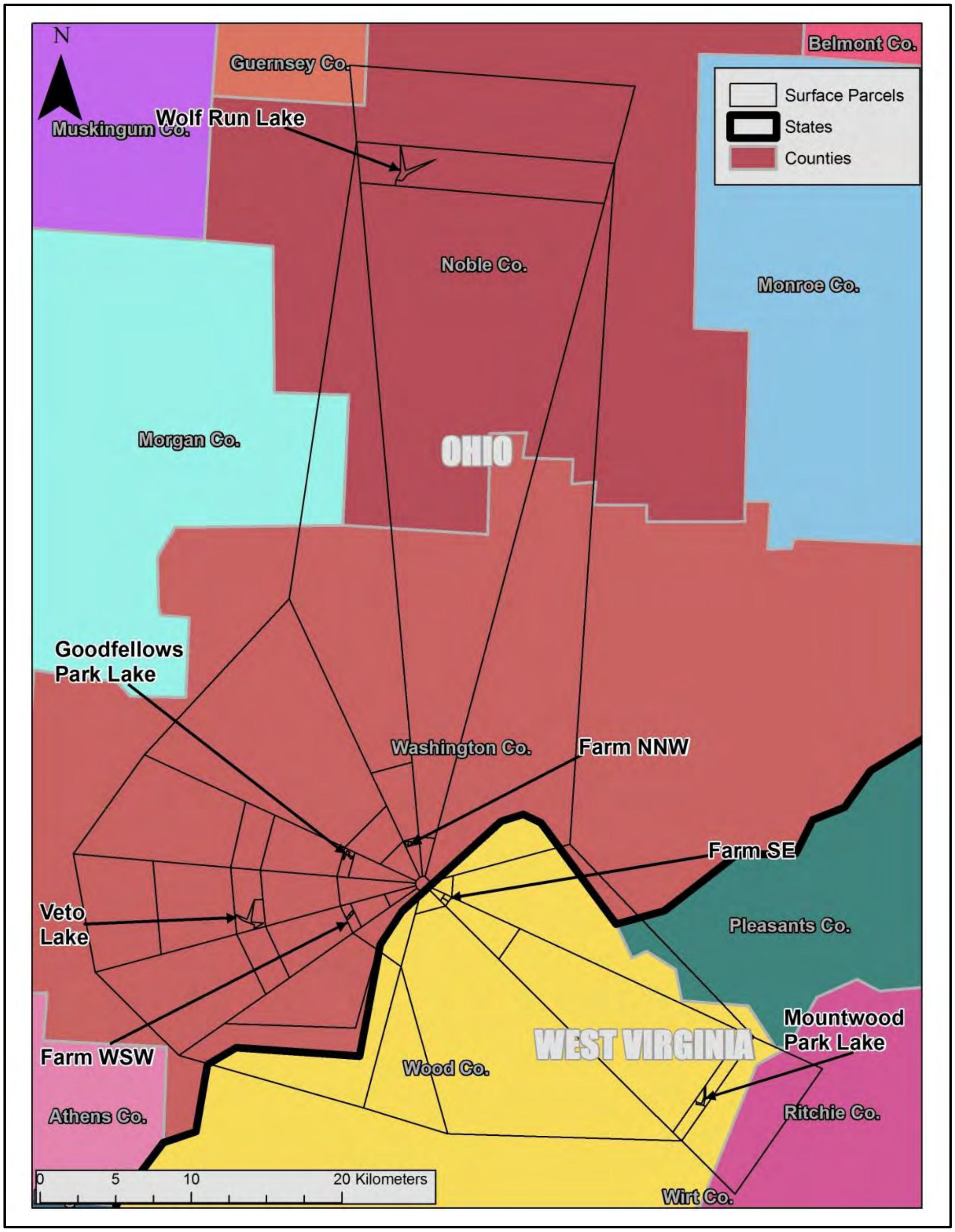
[a] Shuttle Radar Topography Mission elevation data (see: http://www.esri.com/news/arcnews/spring07articles/global-elevation.html)

[b] As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

Figure 4-7. Modeled Surface Parcels for NEI11660 and County Base Map[a]



[a]As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

Figure 4-8. Modeled Surface Parcels for NEI11660, Zoomed on Farms and Lakes Near the Facility[a]

[a] As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

Three lakes were selected to be included in the site-specific TRIM.FaTE modeling and then used to evaluate exposures via the fish consumption pathway—Veto Lake (12 km west-southwest of the facility), Mountwood Park Lake (23 km southeast of the facility), and Wolf Run Lake (48 km north of the facility).[8] Veto Lake and Wolf Run Lake also were used in the Tier 2 emission screening analysis. The modeled surface areas for each lake were nearly identical to their actual surface areas (Table 4-4). For the other properties needed to model surface water and sediment, some site-specific values were available from literature and Internet sources, and default state, regional, or national values or estimation methods were used as a last resort. Three significant rivers (Ohio, Muskingum, and Little Kanawha) crossed through the modeled domain. These rivers were not explicitly modeled, although the water runoff they collect from surrounding land (carrying chemical out of the domain) was accounted for.

Table 4-4. Lake Sizes

Lake Name	Modeled Lake Size (same as actual size) km^2 (acres)
Veto Lake	0.51 (126)
Mountwood Park Lake	0.16 (39.5)
Wolf Run Lake	0.92 (227)

EPA used recent land cover data (MLRC 2006) and farming data (USDA 2011, USDA 2007) to identify areas that were within approximately 5 km of the emission source and that appeared to support farming activities. Most of the crops were soybeans and corn. Local animal husbandry included cattle, hogs, sheep, and poultry. EPA selected three farming areas close to the facility—one to the north-northwest (labeled “Farm NNW” in Figure 4-4; see Figure 4-8 for greater resolution), one to the west-southwest (“Farm WSW”), and one to the southeast (“Farm SE”). A modeled farm parcel does not necessarily represent a single, entire farm owned by one entity; instead, the farms were delineated to represent where farming likely would occur in general. EPA split in half each modeled farming area—one half was modeled with tilled soil (representing crop farming), the other half with untilled soil (representing where animals graze).

For each non-lake parcel other than those modeled for subsistence farming activities, EPA analyzed land cover data (MLRC 2006) to identify the major land cover type and then related those land cover types to the types used in TRIM.FaTE (i.e., coniferous forest, deciduous forest, grasses/herbs, tilled soil, untilled soil, and bare earth). The other properties of soil compartments unrelated to vegetation were set to site-specific values when readily available (i.e., from literature, Internet sources, and the U.S. Department of Agriculture Web Soil Survey [USDA 2012]), and default state, regional, or national values or estimation methods otherwise. See Appendix A to this report for these values and other modeled properties of soil-related compartments.

4.1.4.2 Air Parcels

The air parcel design for NEI11660 is shown in Figure 4-9. Each lake and farm surface parcel, and any “misfit” surface parcels that were included adjacent to those parcels, had a single air parcel overlaying it. For all other parcels, air parcels were collocated with surface parcels.

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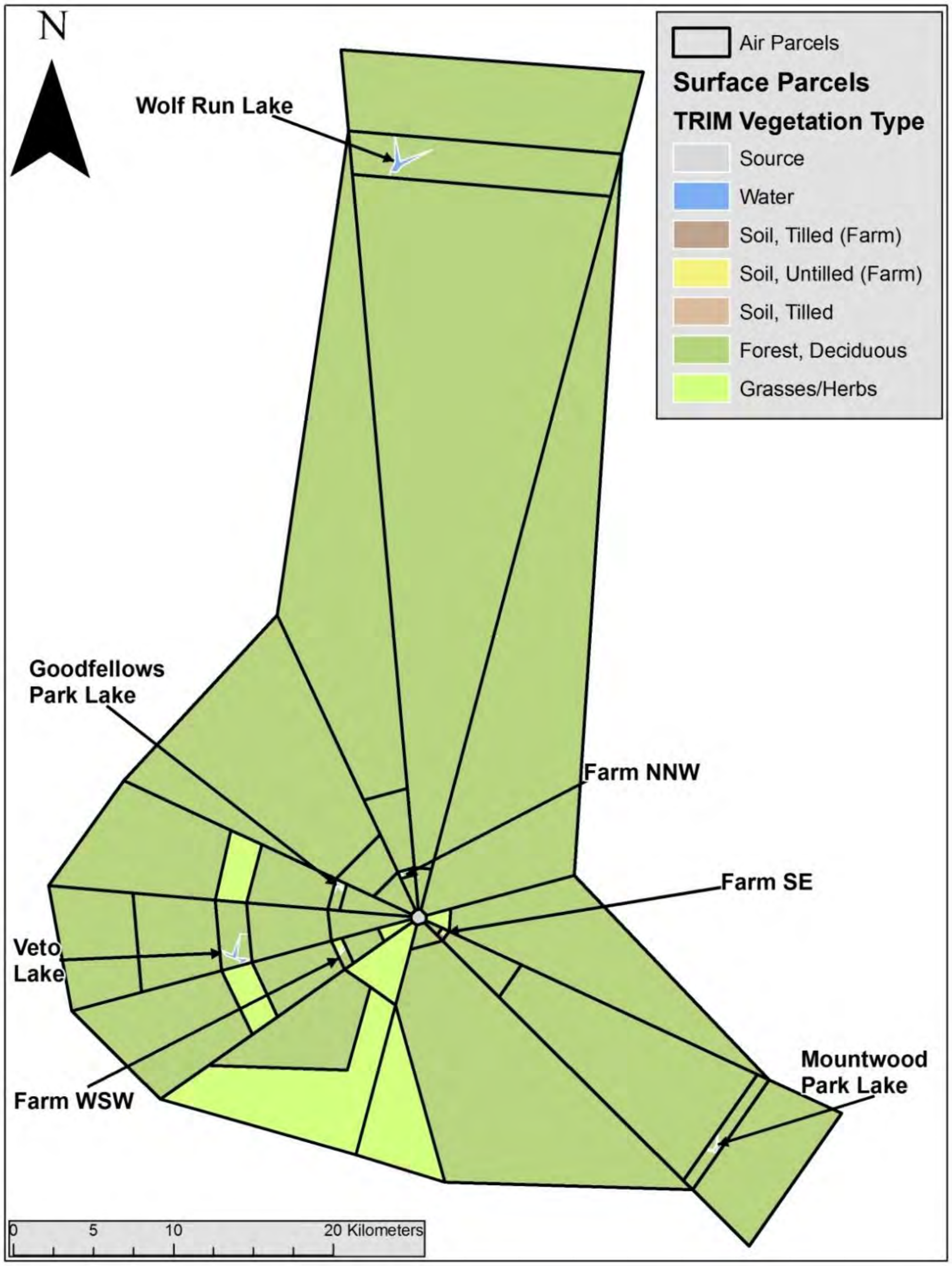
[8] Goodfellows Park Lake is present in some of the tables, figures, and setup discussion in this report and accompanying appendices, but it is not included in the modeling results. This is because it was initially part of the analysis, but it was later learned that it is likely still owned by a private company, is not for public access, and was dry in some recent years. Very little data on the lake were available for modeling.

Figure 4-9. Modeled Air Parcels for NEI11660[a,b]



[a] For reference, the base map (the lightly colored parcels) shows the surface parcels shaded as in Figure 4-4 and without labels.

[b] As explained in the text (Footnote 8), Goodfellows Park Lake ultimately was not included in the risk results.

4.1.5 Abiotic Environment

TRIM.FaTE requires various environmental properties for each abiotic compartment included in a scenario. Examples of abiotic environmental properties include the depth of surface soil, soil porosity and water content, erosion and runoff rates for surface soil compartments, and suspended sediment concentrations in surface water. The values used in this assessment are shown in Appendix A to this report. Following the site-specific protocol presented in Appendix 9 to the Risk Report, site-specific inputs were used for this assessment where data supporting such values were readily available, and these site-specific values are indicated in the tables in Appendix A using shading and footnotes. State, regional, or national default values or estimation methods were used for all other inputs, especially for those not expected to strongly influence chemical concentrations. Following the site-specific protocol, examples of properties that were at least partially site-specific for at least some parcels included: soil pH; concentration of suspended sediment in surface water; and surface water pH, depth, algal density, temperature, and flush rate. USLE (universal soil loss equation) erosion factors were site-specific because they were readily available. Fraction of precipitation that runs off (i.e., “runoff fractions”) was also site-specific, following the “with sophisticated GIS software” steps in Section 5.3 of the site-specific protocol (Appendix 9 to the Risk Report).

The approach to parameterizing flush rates for lakes in TRIM.FaTE was to rely on measured site-specific values, where available, from literature or other reliable sources. In the absence of such values (i.e., for Veto Lake), EPA computes lake flush rate estimates from precipitation input to the lake or assumptions about the lake’s watershed area, the fraction of precipitation that runs off toward the lake from other non-water surface parcels, lake evaporation rate, lake volume, and inflow from other water bodies to the lake. Properties of the surface waters of individual lakes, and of surrounding land parcels, are shown in Appendix A to this report.

4.1.6 Biotic Environment

The TRIM.FaTE biotic environment includes terrestrial plants and aquatic ecosystems. Examples of biotic environmental properties include leaf litterfall rate and lipid content, water content of plant parts, chemical transformation rates and transfer factors, and biomass densities in surface water and sediment. The values used in this assessment are shown in Appendix A to this report. Because site-specific information is generally lacking, default state, regional, or national values or estimation methods were used for most biotic properties. Examples of properties that were at least partially site-specific for at least some parcels included litterfall period (October 1 through October 30) and the period where leaves are on trees (April 10 through October 1), both estimated based on local frost and freeze data. Site-specific values are indicated in the tables in Appendix A using shading and footnotes.

4.2 Methods for Exposure and Risk Modeling

This section describes the methods applied to conduct the exposure assessment and risk characterization for the scenarios described above. Specifically, this section describes the methods for modeling chemical concentrations in FFC and other media relevant to the selected exposure scenarios (Section 4.2.1); estimating human exposures associated with ingestion of FFC media, incidental ingestion of soil, consumption of fish, and infant consumption of breast milk, where applicable (Section 4.2.2); and estimating human health risk metrics associated with these exposure media (Section 4.2.3). All calculations were conducted using the MIRC exposure model.

4.2.1 Methods for Calculating Exposure Concentrations

Farm Food Chain Media

For foodstuffs that are part of the FFC, MIRC was used to calculate concentrations of PB-HAPs as described in Attachment 4 to the Risk Report (see Attachment A, Section A.4.1 and Addendum 2). The FFC media in the evaluated exposure scenarios included

- exposed and protected fruit,
- exposed and protected vegetables,
- root vegetables,
- beef,
- dairy products,
- pork, and
- poultry and eggs.

The algorithms used in MIRC were obtained from EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP; U.S. EPA 2005). These algorithms model the transfer of concentrations of PB-HAPs in FFC media using biotransfer factors. Environmental media concentrations (i.e., the chemical source terms in these algorithms) were obtained from TRIM.FaTE. TRIM.FaTE outputs included as inputs to MIRC to calculate exposure concentrations in farm foodstuffs included

- PB-HAP concentrations in air,
- air-to-surface deposition rates for PB-HAPs in both particle and vapor phases, and
- PB-HAP concentrations in surface soil and root zone soil.

In general, plant- and animal-specific parameter values, including chemical-specific transfer factors for FFC media, were obtained from the Hazardous Waste Companion Database included in HHRAP (U.S. EPA 2005). Except where noted specifically in this report, the parameter values used in MIRC for this risk assessment matched those used to develop Tier 1 and Tier 2 screening thresholds as described in Appendix 4 to the Risk Report. Surface soil concentrations were obtained from the estimated untilled surface soil compartments representative of hypothetical farm locations.

Fish

For the fish consumption exposure scenarios, PB-HAP concentrations in uncooked fish tissue were estimated by TRIM.FaTE. All individuals consuming fish were assumed to eat fish obtained exclusively from one of the modeled water bodies. Anglers consumed fish from two of the five fish compartments: 50 percent biomass from water column carnivores and 50 percent from benthic carnivores (as modeled in TRIM.FaTE). The average size of fish in those two compartments is 2 kg, or approximately 1 pound per fish. Although anglers can and probably do also consume smaller "pan" fish from many lakes, for the screening-level assessment, we make the health protective assumption that all fish consumed are top predatory fish in the lake.

Because the fish consumption data are reported "as consumed" and the estimated fish tissue concentrations are for uncooked fish, we adjusted the concentrations to reflect possible changes in concentration due to cooking. When cooked, fish tends to lose both water and fat, with the amount and proportion of each dependent on the cooking method. These losses affect chemical concentration in the fish as served. For chemicals that bind primarily to muscle proteins, such as mercury and cadmium, the loss of water and fat will reduce the overall weight of the fish serving without reducing the mass of chemical retained in the muscle. Cooking, therefore, effectively increases the concentrations of mercury and cadmium in the fish tissue. A cooking conversion factor of 1.5, based on data presented in Morgan et al. (1997, as cited in U.S. EPA 2011a), was used for mercury and cadmium to account for this potential.

Dioxins, however, are lipophilic and have been demonstrated to be lost during cooking. Based on a literature review, a conversion factor of 0.7 was applied to dioxin concentrations to account for the losses during the cooking process (Schecter et al., 1998; Reinert et al., 1972; Zabik and Zabik 1995).

Although assuming losses of lipophilic PAHs during the cooking process might be reasonable, information is insufficient to distinguish what the net loss (or gain) during cooking might be because cooking can create PAHs from proteins in the tissue. The literature acknowledges these competing processes, but does not provide information sufficient to disentangle the gain and loss mechanisms. As such, a neutral approach was taken, which is to assume an adjustment factor of 1.0 (i.e., no adjustment) for PAHs. (See Appendix 4 of the Risk Report: Attachment A, Addendum B, Section 6.4.4 for additional detail on cooking conversion factors.)

Breast Milk

For dioxins, exposure scenarios were evaluated in this assessment to cover exposures to nursing infants during the first year of life. Only dioxins were evaluated, given the potential for these lipophilic chemicals to partition to breast milk and the availability of methods to assess dioxins for this exposure medium. Methods for estimating chemical concentrations in breast milk based on exposure to the lactating mother are described in Appendix 4 to the Risk Report.

4.2.2 Ingestion Exposure Assessment

The following subsections describe the ingestion exposure scenarios and corresponding exposure factors used in this risk assessment.

Ingestion Exposure Media and Routes of Uptake

MIRC was used to estimate ingestion rates as average daily doses normalized to body weight for a range of exposure media. Exposure media included were incidental ingestion of soil and consumption of fish, produce, and farm animals and related products. Specific methods used to estimate exposures via these media (including calculations for any intermediate exposure media for farm animals, such as ingestion of forage) are described in detail in Appendix 4 to the Risk Report.

Summary of Exposure Scenarios

The exposure scenarios described previously were evaluated by defining ingestion activity patterns (i.e., estimating how much of each medium was consumed and the fraction of the consumed medium that was grown in or obtained from contaminated areas) and the characteristics of the hypothetical human exposed (e.g., age and body weight). MIRC computes exposure doses and risks for each ingestion medium separately, with variants of three exposure scenarios evaluated in this assessment:

1. consumption of farm-grown fruits, vegetables, and animal products, and incidental ingestion of soil;
2. consumption of self-caught fish from local water bodies; and
3. ingestion of contaminated breast milk by an infant.

For the first of these scenarios, exposed individuals were assumed to consume produce and livestock products grown at one of the farm locations. Fruits and vegetables were assumed to be contaminated from air and soil at those farms. Contaminant uptake by plants included deposition to leaves/plants, vapor transfer, and root uptake. Livestock was assumed to ingest contaminants in locally grown feed plants (i.e., forage, silage, and grain) and in soil incidentally ingested during grazing. The selection of the evaluated farm locations is described in the preceding section on fate and transport modeling. In the angler scenario, the exposed individuals were assumed to eat freshwater game fish caught in one of the modeled lakes and included in the TRIM.FaTE evaluation.

In the breast milk scenario, an infant was assumed to be exposed to contaminants ingested in the fat-content (i.e., lipid phase) of the mother's breast milk. In estimating contaminant concentrations in breast milk for the subsistence farmer scenario, the mother was assumed to be exposed through consumption of farm-grown fruits, vegetables, and animal products and through incidental ingestion of soil. For the angler scenario, maternal exposure was assumed to include only consumption of self-caught fish from modeled water bodies.

Exposure Scenario Characterization

With the exception of ingestion rates, exposures were estimated for each scenario evaluated using the same exposure factor assumptions applied in developing the Tiers 1 and 2 multipathway screening thresholds (i.e., as documented in detail in Appendix 4 to the Risk Report). This approach is likely to result in a relatively high estimate of exposure, given the assumption that all foods specific to the scenario were obtained from the local farm or lake, consumption of contaminated foods occurred continuously (i.e., exposure frequency was daily without interruption), and the exposure duration was long. With respect to ingestion rates, high-end assumptions equal to those used to derive screening thresholds were used, as were other, alternative exposure assumptions.

For the subsistence farmer scenario, two variants were evaluated using two sets of ingestion rates.

- A **reasonable maximum exposure (RME)** estimate was evaluated that uses farm foodstuff ingestion rates corresponding to the 90th percentile of consumers who produce their own food items. Soil ingestion rates corresponded to the 90th percentile of the general population. These rates are equal to the inputs used to develop the Tiers 1 and 2 screening thresholds.
- A **central tendency exposure (CTE)** estimate was evaluated that uses ingestion rates corresponding to the mean of the distribution of consumers who produce their own food. Soil ingestion rates were set to the mean of the general population.

Farm food chain and soil ingestion rates used for the farmer scenarios are summarized in Table 4-5.

Table 4-5. Farm Food Chain and Soil Ingestion Rates Used for Farmer Scenario

Product	Child (age in yr)					Adult (20–70 yrs)
	<1	1–2	3–5	6–11	12–19	
Mean ingestion rates (g/kg-day)						
Beef[a]	N/A	4.14	4.00	3.77	1.72	1.93
Dairy[b]	N/A	91.6	50.9	27.4	13.6	2.96
Eggs[a]	N/A	2.46	1.42	0.86	0.578	0.606
Exposed Fruit[a]	N/A	6.14	2.60	2.52	1.33	1.19
Exposed Vegetable[a]	N/A	3.48	1.74	1.39	1.07	1.38
Pork[a]	N/A	2.23	2.15	1.50	1.28	1.10
Poultry[a]	N/A	3.57	3.35	2.14	1.50	1.37
Protected Fruit[a]	N/A	16.6	12.4	8.50	2.96	5.19
Protected Vegetable[a]	N/A	2.46	1.30	1.10	0.78	0.862
Root Vegetable[a]	N/A	2.52	1.28	1.32	0.94	1.03
Soil (mg/day)[c]	N/A	50	50	50	50	20
90th percentile ingestion rates (g/kg-day)[d]						
Beef[a]	N/A	9.49	8.83	11.4	3.53	4.41
Dairy[b]	N/A	185	92.5	57.4	30.9	6.16
Eggs[a]	N/A	4.90	3.06	1.90	1.30	1.31
Exposed Fruit[a]	N/A	12.7	5.41	6.98	3.41	2.37
Exposed Vegetable[a]	N/A	10.7	3.47	3.22	2.35	3.09
Pork[a]	N/A	4.90	4.83	3.72	3.69	2.23
Poultry[a]	N/A	7.17	6.52	4.51	3.13	2.69
Protected Fruit[a]	N/A	44.8	32	23.3	7.44	15.1
Protected Vegetable[a]	N/A	3.88	2.51	2.14	1.85	1.81
Root Vegetable[a]	N/A	7.25	4.26	3.83	2.26	2.49
Soil (mg/day)	N/A	200[d]	200[d]	201[e]	201[e]	201[e]

[a] Primary source for values was the 1987–1988 NFCS survey; compiled results are presented in Chapter 13 of 2011 Exposure Factors Handbook (U.S. EPA 2011b). When data were unavailable for a particular age group, intake rate for all age groups was used multiplied by the age-specific ratio of intake based on national population intake rates from CSFII.

[b] Primary source for values was 1987–1988 NFCS survey, compiled results presented in Chapter 13 of 2011 Exposure Factors Handbook (U.S. EPA 2011b). When data were unavailable for a particular age group, intake rate for all age groups was used multiplied by the age-specific ratio of intake based on national population intake rates from an NHANES 2003–2006 analysis in Chapter 11 of the Exposure Factors Handbook.

[c] The recommended general population central tendency rates from EPA's 2011 EFH; Table ES-1 Chapter 5 (U.S. EPA 2011b).

[d] The recommended general population "upper percentile" rate for children aged 3 to <6 from EPA's 2011 EFH (U.S. EPA 2011b).

[e] 90th percentile adult ingestion rate calculated in Stanek et al. 1997; used to represent older children and adults.

For the angler scenario, multiple variants involving fish consumption rates for adults and children were evaluated given the importance of this parameter to multipathway exposures and the potentially wide range of fish ingestion rates.

- A **subsistence angler** was evaluated that corresponds to the same fish ingestion rates used to develop the Tiers 1 and 2 screening thresholds (see Exhibit_Att A 16 in Appendix 4 of the Risk Report). The adult rate is the 99th percentile value for adult females from Burger (2002) and is considered representative of male and female subsistence anglers. Fish ingestion rates for children are based on the 99th percentile, consumer-only fish ingestion rates from U.S. EPA (2002). Rates were adjusted to be representative of the age groups modeled in MIRC (see Attachment A, Addendum 2, Section 6.3.4.1 of Appendix 4 to the Risk Report for a detailed discussion).

- A **high-end recreational angler** was assessed by using the 95th percentile ingestion rates from the same two data sets that were used for the subsistence angler (i.e., Burger [2002] and U.S. EPA [2002]).
- **Central tendency recreational anglers** were evaluated by using mean values from the aforementioned Burger (2002) and U.S. EPA (2002) sources.
- **Fish ingestion rates for the general population** were represented by three statistics: **mean, 90th percentile, and 99th percentile.** These values are from the per-capita ingestion rates from U.S. EPA (2002) for adults and children. Per-capita ingestion rates are based on the entire population rather than the subset of the population that ingests the particular food category (i.e., consumer-only). Thus, the general population includes anglers and nonanglers, including individuals who rarely or never consume fish.

Fish ingestion rates used in these angler scenarios are summarized in Table 4-6.

Table 4-6. Fish Ingestion Rates Used for Angler Scenarios Evaluated

Scenario	Fish Ingestion Rates (g/day)	Source
Subsistence Angler[a]		
Adult	373	Female 99th %-ile ingestion rate of wild-caught fish from Burger (2002)
Child 1–2	108	Based on the 99th %-ile, *consumer-only* ingestion rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 3–5	159	
Child 6–11	268	
Child 12–19	331	
High-end Recreational Angler		
Adult	172	Female 95th %-ile ingestion rate of wild-caught fish from Burger (2002)
Child 1–2	65	Based on the 95th %-ile, *consumer-only* ingestion rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 3–5	96	
Child 6–11	181	
Child 12–19	167	
Central-tendency Recreational Angler		
Adult	39	Female mean ingestion rate of wild-caught fish from Burger (2002)
Child 1–2	18	Based on the mean, *consumer-only* ingestion rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 3–5	27	
Child 6–11	44	
Child 12–19	58	
General Population 99th Percentile		
Adult	105	Based on 99th %-ile percentile *per-capita* consumption rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 1–2	26.23	
Child 3–5	38.72	
Child 6–11	62.29	
Child 12–19	81.39	

Scenario	Fish Ingestion Rates (g/day)	Source
General Population 90th Percentile		
Adult	17	Based on 90th %-ile *per-capita* consumption rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 1–2	3.24	
Child 3–5	4.79	
Child 6–11	6.9	
Child 12–19	8.95	
General Population Central-tendency		
Adult	6.9	Based on mean *per-capita* consumption rates from U.S. EPA (2002); rates were adjusted to represent the age groups used in MIRC
Child 1–2	1.37	
Child 3–5	2.03	
Child 6–11	2.71	
Child 12–19	3.90	

[a] This ingestion scenario is the same as that evaluated in the tiered screening assessment

Evaluation of Combined Exposures

In general, exposures and the associated health risks were evaluated separately as described above for the subsistence farmer and angler scenarios, based on the assumption that a single individual at this location would be unlikely to obtain primary dietary needs (and especially protein) simultaneously from both fishing and farming. In other words, exposures were not combined across these two scenarios in most cases. There was one exception to this approach: exposures to each PB-HAP from consuming self-caught fish ***and*** farm products grown/raised at home were evaluated at the same ingestion rates used to evaluate the exposure scenario supporting Tiers 1 and 2 screening thresholds (as described in Appendix 4 to the Risk Report).

4.2.3 Risk Characterization

MIRC was used to calculate estimated incremental lifetime cancer risks and chronic non-cancer HQs using the calculated average daily doses and ingestion dose-response values. Chemical dose-response data included cancer slope factors for ingestion and non-cancer oral reference doses (RfDs) for chronic exposures. The cancer slope factors and RfDs for the PB-HAPs used to evaluate risks for this assessment are the same as those used to develop screening thresholds and are presented in the dose-response assessment in Appendix 4 to the Risk Report, along with equations used to estimate cancer risk and non-cancer hazard.

5. Results

5.1 Media Concentrations

The modeled concentrations in environmental media are presented in Appendix B to this report for the chemicals assessed. These are annual average concentrations for the 50th year of the modeling period.

For mercury (Table B-1), the relative speciation results indicate that divalent mercury was the dominant species in surface water, sediment, and surface soil. Methyl mercury was the dominant species in the higher trophic levels of the aquatic biota, progressively bioaccumulating in the food chain until it represents more than 95 percent of total mercury in game fish. These speciation trends are consistent with literature (Raymond and Rossmann 2009). The media concentrations for cadmium (Table B-2), PAH congeners (Table B-3), and dioxin congeners (Table B-4) also are provided in Appendix B.

5.2 Risk Assessment Results

The ingestion human health risk assessment results for NEI11660 are presented in this section. An overview of the risk assessment results for the exposure scenarios evaluated is provided in Section 5.2.1, while Sections 5.2.2, 5.2.3, 5.2.4, and 5.2.5 contain the results for each of the four groups of PB-HAPs. In Section 5.2.6, these results are compared to the screening-level results.

5.2.1 Risk Assessment Summary

The annual average concentrations estimated by TRIM.FaTE and MIRC for the 50th year of the modeling period were used to calculate individual, incremental lifetime cancer risks and chronic non-cancer HQs attributable to source emissions. Exposures to the emitted chemicals were based on two scenarios: a subsistence farmer who grows and consumes the majority of his food on a farm near the facility (including animal products and incidental soil ingestion) and an angler who ingests self-caught fish from nearby lakes. Because dioxin exposure can occur via consumption of breast milk by nursing infants, this medium was included in the incremental lifetime cancer risk where indicated.

Exposures to four groups of PB-HAPs were included in this assessment: mercury HQs (divalent for farm exposure, and methyl for fish exposure), cadmium HQs, dioxin incremental lifetime cancer risks (with 17 individual congeners), and PAH incremental lifetime cancer risks (with 13 individual congeners; 3 of the 18 emitted PAH congeners were not carcinogenic and not modeled, and the emissions of 2 other congeners were merged with other congeners because they are not parameterized in TRIM.FaTE). The cancer risks for dioxin congeners were summed into a total dioxin risk, and likewise for PAH congeners.

Non-cancer HQs from mercury or cadmium did not exceed 1 (interpreted as values 1.5 or larger) for any exposure location or scenario exposure. For methyl mercury, the largest HQ was 1 for the subsistence angler. For cadmium, the largest HQ was 0.09 for the subsistence angler.

Cancer results from exposure to PAHs included incremental lifetime cancer risks greater than 1-in-one million for several ingestion scenarios from exposure at Veto Lake (risks up to 3-in-one million) and from exposure at all modeled farms (risks up to 7-in-one million).

Cancer risks from exposure to dioxins did not exceed 1-in-one million for angler exposure, although risks from farm exposure were as large as 3-in-one million at 90th percentile ingestion rates.

For each PB-HAP group, these site-specific assessment hazard and risk estimates were smaller than the screening-level assessment results presented in Section 2 using the subsistence farmer at 90th percentile ingestion rate and the subsistence angler fish ingestion rate (which were the screening assessment exposure scenarios), and using the same lakes as in the screening. This demonstrates that the screening-level assessments avoided underestimating risk for this facility.

More detailed results for each PB-HAP chemical or group are presented in the following subsections, along with a more comprehensive comparison with the screening-level assessment results.

5.2.2 Hazard Quotients Associated With Mercury Exposure

Non-cancer HQs from exposure to methyl mercury (from fish exposure only) and to divalent mercury (from subsistence farm exposure only) are presented in Table 5-1 and Table 5-2, respectively. The HQs from exposure to methyl mercury via fish ingestion did not exceed 1 (i.e., were smaller than 1.5). HQs for angler scenarios are not shown here for divalent mercury because they were several orders of magnitude less than the methyl mercury values. The HQs from exposure to divalent mercury via the farm were several orders of magnitude less than 1; HQs for the subsistence farm scenarios are not shown for methyl mercury because they were over an order of magnitude less than the divalent mercury values.

Figure 5-1 shows the levels at which each ingested farm medium (beef, eggs, pork, etc.) contributed to the total subsistence farmer HQ for each age group (farm medium-specific hazard quotients are provided in Table 5-3). No one medium contributed a majority of the HQ value. Overall, protected fruit, root vegetables, soil, protected vegetables, and exposed fruit each tended to contribute at least 10 percent of the value and together accounted for most of the value.

5.2.3 Hazard Quotients Associated With Cadmium Exposure

Non-cancer HQs from exposure to cadmium via fish exposure only and via subsistence farm exposure only are presented in Table 5-4 and Table 5-5, respectively. All HQs were several orders of magnitude lower than 1.

Figure 5-2 shows the levels at which each ingested farm medium (beef, eggs, pork, etc.) contributed to the total subsistence farmer HQ for each age group (farm medium-specific hazard quotients are provided in Table 5-6). Exposure to protected fruit tended to contribute close to the majority of the total HQ value, followed distantly by exposed fruit and protected vegetables.

Table 5-1. Hazard Quotients from Exposure to Methyl Mercury for Angler Scenarios[a]

Angler Population	Ingestion Level	Period of Exposure (years of age)	Hazard Quotient		
			Wolf Run Lake	**Veto Lake**	**Mountwood Park Lake**
Subsistence Angler	99th %ile	1–2	**<u>1E+00</u>**	2E-01	2E-02
		3–5	1E+00	2E-01	2E-02
		6–11	1E+00	2E-01	1E-02
		12–19	7E-01	1E-01	1E-02
		20–70 (adult)	6E-01	1E-01	9E-03
Recreational Angler	Central Tendency (Mean)	1–2	2E-01	3E-02	3E-03
		3–5	2E-01	3E-02	3E-03
		6–11	2E-01	3E-02	2E-03
		12–19	1E-01	2E-02	2E-03
		20–70 (adult)	6E-02	1E-02	9E-04
	High-end (95th %ile)	1–2	7E-01	1E-01	9E-03
		3–5	7E-01	1E-01	9E-03
		6–11	7E-01	1E-01	9E-03
		12–19	3E-01	6E-02	5E-03
		20–70 (adult)	3E-01	5E-02	4E-03
General Population	Central Tendency (Mean)	1–2	1E-02	2E-03	2E-04
		3–5	1E-02	2E-03	2E-04
		6–11	1E-02	2E-03	1E-04
		12–19	8E-03	1E-03	1E-04
		20–70 (adult)	1E-02	2E-03	2E-04
	90th %ile	1–2	3E-02	6E-03	5E-04
		3–5	3E-02	6E-03	5E-04
		6–11	3E-02	4E-03	4E-04
		12–19	2E-02	3E-03	3E-04
		20–70 (adult)	3E-02	5E-03	4E-04
	99th %ile	1–2	3E-01	5E-02	4E-03
		3–5	3E-01	5E-02	4E-03
		6–11	2E-01	4E-02	3E-03
		12–19	2E-01	3E-02	2E-03
		20–70 (adult)	2E-01	3E-02	2E-03

[a] Bolded, underlined cell indicates the largest value in this table. Hazard quotients rounded to one significant figure.

Table 5-2. Hazard Quotients from Exposure to Divalent Mercury for Subsistence Farmer Scenarios[a]

Ingestion Level	Period of Exposure (years of age)	Hazard Quotient		
		Farm_SE	Farm_NNW	Farm_WSW
Mean	1–2	4E-03	2E-03	6E-04
	3–5	2E-03	1E-03	3E-04
	6–11	2E-03	9E-04	3E-04
	12–19	1E-03	5E-04	1E-04
	20–70 (adult)	1E-03	6E-04	2E-04
90th %ile	1–2	**1E-02**	5E-03	2E-03
	3–5	7E-03	3E-03	9E-04
	6–11	5E-03	2E-03	7E-04
	12–19	3E-03	1E-03	4E-04
	20–70 (adult)	3E-03	2E-03	4E-04

[a] Bolded, underlined cell indicates the largest value in this table. Hazard quotients rounded to one significant figure.

Figure 5-1. Contribution to Hazard Quotients by Ingested Medium, per Age Group, from Exposure to Divalent Mercury at "Farm_SE"

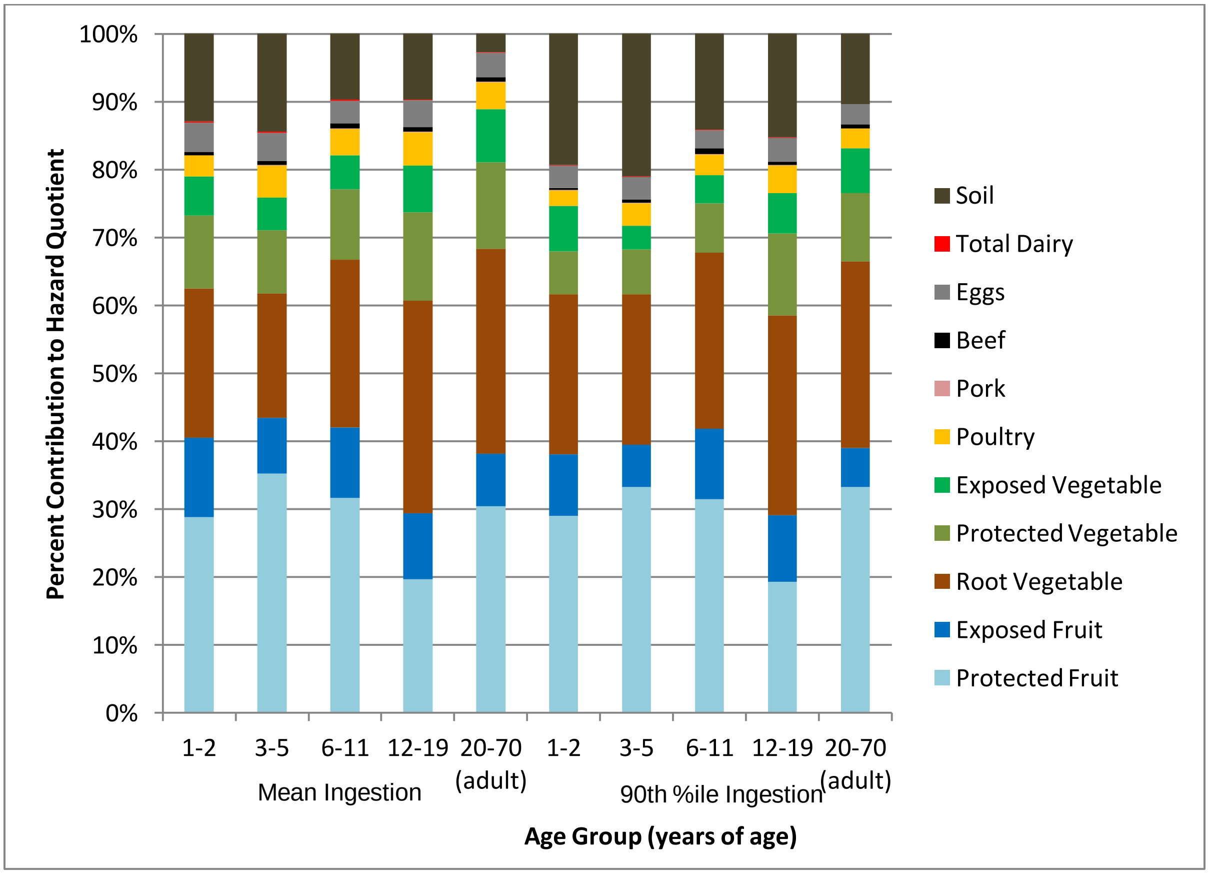


Table 5-3. Hazard Quotients by Ingested Medium, per Age Group, from Exposure to Divalent Mercury at "Farm_SE"[a]

Ingestion Level	Period of Exposure (years of age)	Hazard Quotient											
		Breast Milk	**Soil**	**Total Dairy**	**Eggs**	**Beef**	**Pork**	**Poultry**	**Exposed Vegetable**	**Protected Vegetable**	**Root Vegetable**	**Exposed Fruit**	**Protected Fruit**
Mean	1-2	0	5.0E-04	6.9E-06	1.7E-04	1.5E-05	1.7E-06	1.2E-04	2.3E-04	4.2E-04	8.6E-04	4.6E-04	1.1E-03
	3-5	0	3.4E-04	3.8E-06	9.9E-05	1.5E-05	1.7E-06	1.1E-04	1.1E-04	2.2E-04	4.3E-04	1.9E-04	8.4E-04
	6-11	0	1.8E-04	2.1E-06	6.0E-05	1.4E-05	1.1E-06	7.2E-05	9.1E-05	1.9E-04	4.5E-04	1.9E-04	5.7E-04
	12-19	0	9.9E-05	1.0E-06	4.0E-05	6.4E-06	9.8E-07	5.0E-05	7.0E-05	1.3E-04	3.2E-04	9.9E-05	2.0E-04
	20-70 (adult)	0	3.2E-05	2.2E-07	4.2E-05	7.2E-06	8.4E-07	4.6E-05	9.0E-05	1.5E-04	3.5E-04	8.9E-05	3.5E-04
90th %ile	1-2	0	2.0E-03	1.4E-05	3.4E-04	3.5E-05	3.8E-06	2.4E-04	7.0E-04	6.6E-04	2.5E-03	9.5E-04	**3.0E-03**
	3-5	0	1.4E-03	7.0E-06	2.1E-04	3.3E-05	3.7E-06	2.2E-04	2.3E-04	4.3E-04	1.4E-03	4.0E-04	2.2E-03
	6-11	0	7.1E-04	4.3E-06	1.3E-04	4.2E-05	2.9E-06	1.5E-04	2.1E-04	3.7E-04	1.3E-03	5.2E-04	1.6E-03
	12-19	0	4.0E-04	2.3E-06	9.1E-05	1.3E-05	2.8E-06	1.0E-04	1.5E-04	3.2E-04	7.7E-04	2.5E-04	5.0E-04
	20-70 (adult)	0	3.2E-04	4.7E-07	9.1E-05	1.6E-05	1.7E-06	9.0E-05	2.0E-04	3.1E-04	8.4E-04	1.8E-04	1.0E-03

[a]The numbers in this table were used to make the cumulative stacked bar chart shown in Figure 5-1. The bolded, underlined cell indicates the largest risk value in this table. Hazard quotients rounded to two significant figures.

Table 5-4. Hazard Quotients from Exposure to Cadmium for Angler Scenarios[a]

Angler Population	Ingestion Level	Period of Exposure	Hazard Quotient		
			Wolf Run Lake	Veto Lake	Mountwood Park Lake
Subsistence Angler	99th %ile	1–2	5E-02	**9E-02**	3E-02
		3–5	5E-02	9E-02	3E-02
		6–11	5E-02	8E-02	3E-02
		12–19	3E-02	5E-02	2E-02
		20–70 (adult)	3E-02	5E-02	2E-02
Recreational Angler	Central Tendency (Mean)	1–2	9E-03	2E-02	5E-03
		3–5	9E-03	2E-02	5E-03
		6–11	8E-03	1E-02	4E-03
		12–19	6E-03	9E-03	3E-03
		20–70 (adult)	3E-03	5E-03	2E-03
	High-end (95th %ile)	1–2	3E-02	5E-02	2E-02
		3–5	3E-02	5E-02	2E-02
		6–11	3E-02	5E-02	2E-02
		12–19	2E-02	3E-02	9E-03
		20–70 (adult)	1E-02	2E-02	7E-03
General Population	Central Tendency (Mean)	1–2	7E-04	1E-03	4E-04
		3–5	7E-04	1E-03	4E-04
		6–11	5E-04	8E-04	3E-04
		12–19	4E-04	6E-04	2E-04
		20–70 (adult)	5E-04	9E-04	3E-04
	90th %ile	1–2	2E-03	3E-03	9E-04
		3–5	2E-03	3E-03	9E-04
		6–11	1E-03	2E-03	7E-04
		12–19	9E-04	1E-03	5E-04
		20–70 (adult)	1E-03	2E-03	7E-04
	99th %ile	1–2	1E-02	2E-02	7E-03
		3–5	1E-02	2E-02	7E-03
		6–11	1E-02	2E-02	6E-03
		12–19	8E-03	1E-02	4E-03
		20–70 (adult)	8E-03	1E-02	5E-03

[a] Bolded, underlined cell indicates the largest value in this table. Hazard quotients rounded to one significant figure.

Table 5-5. Hazard Quotients from Exposure to Cadmium for Subsistence Farmer Scenarios[a]

Ingestion Level	Period of Exposure (years of age)	Hazard Quotient		
		Farm_SE	Farm_NNW	Farm_WSW
Mean	1–2	2E-02	5E-03	1E-02
	3–5	1E-02	3E-03	8E-03
	6–11	9E-03	2E-03	6E-03
	12–19	5E-03	1E-03	3E-03
	20–70 (adult)	6E-03	1E-03	4E-03
90th %ile	1–2	**5E-02**	1E-02	3E-02
	3–5	3E-02	7E-03	2E-02
	6–11	2E-02	6E-03	2E-02
	12–19	1E-02	3E-03	8E-03
	20–70 (adult)	1E-02	3E-03	1E-02

[a] Bolded, underlined cell indicates the largest value in this table. Hazard quotients rounded to one significant figure.

Figure 5-2. Contribution to Hazard Quotients by Ingested Medium, per Age Group, from Exposure to Cadmium at "Farm_SE"

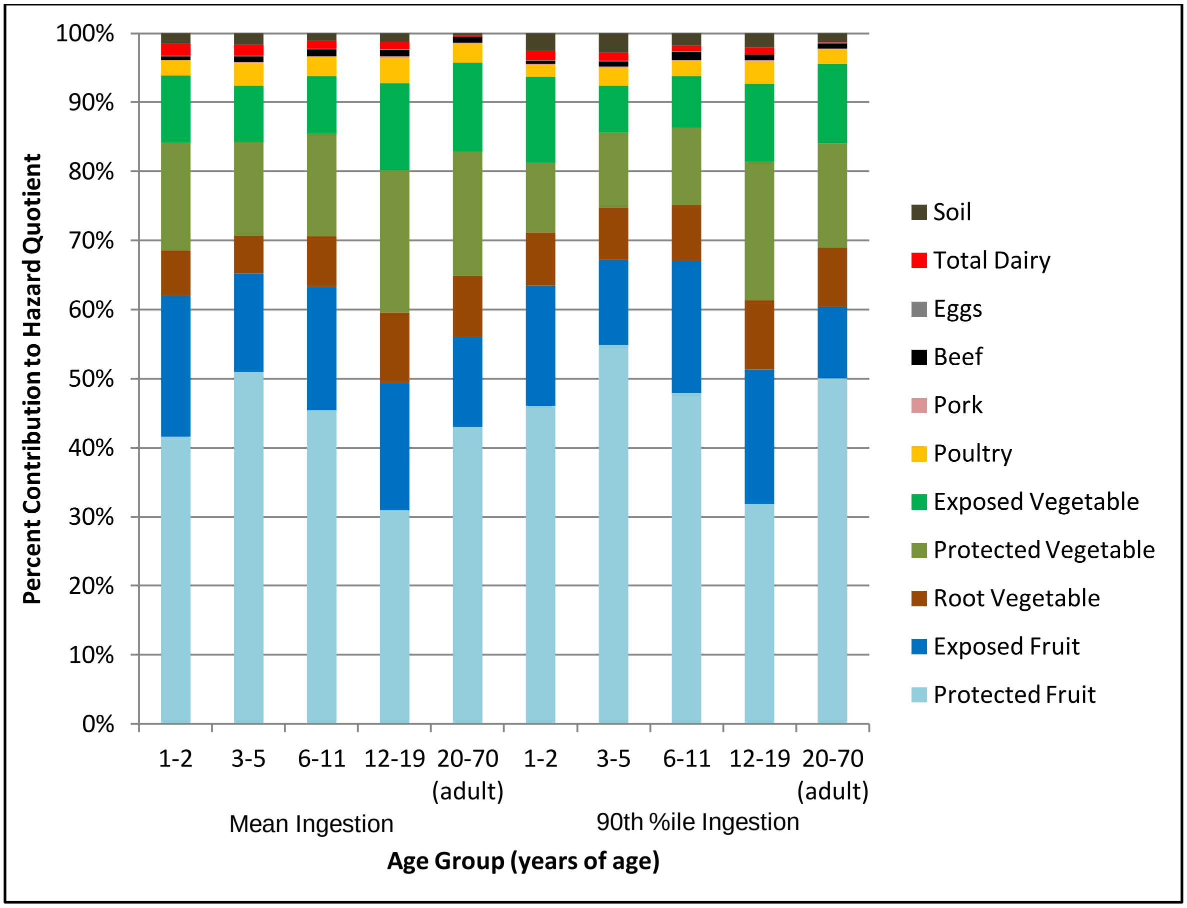


Table 5-6. Hazard Quotients by Ingested Medium, per Age Group, from Exposure to Cadmium at "Farm_SE"[a]

Ingestion Level	Period of Exposure (years of age)	Hazard Quotient											
		Breast Milk	**Soil**	**Total Dairy**	**Eggs**	**Beef**	**Pork**	**Poultry**	**Exposed Vegetable**	**Protected Vegetable**	**Root Vegetable**	**Exposed Fruit**	**Protected Fruit**
Mean	1-2	0	2.8E-04	3.3E-04	1.4E-05	1.0E-04	1.4E-05	4.1E-04	1.9E-03	3.0E-03	1.2E-03	3.9E-03	7.9E-03
	3-5	0	1.9E-04	1.8E-04	8.0E-06	1.0E-04	1.3E-05	3.8E-04	9.3E-04	1.6E-03	6.3E-04	1.6E-03	5.9E-03
	6-11	0	1.0E-04	9.9E-05	4.8E-06	9.4E-05	9.2E-06	2.4E-04	7.5E-04	1.3E-03	6.5E-04	1.6E-03	4.0E-03
	12-19	0	5.6E-05	4.9E-05	3.2E-06	4.3E-05	7.9E-06	1.7E-04	5.7E-04	9.4E-04	4.6E-04	8.4E-04	1.4E-03
	20-70 (adult)	0	1.8E-05	1.1E-05	3.4E-06	4.8E-05	6.8E-06	1.6E-04	7.4E-04	1.0E-03	5.1E-04	7.5E-04	2.5E-03
90th %ile	1-2	0	1.1E-03	6.7E-04	2.7E-05	2.4E-04	3.0E-05	8.2E-04	5.7E-03	4.7E-03	3.6E-03	8.0E-03	**2.1E-02**
	3-5	0	7.7E-04	3.3E-04	1.7E-05	2.2E-04	3.0E-05	7.4E-04	1.9E-03	3.0E-03	2.1E-03	3.4E-03	1.5E-02
	6-11	0	4.0E-04	2.1E-04	1.1E-05	2.9E-04	2.3E-05	5.2E-04	1.7E-03	2.6E-03	1.9E-03	4.4E-03	1.1E-02
	12-19	0	2.2E-04	1.1E-04	7.3E-06	8.8E-05	2.3E-05	3.6E-04	1.3E-03	2.2E-03	1.1E-03	2.2E-03	3.5E-03
	20-70 (adult)	0	1.8E-04	2.2E-05	7.3E-06	1.1E-04	1.4E-05	3.1E-04	1.7E-03	2.2E-03	1.2E-03	1.5E-03	7.2E-03

[a] The values in this table were used to make the cumulative stacked bar chart shown in Figure 5-2. The bolded, underlined cell indicates the largest risk value in this table. Hazard quotients rounded to two significant figures.

5.2.4 Cancer Risks Associated With PAH Exposure

Incremental lifetime cancer risks from exposure to PAHs via fish exposure only and via subsistence farm exposure only are presented in Table 5-7 and Table 5-8, respectively. The risks from exposure to PAHs via fish ingestion exceeded 1-in-one million for Veto Lake (3-in-one million or 2-in-one million, depending on the ingestion scenario) and was driven primarily by emissions of benzo(b)fluoranthene and secondarily by emissions of benzo(k)fluoranthene. The risks from exposure to PAHs via the farm exceeded 1-in-one million using the mean ingestion rate at “Farm_NNW” and “Farm_SE” (3-in-one million for both), and for all farms using the 90th percentile ingestion rate (7-, 7-, and 2-in-one million respectively at Farm_NNW, Farm_SE, and Farm_WSW) and were driven primarily by emissions of BaP and benzo(b)fluoranthene and secondarily by emissions of benzo(k)fluoranthene. HQs for PAH exposure are not shown because non-cancer RfDs were available only for a small subset of congeners, and the HQs for these congeners summed to values many orders of magnitude less than 1 (thus, the cancer assessment was more protective).

Figure 5-3 shows the levels at which each ingested farm medium (beef, eggs, pork, etc.) contributed to the total incremental lifetime subsistence farmer risk (farm medium-specific risks are provided in Table 5-9). No one medium contributed a majority of the risk value, although exposures to dairy and exposed fruits together accounted for most of the risk, followed by exposed vegetables and beef.

Table 5-7. Incremental Lifetime Cancer Risks from Exposure to PAHs for Angler Scenarios[a,b,c]

Angler Population	Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk		
			Wolf Run Lake	Veto Lake	Mountwood Park Lake
Subsistence Angler	99th %ile	Lifetime	1E-06	**3E-06**	5E-07
Recreational Angler	Central Tendency (Mean)	Lifetime	2E-07	5E-07	7E-08
	95th %ile	Lifetime	6E-07	2E-06	3E-07
General Population	Mean	Lifetime	2E-08	5E-08	7E-09
	90th %ile		4E-08	1E-07	2E-08
	99th %ile		3E-07	9E-07	1E-07

[a] Lifetime is ages 1 through 70. Risks rounded to one significant figure.

[b] Shading corresponds to values that exceed 1-in-one million, rounded (which is defined as at least 1.5-in-one million).

[c] Bolded, underlined cell indicates the largest value in this table.

Table 5-8. Incremental Lifetime Cancer Risk from Exposure to PAHs for Subsistence Farmer Scenarios[a,b,c]

Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk		
		Farm_SE	Farm_NNW	Farm_WSW
Mean	Lifetime	3E-06	3E-06	1E-06
90th %ile	Lifetime	7E-06	**7E-06**	2E-06

[a] Lifetime is ages 1 through 70. Risks rounded to one significant figure.

[b] Shading corresponds to values that exceed 1-in-one million, rounded (which is defined as at least 1.5-in-one million).

[c] Bolded, underlined cell indicates the largest value in this table.

Figure 5-3. Contribution to Incremental Lifetime Cancer Risk by Ingested Medium from Exposure to PAHs at "Farm_NNW"

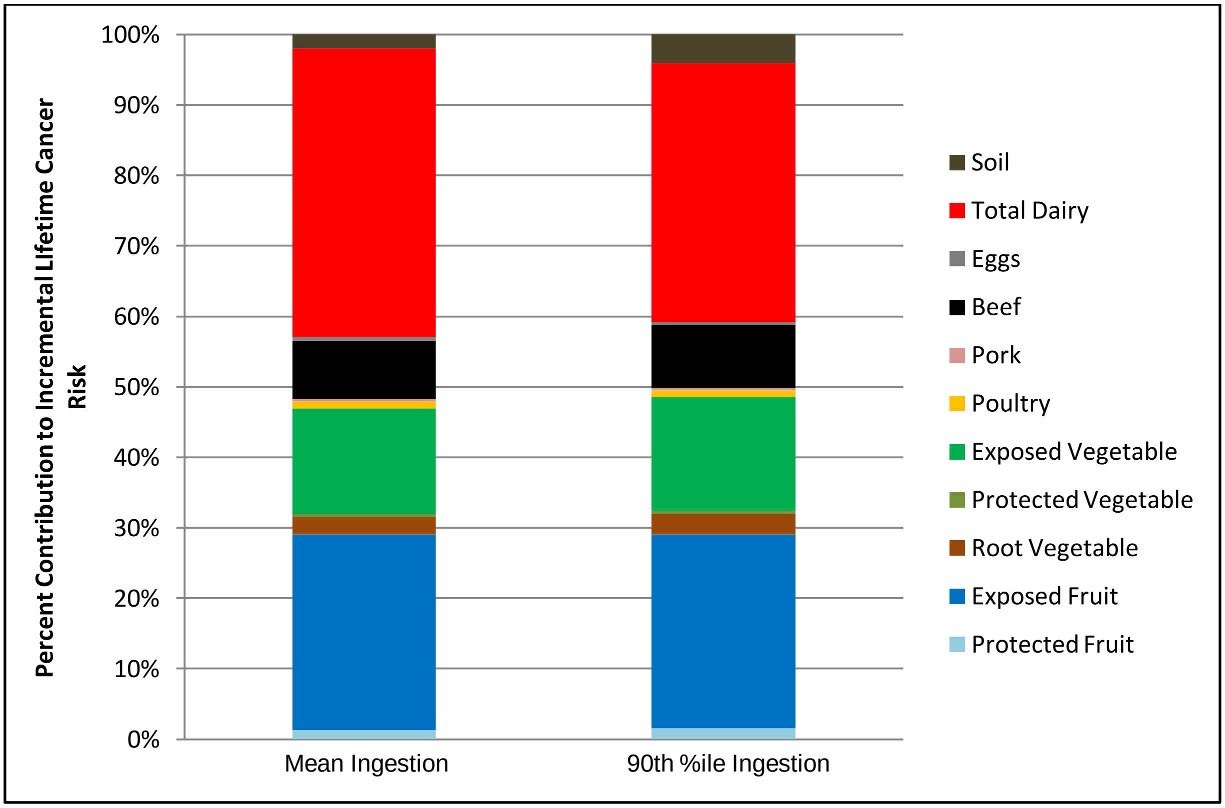


Table 5-9. Incremental Lifetime Cancer Risk by Ingested Medium from Exposure to PAHs at "Farm_NNW"[a]

Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk											
		Breast Milk	Soil	Total Dairy	Eggs	Beef	Pork	Poultry	Exposed Vegetable	Protected Vegetable	Root Vegetable	Exposed Fruit	Protected Fruit
Mean	Lifetime	0	6.6E-08	1.3E-06	1.8E-08	2.7E-07	1.2E-08	3.2E-08	4.9E-07	1.6E-08	7.9E-08	9.1E-07	4.3E-08
90th %ile	Lifetime	0	3.0E-07	**2.7E-06**	3.9E-08	6.6E-07	2.8E-08	6.5E-08	1.2E-06	3.2E-08	2.1E-07	2.0E-06	1.2E-07

[a] The values in this table were used to make the cumulative stacked bar chart shown in Figure 5-3. The bolded, underlined cell indicates the largest risk value in this table. Risks rounded to two significant figures.

5.2.5 Cancer Risks Associated With Dioxin Exposure

Incremental lifetime cancer risks from exposure to dioxins via fish exposure only and via subsistence farm exposure only are presented in Table 5-10 and Table 5-11, respectively. The risks from exposure to dioxins exceeded 1-in-one million for “Farm_SE” and “Farm_NNW” using the 90th percentile ingestion rate (3-in-one million for both) and were below 1-in-one million for all angler exposure scenarios. The angler risks were driven primarily by emissions of 1,2,3,7,8-PCDD and secondarily by 2,3,7,8-TCDD. The subsistence farmer risks were driven primarily by emissions of 1,2,3,7,8-PCDD and secondarily by 2,3,4,7,8-PCDF and 2,3,7,8-TCDD. HQs for dioxin exposure are not shown because non-cancer RfDs were available only for one modeled congener, and the HQs for that congener were well below 1 (thus, the cancer assessment was more protective).

Figure 5-4 shows the levels at which each ingested farm medium (beef, eggs, pork, etc.) contributed to the total lifetime subsistence farmer risk (farm medium-specific risks are provided in Table 5-12). The dairy medium contributed most of the risk, followed by infant exposure via breast milk and beef exposure.

Table 5-10. Incremental Lifetime Cancer Risks from Exposure to Dioxins for Angler Scenarios[a,b]

Angler Population	Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk		
			Wolf Run Lake	Veto Lake	Mountwood Park Lake
Subsistence Angler	99th %ile	Lifetime	6E-07	**<u>1E-06</u>**	3E-07
Recreational Angler	Central Tendency (Mean)	Lifetime	8E-08	1E-07	3E-08
	95th %ile	Lifetime	3E-07	5E-07	1E-07
General Population	Mean	Lifetime	1E-08	2E-08	4E-09
	90th %ile		3E-08	4E-08	1E-08
	99th %ile		2E-07	3E-07	7E-08

[a] Lifetime is ages 1 through 70, including infant exposure to chemical from an adult mother’s breast milk, where the adult mother’s exposure period did not include childhood. Risks rounded to one significant figure.

[b] Bolded, underlined cell indicates the largest value in this table.

Table 5-11. Incremental Lifetime Cancer Risk from Exposure to Dioxins for Subsistence Farmer Scenarios[a,b,c]

Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk		
		Farm_SE	Farm_NNW	Farm_WSW
Mean	Lifetime	1E-06	1E-06	5E-07
90th %ile	Lifetime	3E-06	**<u>3E-06</u>**	1E-06

[a] Lifetime is ages 1 through 70, including infant exposure to chemical from an adult mother’s breast milk, where the adult mother’s exposure period did not include childhood. Risks rounded to one significant figure.

[b] Shading corresponds to values that exceed 1-in-one million, rounded (which is defined as at least 1.5-in-one million).

[c] Bolded, underlined cell indicates the largest value in this table.

Figure 5-4. Contribution to Incremental Lifetime Cancer Risk by Ingested Medium from Exposure to Dioxins at "Farm_NNW"

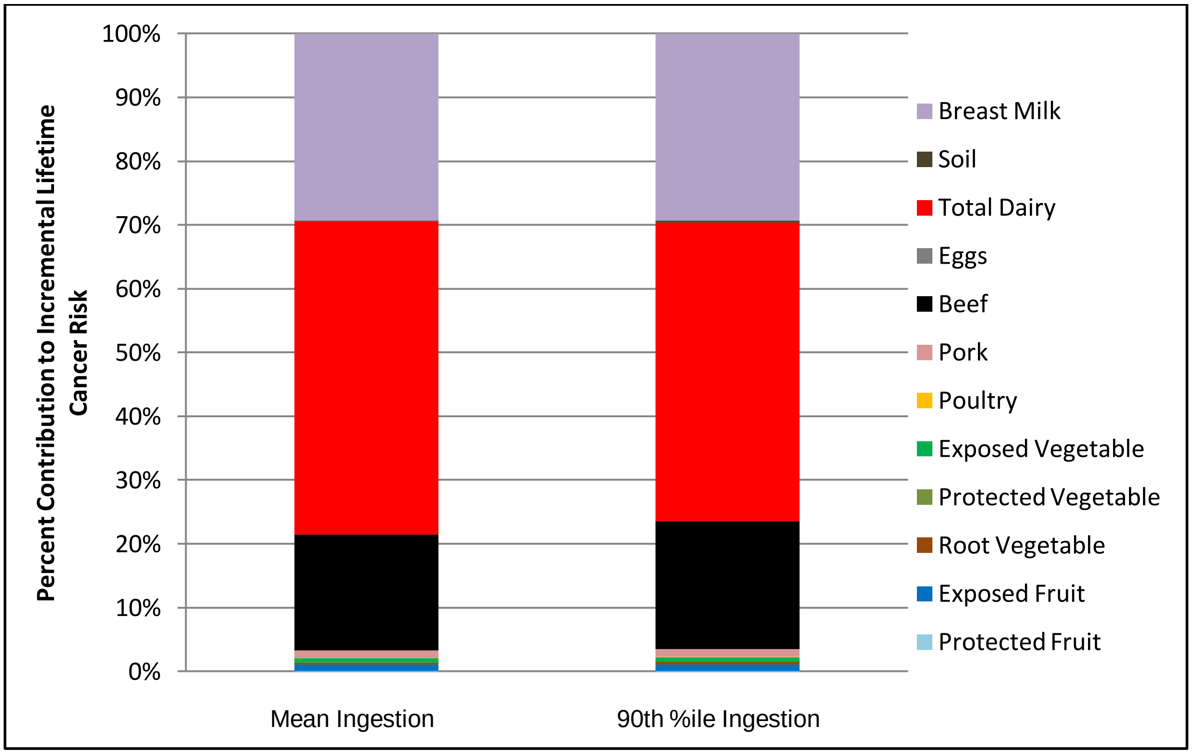


Table 5-12. Incremental Lifetime Cancer Risk by Ingested Medium from Exposure to Dioxins at "Farm_NNW"[a]

Ingestion Level	Period of Exposure	Incremental Lifetime Cancer Risk											
		Breast Milk	Soil	Total Dairy	Eggs	Beef	Pork	Poultry	Exposed Vegetable	Protected Vegetable	Root Vegetable	Exposed Fruit	Protected Fruit
Mean	Lifetime	4.2E-07	1.5E-09	7.0E-07	2.9E-10	2.6E-07	1.7E-08	5.5E-10	1.0E-08	2.3E-10	4.2E-09	1.5E-08	5.7E-10
90th %ile	Lifetime	9.0E-07	8.9E-09	**1.4E-06**	6.3E-10	6.2E-07	3.7E-08	1.1E-09	2.3E-08	4.8E-10	1.1E-08	3.2E-08	1.6E-09

[a] The values in this table were used to make the cumulative stacked bar chart shown in Figure 5-4. The bolded, underlined cell indicates the largest risk value in this table. Risks rounded to two significant figures.

5.2.6 Comparison to Screening-level Assessment Results

Table 5-13 presents the screening-level assessment results (from Section 2) as ratios of the emissions for this facility to the screening thresholds. Although these values are not intended to be interpreted as “risk estimates,” they can be used to evaluate the impact of site-specific fate and transport modeling by comparing the screening quotients to the site-specific risk results. The site-specific HQs and incremental lifetime cancer risks shown here correspond to the same exposure scenarios used in the screening-level assessment, which represents ingestion of both farm products and fish.

As discussed in Section 2.2, the Tier 2 screening resulted in lower screening quotients than the Tier 1 screening, and, as expected (and illustrated by the results shown in Table 5-13), the site-specific risks and hazards were lower than the Tier 2 screening quotients.

- The site-specific HQ for mercury, summed for the highest-risk lake and highest-risk farm, was approximately 50 times smaller than the Tier 2 screening quotient.
- For cadmium, the site-specific HQ was approximately 6 times smaller than the Tier 2 screening quotient.
- The site-specific incremental lifetime cancer risk from PAH exposure was approximately 3 times smaller than the Tier 2 screening quotient.
- The site-specific incremental lifetime cancer risk from dioxin exposure was approximately 2 times smaller than the Tier 2 screening quotient.
- The sum of the site-specific incremental lifetime cancer risks due to exposures to PAHs and dioxins was 10-in-one million, which was much smaller than the Tiers 2 and 1 screening quotients (interpreted for comparative purposes as 30-in-one million and 300-in-one million, respectively).

Table 5-13. Comparison of Site-specific Hazard Quotients and Cancer Risks to the Results of the Screening-level Assessments[a]

	Screening Quotient		Site-specific Hazard Quotient or Risk[b]			Factor Decrease in HQ or Risk		
PB-HAP Group	**Tier 1**	**Tier 2**	**Via Fish Only[c]**	**Via Farm Only[d]**	**Combined Fish + Farm**	**Tier 1 to Tier 2**	**Tier 2 to Site-specific**	**Tier 1 to Site-specific**
Mercury[e] (non-cancer)	100	9	0.2	0.01	0.2	12	47	550
Cadmium (non-cancer)	10	0.9	0.09	0.05	0.1	12	6.4	76
PAHs (cancer)	200	20	1	7	9	10	2.5	26
Dioxins (cancer)	80	7	1	3	4	12	1.6	20
Total Incremental Lifetime Cancer Risk (PAH + Dioxin)	300	30	2	10	10	11	2.2	24

[a] Shading corresponds to values that exceed 1, which is defined as at least 1.5. Rounding artifacts are present.

[b] Site-specific values are hazard quotients for mercury and cadmium, and lifetime incremental cancer risk as "in-one million" (i.e., divided by 1×10^{-6}) for PAHs and dioxins. To be congruent with the setup of the screening assessments, these site-specific values use the Child 1–2 age group for HQs (the ingestion amount per body weight is largest for the Child 1–2 category), a lifetime defined as age 1 through age 70 (including infant breast milk for dioxin exposure) for cancer risk, the "subsistence angler" scenario for fish exposure, and the 90th percentile ingestion rate for subsistence farmer exposure.

[c] Wolf Run Lake for PAHs, Veto Lake for others

[d] Farm_SE for non-cancer, Farm_NNW for cancer

[e] Exposure to methyl mercury was evaluated for fish exposure, while exposure to divalent mercury was evaluated for subsistence farmer exposure.

6. Discussion of Uncertainties and Limitations

The exposure and risk modeling process attempts to simulate naturally occurring physical, chemical, and biological processes using mathematical algorithms. For computational tractability in a risk assessment, the modeling process generally involves simple representations of many complex real-world processes. The simplification introduces uncertainty. Furthermore, algorithms that describe the environmental movement of pollutants depend on numerous environmental parameters for which the values might be naturally variable and for which available data are limited.

The media concentration and risk results presented in Section 5 therefore must be interpreted in light of the uncertainties associated with the model assumptions, structure, and input values. How mercury, cadmium, PAHs, and dioxins behave in the environment is highly complex, and many natural processes are represented in a simplified manner by TRIM.FaTE, including

- gaseous and particulate deposition from air;
- biogeochemical cycling in the aquatic environment, and especially mercury transformations through methylation and demethylation at the sediment-surface interface;
- mixing processes in air, water, and sediment;

- suspended and benthic sediment dynamics in lakes; and
- biotic processes such as growth, reproduction, and predation.

In addition, the toxicology of the modeled chemicals is complex and uncertain, as are the estimates of human exposure to these chemicals given the available empirical data. Note that surrogate congeners were used for emissions of two PAH congeners that currently are not parameterized in TRIM.FaTE.

Examples of parameters for which values are variable and uncertain include aquatic food web structure (e.g., diet of each fish species), biokinetic parameters that influence bioaccumulation (e.g., assimilation efficiencies and elimination rates), topographic characteristics (e.g., lake depth, runoff rates, and erosion rates), meteorological parameters (e.g., evaporation and precipitation rates), chemical transformation rates (e.g., methylation and demethylation rates, in the case of mercury), human exposure parameters (especially fish consumption rates), and the reference dose/cancer slope factors used to assess potential adverse health effects.

We have conducted several analyses of the sensitivity of risk estimates to parameter values over the past decade. For those parameters to which the model is particularly sensitive, we have continued to collect additional data to better quantify the variability and distribution of values. Nonetheless, because of the large number of parameters included, considering the model in total, we did not attempt a probabilistic risk assessment. Instead, this analysis relied on central tendency values and combinations of values that would lead to estimates of reasonable maximum exposures to bound risk estimates.

This analysis evaluated exposure to chemicals that could be attributed to the modeled facility; background levels of the modeled chemicals were not included. Thus, the assessment focuses on incremental risks attributable to the facility. We did not estimate the number or fraction of people potentially affected in the modeling zones, nor did we estimate specific endpoints like IQ decrements or cardiovascular effects. The assessment focused on possible central tendency and high-end exposures for selected exposure scenarios for individuals that might live near a facility now or in the future.

Major sources of uncertainty affecting model results are shown in Table 6-1. Table 6-1 provides the assessment input of concern, a qualitative judgment of the sensitivity of risk results to the assessment input (in general, not limited just to this facility), and a general comment. The table also provides a qualitative judgment of the impact on modeled risk based on the sensitivity to the assessment input and based on the range of values manifested by the assessment input in the environment. In other words, the second column (Sensitivity of Risk Results) describes the sensitivity of model results to changes in the assessment input, and the fourth column (Estimated Impact of Uncertainty on Results) takes into account both the sensitivity (column two) and the variability of the assessment input. Inputs that exhibit high risk sensitivity could have a limited impact in terms of overall uncertainty, and vice versa, depending on the range of values manifested by the input. Each source of uncertainty also is discussed in greater detail below.

6.1 Uncertainties Related to Fate and Transport Modeling (TRIM.FaTE)

The algorithms representing the transport and eventual fate of the modeled chemicals in air, surface water, sediment, and biotic media are simplified representations of complex natural processes. Estimated chemical deposition rates and concentrations will vary across different environmental models and might be most accurate in specific conditions that meet restrictive assumptions. The TRIM.FaTE model represents all fate and transport processes in terms of first-order differential equations; however, some processes like chemical diffusion are known to follow second-order dynamics. Other algorithms—like those dealing with methylation and demethylation in the case of mercury, biotic chemical cycling, and sediment dynamics—do not consider all the factors known to affect these processes, or the processes might not be well understood. This section expands on some of the major uncertainties included in Table 6-1 that are specific to the fate and transport modeling conducted for the case studies.

Table 6-1. Sources of Uncertainty in the Current Site-specific Assessment

Assessment Input	Sensitivity of Risk Results	Comment	Estimated Impact of Uncertainty on Results
Aquatic food web parameters	High	Limited data on chemical- and species-specific parameters, such as assimilation efficiency and elimination rates.	Medium
Depth of lakes	High	Based on limited data. Averaged over lake area and time. Perfect mixing assumed in estimating concentrations.	Medium
Toxicity reference value (RfD) and cancer slope factors	High	Used EPA-recommended values where possible (estimated from TEFs for most dioxin congeners), but estimate includes inherent variability and uncertainty. Surrogate congeners were used for the emissions of two PAH congeners that are not currently fully parameterized in TRIM.FaTE.	Low to Medium
Fate and transport modeling process	High	TRIM.FaTE model might not capture all natural processes or describe them precisely for particular sites.	Low to Medium
Ingestion exposure parameters	High	There is a great deal of variability and uncertainty in ingestion rates, which is compounded when assessing exposures from multiple food groups. In general, used EPA-recommended health-protective values.	Medium
Methylation and demethylation rates in sediment, wetlands, and surface water (mercury only)	High	Model uses fixed rate constants for methylation and demethylation in abiotic media. Model does not capture complex dependence of rate constants on environmental conditions, except for differences between wetlands and unsaturated land.	Medium
Retention time/flush rate	Medium-High	From literature (for Mountwood Park Lake and Wolf Run Lake) or calculated from lake dimensions and flow formulas. Independent data would help validate inflows and runoff fractions.	Low to Medium
Modeling resolution and layout	Medium	Resolution of compartments in modeling zone is relatively coarse. Larger area averaging could dilute exposure point concentrations.	Low
Erosion and runoff flow directions	Medium	Estimated based on topography, watersheds, and streamflows. Could not validate owing to lack of field measurements.	Low to Medium
Erosion rates	Medium	Based on site-specific universal soil loss equation factors. May not be reflective of small areas with higher or lower erosion rates.	Low to Medium
Precipitation rate	Medium	Average annual precipitation total for the 4-year period used in modeling can differ from the 30-year average. Affects deposition quantity and type.	Low to Medium

Assessment Input	Sensitivity of Risk Results	Comment	Estimated Impact of Uncertainty on Results
Evaporation rate	Medium	Not a direct input to TRIM.FaTE—used in offline estimations of chemical movement (e.g., runoff rates) and flush rate. Limited site-specific data. Impacts media concentrations.	Low to Medium
Wind speed and direction	Medium	Data for 4-year period might not represent average conditions . Excessive diffusion could underestimate risk.	Low to Medium
Sediment dynamics	Medium	Model uses simplistic algorithms to describe deposition and resuspension of sediment.	Low to Medium
Other soil, surface water, air, and vegetation physicochemical parameters	Medium	Limited site-specific data available. Default assumptions often used.	Low to Medium
Cooking correction factor	Medium	Limited studies available. Single value does not account for different styles of cooking.	Medium
Breast milk pathway parameters	Medium	All dioxins were assumed to exhibit the same partitioning behavior as 2,3,7,8-TCDD.	Medium

Aquatic Food Web Parameters. Estimates of pollutant concentrations in fish that people consume are sensitive to aquatic food web parameters. Chemical-, site- and species-specific data on food web structure (e.g., species, diets, biomass per species) and chemical- and species-specific biokinetic and biodynamic parameters that influence bioaccumulation (e.g., gill absorption from water, assimilation efficiency from food, elimination rates) are limited. We developed a simplified food web to include both benthic and water column organisms that is consistent with data reported for many lake food webs (Great Lakes excluded) and identified central tendency values for chemical biokinetic/dynamic parameters.

Lake Modeling Assumptions. The concentration of pollutants in modeled lakes (and thereafter up the aquatic food chain) depends on the depth of lake assumed in the model. The assessment used depth data specific to each lake. Each lake is modeled as a single water column compartment with a surface sediment layer and a sediment sink. That approach assumes perfect and instantaneous mixing of chemical in the water body at each modeling time step. The approach does not, therefore, capture possible spatial variation in chemical concentration within the lake (e.g., would not identify local pockets of high concentrations). Similarly, the screening-level simulation does not simulate possible short-term high concentrations that might follow a snow melt or strong storm event.

Surface Water Retention Time/Flush Rate. Retention time, which is inversely proportional to flush rate, determines how quickly pollutants are passed out of a lake. A flush rate that is too high (or retention time that is too low) could result in an underestimate of pollutant concentrations in surface water and in the aquatic food chain. For this assessment, site-specific retention times were available for Mountwood Park Lake and for Wolf Run Lake from literature sources. For Veto Lake, retention time was calculated from estimated values for inflow to the lake and lake volume.

Methylation and Demethylation Rates (Mercury). Methylation and demethylation in sediment and surface water are key processes governing biogeochemical cycling of mercury in the aquatic environment. Saturated wetlands also facilitate mercury transformations at rates higher than unsaturated soils do, and the rate constants used in the model were increased slightly to account for this. How prevalent these processes are greatly influences sensitivity of an aquatic ecosystem to mercury inputs and specifically influences the amount of methyl mercury available for accumulation. Some water bodies that are efficient at methylating inorganic mercury can show significant methyl mercury concentrations in biota despite a relatively small mercury input into the system. The representation of these processes in the TRIM.FaTE model does not explicitly account for known dependencies of transformation rates on redox potential, pH, sulfite concentration, dissolved organic carbon content, and hydrodynamics at the sediment-surface water interface. Both methylation and demethylation can occur either biotically or abiotically. Certain conditions, like specific ranges of chloride, sulfide, and dissolved organic matter concentrations, can increase the bioavailability of divalent mercury for methylation. Redox conditions can influence the rate of abiotic demethylation. These process mechanics, potentially antagonistic interactions with heavy metals like selenium, and the potential for photodegradation of methyl mercury are not captured in the TRIM.FaTE model. Instead, user-supplied first-order rate constants were used to model methylation and demethylation in surface water and sediment. Site-specific data were limited and the regional default rate constants used might not represent conditions at the modeled lakes.

Sediment Dynamics. The suspension and burial of sediment can have a significant impact on surface water concentration and mercury speciation by influencing the methylation and demethylation process. Suspended solid concentrations also affect the amount of chemical transported from the water body during flushing. Resuspension of buried sediment could remobilize previously deposited contaminants into the water body. In the TRIM.FaTE model, these processes are simplistically represented by default sediment deposition rates and suspended solids concentrations, which do not account for hydrodynamic sediment cycling processes. These parameters were not based on site-specific data.

Erosion and Runoff Flow Directions. For pollutants for which the risks are transmitted chiefly by the fish consumption pathway, the amount of pollutant entering lakes is a significant variable. Because erosion and runoff can account for a significant portion of the pollutant transported into the lake in some locations, erosion and runoff flows from the watershed are a potentially sensitive parameter in the model. These flow directions were estimated based on information about the surrounding topography.

Erosion Rates. Similar to runoff rates, erosion rates can affect the quantity of pollutants transported into a water body. Erosion rates were estimated using the USLE, which is a generalized estimate that depends on local topography, land use, and climate. Site-specific USLE factors were used in this assessment. Local erosion rates could differ from the USLE estimate.

Precipitation Rate. The precipitation rate in the model affects the rate at which pollutants are transported between surface soil compartments and water bodies and also the rate at which pollutants are flushed from water bodies. This assessment used precipitation data for a 4-year period. Although the annualized average precipitation total for that 4-year period was approximately equal to the 30-year annual average, it contained periods (e.g., months, seasons, and individual years) where precipitation was considerably smaller or larger than the 30-year average.

Evaporation Rate. Evaporation rate is not directly input to TRIM.FaTE; it is used in offline estimations of chemical movement (e.g., chemical runoff rates from land) and flush rates. Consequently, evaporation rate affects lake concentration and aquatic biota concentration estimates. Limited site-specific data were available and regional estimates had to be used.

Wind Speed and Direction. Wind speed and direction affect advection and diffusion of the pollutant in the model. Because these data were derived from a single, 4-year period, they might not be representative of average or future conditions.

Other Soil, Surface Water, Air, and Vegetation Physicochemical Parameters. Default or national-average values or estimation methods were used for some soil, surface water, and air and vegetation physical and chemical parameters due to a lack of easily accessible site-specific data.

Algorithm Uncertainty. The TRIM.FaTE model represents all fate and transport processes in terms of first-order differential equations. Some processes like diffusion, however, are known to follow second-order dynamics. TRIM.FaTE also does not explicitly deal with lateral or vertical dispersion in the air compartments. As noted earlier, some algorithms like methylation and sediment transport do not consider all the factors known to affect the process. Biotic processes including chemical absorption, chemical elimination, growth, reproduction, predation, and death have been represented relatively simplistically in the model. Although the model's algorithms have been validated and are based on professional judgment, some level of uncertainty results from such simplifications.

6.2 Uncertainties Related to Exposure Modeling and Risk Characterization (MIRC)

Ingestion Exposure Parameters. We evaluated all the surveys and data analyses EPA presented in its 2011 Exposure Factors Handbook (Chapter 10) (U.S. EPA 2011b). For possible subsistence populations and high-end recreational fish consumers, numerous studies have reported catch and ingestion rates, predominantly for adults, but some for children as well. All of these studies can be characterized as having relatively small sample sizes (tens to a few hundred) and as applying to a localized population with varying lakes and rivers available for fishing. Many of the studies also focus on specific racial or ethnic groups with culturally higher fish harvesting practices. As a consequence, extrapolating fish ingestion rates from one population or location to another or using any single study to represent a cultural group is difficult. We therefore used one of the studies reporting high-end consumption rates by avid sports anglers (Burger 2002) to represent subsistence anglers. One advantage of the Burger (2002) data is that all ingestion rates were reported for self- or wild-caught fish (many fish ingestion surveys do not distinguish wild-caught from store-bought fish). A difficulty with all of the studies, however, is that given the small sample sizes, the certainty associated with upper-percentile values is relatively low.

To represent fish consumption for children and for the general population, two large (i.e., hundreds to thousands surveyed) data sets are available. We used EPA's 2002 analysis of the U.S. Department of Agriculture's Continuing Survey of Food Intakes by Individuals (CSFII) for 1994–1996 and 1998 (USDA 2000). Another more recent large data set is available from the 2003–2006 National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention. EPA presented its analysis of those data by consumers and non-consumers and by age categories in its 2011 Exposure Factors Handbook. Total sample size for each age category from the NHANES data set is somewhat smaller at this time than from the CSFII data set (U.S. EPA 2011b). The overall fish ingestion rates from the CSFII data set are somewhat higher than for the NHANES data set. Several factors might contribute to that trend (e.g., lower fish ingestion rates for more recent data as people heed fish consumption warnings, shellfish included as a separate category in the NHANES data set but included with fish in the CSFII data set). We used EPA's 2002 analysis of the CSFII data set for this risk assessment to be somewhat conservative, given the difficulty in evaluating temporal trends in fish consumption at this time, and because the data for adults as summarized by EPA (2002) were more similar to the data reported for adults in the Burger (2002) study.

For site-specific risk assessment, using data on actual fish harvesting and consumption practices by people living in the vicinity of the specific facility would be preferable. Such data, however, were not available for the facility evaluated in this report. High-end values from nationwide surveys should be protective of possible future populations around any given facility. The likelihood of any families or residents in the vicinity of a given facility being subsistence fishers now or in the future is low.

Cooking Correction Factor. As described in Section 4.2.1, a cooking conversion factor of 1.5 was used for mercury and cadmium to account for the fact that cooking fish reduces the overall mass of the fish without reducing the amount of the chemical bound to proteins, which effectively increases the chemical concentration in the cooked fish. The cooking conversion factor assumption was developed based on information presented by Morgan et al. (1997, as cited in U.S. EPA 2011a) and might overestimate the loss of fat and water from fish when steamed or poached and underestimate the loss of water by some dry-cooking methods (e.g., broiling, grilling).

A conversion factor of 0.7 was applied to dioxin concentrations to account for loss of the chemical along with loss of fats during cooking methods that include grilling, broiling, and steaming and poaching. The one value was assumed based on data from several sources (Schecter et al., 1998; Reinert et al., 1972; Zabik and Zabik 1995) and might not apply to all species of fish or cooking methods.

Although PAHs in fish taken up from their environment also might be lost along with lipids during cooking, PAHs also can be created by cooking, particularly at higher heats often associated with broiling or grilling. Although one could argue for reducing the PAH concentration in fish due to loss of lipids during cooking, we decided not to adjust the TRIM.FaTE-estimated PAH concentrations in fish because of the uncertainty associated with both the loss and gain processes.

Breast Milk Pathway Parameters. Exposure to dioxins via the breast milk pathway was estimated using algorithms and assumptions to simulate the partitioning behavior of the chemical in breast milk and the rate and duration of breast milk consumption. All dioxins were assumed to exhibit the same partitioning behavior as 2,3,7,8-TCDD, owing to a lack of data. Although the methods and assumptions are supported by scientific literature, they have not been evaluated against empirical biomonitoring data or other models.

Toxicity Reference Value. Incremental hazard quotients and incremental lifetime cancer risks were calculated using EPA's recommended oral reference doses and cancer slope factors where available (for most dioxins, cancer slope factors were estimated from toxicity equivalency factors). Reference doses and cancer slope factors are typically estimated after building in uncertainty factors for pharmacokinetic variability and uncertainty, pharmacodynamic variability and uncertainty, inter- or intra-species variability, and potentially other factors. An awareness of the values and ranges of these uncertainty factors (documented in EPA's IRIS data base) could help inform risk management decisions.

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Appendix A
User-Specified Values for TRIM.FaTE Properties

The properties of the TRIM.FaTE scenario developed to model the environmental fate and transport of mercury, cadmium, dioxins, and particulate organic matter (POM) for this risk assessment are shown in the following tables. Shaded cells in these tables indicate where site-specific values were developed for this site-specific assessment, with additional information provided for some values in table notes. In some instances where an entire table shows site-specific values (such as the values for estimated erosion rates for modeled surface soil compartments), table notes are used and cells are left unshaded. All values presented in unshaded and otherwise unmarked tables were unchanged from the Tiers 1 and 2 screening assessments.

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Table A-1. TRIM.FaTE Simulation Parameters[a]

Parameter Name	Units	Value	Reference
Start of simulation	date/time	1/1/1990, midnight	Consistent with met data.
End of simulation	date/time	1/1/2040, midnight	Consistent with met data set; selected to provide a 50-year modeling period.
Simulation time step	hr	1	Selected value.
Output time step[b]	hr	4	Selected value.

[a] All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[b] Output time step is set in TRIM.FaTE using the scenario properties "simulationStepsPerOutputStep" and "simulationTimeStep."

Table A-2. Meteorological Inputs[a]

Parameter Name	Units	Value	Reference
Meteorological Inputs			
Air temperature	degrees K	Varies by hour	Hourly surface meteorological data from NOAA; see Section 4 of main report for details on station and data processing.
Horizontal wind speed	m/sec	Varies by hour	Hourly surface meteorological data from NOAA; see Section 4 of main report for details on station and data processing.
Vertical wind speed	m/sec	0.0	Professional judgment; vertical wind speed not used by any of the algorithms in the version of the TRIM.FaTE library used for the ferroalloy analysis.
Wind direction	degrees clockwise from N (blowing from)	Varies by hour	Hourly surface meteorological data from NOAA; see Section 4 of main report for details on station and data processing.
Rainfall rate	m^3[rain]/m^2[surface area]-day	Varies by hour	Hourly surface meteorological data from NOAA; see Section 4 of main report for details on station and data processing.
Mixing height (used to set air VE property named "top")	m	Varies by hour	Twice-daily upper-air meteorological data from NOAA; see Section 4 of main report for details on station and data processing.
isDay_SteadyState_forAir	unitless	-	Value not used in current dynamic runs (would need to be reevaluated if steady-state runs are needed).
isDay_SteadyState_forOther	unitless	-	

[a] Shaded values indicate where refined values were developed for this site-specific assessment. All other values (unshaded) were unchanged from the Tiers 1 and 2 screening assessments.

Table A-3. Air Parameters[a]

Parameter Name	Units	Value	Reference
Atmospheric dust load	kg[dust]/m^3[air]	6.15E-08	Bidleman 1988.
Density of air	g/cm^3	0.0012	U.S. EPA 1997.
Dust density	kg[dust]/m^3[dust]	1,400	Bidleman 1988.
Fraction organic matter on particulates	unitless	0.2	Harner and Bidleman 1998.

[a] All values were unchanged from the Tiers 1 and 2 screening assessments (no site-specific values used).

Table A-4. Soil and Ground Water Parameters*

Parameter Name	Units	Value				
		Soil-Tilled (incl. farms)	Soil-Untilled (incl. farms)	Grasses/ Herbs	Deciduous Forest	References
Surface Soil Compartment Type						
Air content	volume[air]/volume [compartment]	0.25	varies[2]	varies[2]	varies[2]	See additional Soil table.
Average vertical velocity of water (percolation)	m/day	0.000624	0.000624	0.000624	0.000624	= Average Annual Precipitation / 365 × Fraction of Precipitation that Percolates, where 365 = days per year; percolation fraction is professional judgment = 0.20
Boundary layer thickness above surface soil	m	0.006	0.006	0.006	0.006	Thibodeaux 1996; McKone et al. 2001 (Table 3).
Density of soil solids (dry weight)	kg[soil]/m^3[soil]	2600	2600	2600	2600	Default in McKone et al. 2001 (Table 3)
Thickness[1]	m	0.2[a]	0.01[b]	0.01[b]	0.01[b]	[a]U.S. EPA 2005b [b]McKone et al. 2001 (p. 30)
Erosion fraction	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See Erosion and Runoff Fraction table.
Fraction of area available for erosion	m^2[area available]/m^2[total]	1	1	1	1	Professional judgment; area is rural.
Fraction of area available for runoff	m^2[area available]/m^2[total]	1	1	1	1	Professional judgment; area is rural.
Fraction of area available for vertical diffusion	m^2[area available]/m^2[total]	1	1	1	1	Professional judgment; area is rural.

Table A-4. Soil and Ground Water Parameters (Cont.)*

Parameter Name	Units	Value				
		Soil-Tilled (incl. farms)	Soil-Untilled (incl. farms)	Grasses/ Herbs	Deciduous Forest	References
Surface Soil Compartment Type						
Fraction sand	unitless	0.181	varies[2]	0.181	varies[2]	USDA Web Soil Survey
Organic carbon fraction	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See additional Soil table
pH	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See additional Soil table
Runoff fraction	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See Erosion and Runoff Fraction table.
Total erosion rate	kg [soil]/m^2/day	varies[2]	varies[2]	varies[2]	varies[2]	See Total Erosion Rates table.
Total runoff rate	m^3[water]/m^2 /day	0.00125	0.00125	0.00125	0.00125	Calculated using scenario-specific precipitation rate and assumptions associated with water balance.(= Average Annual Precipitation / 365 × Fraction of Precipitation that Runs Off, where 365 = days per year; runoff fraction is professional judgment = 0.4)
Water content	volume[water]/volume[compartment]	0.22	varies[2]	varies[2]	varies[2]	McKone et al. 2001 (Table A-3).
Root Zone Soil Compartment Type						
Air content	volume[air]/volume[compartment]	0.25	varies[2]	varies[2]	varies[2]	See additional Soil table

Table A-4. Soil and Ground Water Parameters (Cont.)*

Parameter Name	Units	Value				
		Soil-Tilled (incl. farms)	Soil-Untilled (incl. farms)	Grasses/ Herbs	Deciduous Forest	References
Root Zone Soil Compartment Type						
Average vertical velocity of water (percolation)	m/day	0.000624	0.000624	0.000624	0.000624	= Average Annual Precipitation / 365 × Fraction of Precipitation that Percolates, where 365 = days per year; percolation fraction is professional judgment = 0.20
Density of soil solids (dry weight)	kg[soil]/m^3[soil]	2601	2601	2600	2601	Default in McKone et al. 2001 (Table 3)
Fraction sand	unitless	0.181	varies[2]	0.181	varies[2]	See additional Soil table
Thickness[1]	m	0.6[a]	0.79[a]	0.79[a]	0.79[a]	[a]McKone et al. 2001 (Table 16 directly or adjusted).
Organic carbon fraction	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See additional Soil table
pH	unitless	varies[2]	varies[2]	varies[2]	varies[2]	See additional Soil table
Water content	volume[water]/volume[compartment]	0.22	varies[2]	varies[2]	varies[2]	See additional Soil table

[*] Shaded values indicate where refined values were developed for this site-specific assessment. All other values (unshaded) were unchanged from the Tiers 1 and 2 screening assessments.

[1] Set using the volume element properties file.

[2] See separate tables for values of these parameters.

Table A-5. Additional Soil Parameters*

Surface Parcel	Surface Soil Compartment Type				Root Zone Compartment Type			
	Air Content[c]	**Fraction Organic Carbon[a]**	**Water Content[b]**	**pH[c]**	**Fraction Organic Carbon[a]**	**Fraction Sand[c]**	**Water Content[b]**	**pH[c]**
Farm_NNW_Tilled	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
Farm_NNW_Untilled	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
Farm_SE_Tilled	0.25	0.010174	0.22	5.5	0.010174	0.181	0.22	5.5
Farm_SE_Untilled	0.25	0.010174	0.22	5.5	0.010174	0.181	0.22	5.5
Farm_WSW_Tilled	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
Farm_WSW_Untilled	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
E1	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
E2	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
N1	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
N2	0.25	0.014535	0.22	5.5	0.014535	0.367	0.22	5.5
N3e	0.25	0.010174	0.22	5.1	0.010174	0.304	0.22	5.1
N3w	0.25	0.010174	0.22	5.1	0.010174	0.304	0.22	5.1
N4	0.25	0.010174	0.22	5.1	0.010174	0.304	0.22	5.1
NE1	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
NNW1	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
NNW2e	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
NNW2w	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
NNW3	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
NNW4	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
NW1	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
NW2	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
NW3	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
S1	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
S2	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
S3	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
SE1	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
SE2	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5

Table A-5. Additional Soil Parameters (Cont.)*

Surface Parcel	Surface Soil Compartment Type				Root Zone Compartment Type			
	Air Content[c]	Fraction Organic Carbon[a]	Water Content[b]	pH[c]	Fraction Organic Carbon[a]	Fraction Sand[c]	Water Content[b]	pH[c]
SE3	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
SE4n	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
SE4s	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
SE5	0.3	0.010174	0.2	5.5	0.010174	0.181	0.2	5.5
Source	0.28	0.008	0.19	6.9	0.008	0.25	0.21	6.9
SW1	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
SW2	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
SW3	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
W1	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
W2	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
W3n	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
W3s	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
W4	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
W5	0.25	0.01	0.22	5.3	0.01	0.181	0.22	5.3
WNW1	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
WNW2n	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
WNW2s	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
WNW3	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
WNW4	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
WNW5	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
WSW1	0.25	0.00727	0.22	5.3	0.00727	0.181	0.22	5.3
WSW2	0.25	0.007	0.22	5.3	0.007	0.181	0.22	5.3
WSW3n	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
WSW3s	0.25	0.007267	0.22	5.3	0.007267	0.181	0.22	5.3
WSW4	0.25	0.01017	0.22	5.3	0.01017	0.181	0.22	5.3
WSW5	0.25	0.010174	0.22	5.3	0.010174	0.181	0.22	5.3
WSW6	0.25	0.0102	0.22	5.3	0.0102	0.181	0.22	5.3

[*] All values shown were refined for this site-specific assessment (versus the values used in Tiers 1 and 2 screening assessments).

[a] =fraction organic matter / 1.72, as per McKone et al. 2001.

[b] McKone et al. 2001 (Table A-3).

[c] USDA Web Soil Survey.

Table A-6. Runoff Fractions[a]

Sending parcel	Receiving parcel																													
	Sink	**E1**	**E2**	**Farm_NNW_Tilled**	**Farm_NNW_Untilled**	**Farm_SE_Tilled**	**Farm_SE_Untilled**	**Farm_WSW_Tilled**	**Farm_WSW_Untilled**	**Goodfellows_Park_Lake**	**Mountwood_Park_Lake**	**N1**	**N2**	**N3e**	**N3w**	**N4**	**NE1**	**NNW1**	**NNW2e**	**NNW2w**	**NNW3**	**NNW4**	**NW1**	**NW2**	**NW3**	**S1**	**S2**	**S3**	**SE1**	**SE2**
E1	.20	0	.24	0	0	0	.35	0	0	0	0	0	0	0	0	0	.20	0	0	0	0	0	0	0	0	0	0	0	.01	0
E2	.48	.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.41	0	0	0	0	0	0	0	0	0	0	0	0	.01
Farm_NNW_Tilled	.94	0	0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.04	0	0	0	0	0	0	0	0	0	0
Farm_NNW_Untilled	.13	0	0	.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.46	0	0	0	0	0	0	0	0	0	0	0
Farm_SE_Tilled	0	0	0	0	0	0	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.88	.06
Farm_SE_Untilled	0	.02	0	0	0	.96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02	0
Farm_WSW_Tilled	0	0	0	0	0	0	0	0	.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_WSW_Untilled	.11	0	0	0	0	0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodfellows_Park_Lake	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mountwood_Park_Lake	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N1	0	0	0	0	0	0	0	0	0	0	0	0	.04	0	0	0	.92	.01	.01	0	0	0	0	0	0	0	0	0	0	0
N2	.05	0	0	0	0	0	0	0	0	0	0	0	0	.03	.01	0	.78	0	0	0	.02	.11	0	0	0	0	0	0	0	0
N3e	.01	0	0	0	0	0	0	0	0	0	0	0	.80	0	0	.10	.08	0	0	0	0	0	0	0	0	0	0	0	0	0
N3w	0	0	0	0	0	0	0	0	0	0	0	0	.10	.04	0	.69	0	0	0	0	0	.07	0	0	0	0	0	0	0	0
N4	.45	0	0	0	0	0	0	0	0	0	0	0	0	.32	.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE1	.47	.01	.01	0	0	0	0	0	0	0	0	0	.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW1	0	0	0	0	0	0	0	0	0	0	0	.24	0	0	0	0	0	0	.04	0	0	0	.68	0	0	0	0	0	0	0
NNW2e	0	0	0	0	0	0	0	0	0	0	0	.76	0	0	0	0	0	.04	0	0	.19	0	0	0	0	0	0	0	0	0
NNW2w	.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.11	.02	0	.02	0	.38	0	0	0	0	0	0	0
NNW3	0	0	0	0	0	0	0	0	0	0	0	0	.07	0	0	0	0	0	.19	0	0	.26	0	.25	.23	0	0	0	0	0
NNW4	.24	0	0	0	0	0	0	0	0	0	0	0	.59	0	.03	0	0	0	0	0	.01	0	0	0	.13	0	0	0	0	0
NW1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.16	0	0	0	0	0	.29	0	0	0	0	0	0
NW2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.12	0	.02	0	.42	0	0	0	0	0
NW3	.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.18	0	.51	0	0	0	0	0	0
S1	.16	0	0	0	0	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.17	0	.15	0
S2	.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.18	0	.12
S3	.59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.19	0	0	0
SE1	.23	.74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02	0	0	0	0
SE2	0	0	.33	0	0	.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.59	0	0	0
SE3	0	0	.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.43	0	0	.01
SE4n	.04	0	0	0	0	0	0	0	0	0	.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE4s	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.05	0	0	0
SE5	.91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-6. Runoff Fractions (Cont.)[a]

	Receiving parcel																													
Sending parcel	**Sink**	**E1**	**E2**	**Farm_NNW_Tilled**	**Farm_NNW_Untilled**	**Farm_SE_Tilled**	**Farm_SE_Untilled**	**Farm_WSW_Tilled**	**Farm_WSW_Untilled**	**Goodfellows_Park_Lake**	**Mountwood_Park_Lake**	**N1**	**N2**	**N3e**	**N3w**	**N4**	**NE1**	**NNW1**	**NNW2e**	**NNW2w**	**NNW3**	**NNW4**	**NW1**	**NW2**	**NW3**	**S1**	**S2**	**S3**	**SE1**	**SE2**
SW1	.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02	.10	0	0	0
SW2	.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SW3	.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02	0	0
Veto_Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W3n	.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W3s	.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W5	.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.03	.04	0	0	0	0	0	0
WNW2n	.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.31	0	0	0	0	0	0
WNW2s	.15	0	0	0	0	0	0	0	0	.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WNW3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.27	0	0	0	0	0
WNW4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.28	0	0	0	0	0
WNW5	.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.13	0	0	0	0	0
Wolf_Run_Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW3n	.79	0	0	0	0	0	0	.01	.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW3s	.01	0	0	0	0	0	0	.41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WSW6	.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-6. Runoff Fractions (Cont.)[a]

	Receiving parcel																												
Sending parcel	**SE3**	**SE4n**	**SE4s**	**SE5**	**Source**	**SW1**	**SW2**	**SW3**	**Veto_Lake**	**W1**	**W2**	**W3n**	**W3s**	**W4**	**W5**	**WNW1**	**WNW2n**	**WNW2s**	**WNW3**	**WNW4**	**WNW5**	**Wolf_Run_Lake**	**WSW1**	**WSW2**	**WSW3n**	**WSW3s**	**WSW4**	**WSW5**	**WSW6**
E1	0	0	0	0	.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_NNW_Tilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_NNW_Untilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_SE_Tilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_SE_Untilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm_WSW_Tilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.67	0	0	0
Farm_WSW_Untilled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.86	0	0	0
Goodfellows_Park_Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mountwood_Park_Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N1	0	0	0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N3e	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N3w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.10	0	0	0	0	0	0	0
N4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NE1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW1	0	0	0	0	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW2e	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW2w	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NNW4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NW1	0	0	0	0	.03	0	0	0	0	0	0	0	0	0	0	.52	0	0	0	0	0	0	0	0	0	0	0	0	0
NW2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.43	.01	0	0	0	0	0	0	0	0	0	0	0	0
NW3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02	.02	.10	0	0	0	0	0	0	0	0
S1	0	0	0	0	0	.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	.05	0	0	0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	0	0	0	0	0	0	0	.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE2	.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE3	0	.15	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE4n	.45	0	0	.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE4s	.11	0	0	.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE5	0	.07	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Source	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-6. Runoff Fractions (Cont.)[a]

	Receiving parcel																												
Sending parcel	**SE3**	**SE4n**	**SE4s**	**SE5**	**Source**	**SW1**	**SW2**	**SW3**	**Veto_Lake**	**W1**	**W2**	**W3n**	**W3s**	**W4**	**W5**	**WNW1**	**WNW2n**	**WNW2s**	**WNW3**	**WNW4**	**WNW5**	**Wolf_Run_Lake**	**WSW1**	**WSW2**	**WSW3n**	**WSW3s**	**WSW4**	**WSW5**	**WSW6**
SW1	0	0	0	0	.01	0	.22	.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.09	.01	0	.03	0	0	0
SW2	0	0	0	0	0	.05	0	.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.42	.03	.23
SW3	0	0	0	0	0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.02
Veto_Lake	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W1	0	0	0	0	0	0	0	0	0	0	.77	0	0	0	0	.03	0	0	0	0	0	0	.06	.09	.04	0	0	0	0
W2	0	0	0	0	0	0	0	0	0	.35	0	.04	.02	0	0	0	0	0	.10	0	0	0	0	0	0	0	.49	0	0
W3n	0	0	0	0	0	0	0	0	.22	0	0	0	.01	.01	0	0	0	0	0	.08	0	0	0	0	0	0	0	0	0
W3s	0	0	0	0	0	0	0	0	.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.26	0
W4	0	0	0	0	0	0	0	0	0	0	0	.06	.02	0	.19	0	0	0	0	0	.01	0	0	0	0	0	0	0	.72
W5	0	0	0	0	0	0	0	0	0	0	0	0	0	.31	0	0	0	0	0	0	.18	0	0	0	0	0	0	0	.21
WNW1	0	0	0	0	0	0	0	0	0	.73	0	0	0	0	0	0	.17	.03	0	0	0	0	0	0	0	0	0	0	0
WNW2n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.06	0	.07	.04	0	0	0	0	0	0	0	0	0	0
WNW2s	0	0	0	0	0	0	0	0	0	.25	0	0	0	0	0	.04	.12	0	.01	0	0	0	0	0	0	0	0	0	0
WNW3	0	0	0	0	0	0	0	0	0	0	.59	0	0	0	0	0	.07	.02	0	.05	0	0	0	0	0	0	0	0	0
WNW4	0	0	0	0	0	0	0	0	0	0	0	.28	0	0	0	0	0	0	.12	0	.32	0	0	0	0	0	0	0	0
WNW5	0	0	0	0	0	0	0	0	0	0	0	0	0	.24	.17	0	0	0	0	.22	0	0	0	0	0	0	0	0	0
Wolf_Run_Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0
WSW1	0	0	0	0	.02	.42	0	0	0	.20	0	0	0	0	0	0	0	0	0	0	0	0	0	.36	0	0	0	0	0
WSW2	0	0	0	0	0	.31	0	0	0	.17	0	0	0	0	0	0	0	0	0	0	0	0	.05	0	.35	.11	0	0	0
WSW3n	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.04	0	0	.06	0	0
WSW3s	0	0	0	0	0	.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.04	0	0	.45	0	0
WSW4	0	0	0	0	0	0	.39	0	0	0	.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.34	0
WSW5	0	0	0	0	0	0	.54	0	0	0	0	0	.25	0	0	0	0	0	0	0	0	0	0	0	0	0	.09	0	.12
WSW6	0	0	0	0	0	0	.02	.42	0	0	0	0	0	.15	.06	0	0	0	0	0	0	0	0	0	0	0	0	.16	0

[a] All values shown were refined for this site-specific assessment (versus the values used in the Tiers 1 and 2 screening assessments).

Table A-7. USLE Erosion Parameters*

Soil Parcel	Area	Rainfall/ Erosivity Index[a]	Soil Erodibility Index[a]	Length-Slope Factor[a]	Cover Mgmt Factor[a]	Supporting Practices Factor[a]	Unit Soil Loss[b]		Sediment Delivery Ratio[c]	Calculated (Adjusted) Erosion Rate[d]
	m^2	R (100 ft-ton/ac)	K (ton/ac/(100 ft-ton/acre))	LS (USCS)	C (USCS)	P	A (ton/ac/yr)	A ($kg/m^2/d$)	SDR	calculated (adjusted) erosion rate ($kg/m^2/d$)
E1	1,312,959	125	0.43	---	0.003	1	0.115[e]	0.0000706	0.32657	2.31E-05
E2	76,917,882	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.12400	1.90E-05
Farm_NNW_Tilled	24,200	125	0.32	5.4	0.11	1	23.76	0.0145926	0.59463	8.68E-03
Farm_NNW_Untilled	24,200	125	0.32	5.4	0.11	1	23.76	0.0145926	0.59463	8.68E-03
Farm_SE_Tilled	152,680	125	0.43	---	0.11	1	25[e]	0.0153541	0.47233	7.25E-03
Farm_SE_Untilled	152,682	125	0.43	---	0.11	1	25[e]	0.0153541	0.47233	7.25E-03
Farm_WSW_Tilled	49,600	125	0.32	5.4	0.11	1	23.76	0.0145926	0.54361	7.93E-03
Farm_WSW_Untilled	49,600	125	0.32	5.4	0.11	1	23.76	0.0145926	0.54361	7.93E-03
N1	1,622,459	125	0.37	3.39	0.001	1	0.156788	0.0000963	0.31804	3.06E-05
N2	371,817,129	125	0.37	5.4	0.001	1	0.24975	0.0001534	0.05092	7.81E-06
N3e	36,817,614	125	0.17	5.4	0.001	1	0.11475	0.0000705	0.13596	9.58E-06
N3w	7,353,631	125	0.17	5.4	0.001	1	0.11475	0.0000705	0.19401	1.37E-05
N4	92,484,526	125	0.17	5.4	0.001	1	0.11475	0.0000705	0.12118	8.54E-06
NE1	216,092,437	125	0.37	3.39	0.001	1	0.156788	0.0000963	0.10898	1.05E-05
NNW1	1,195,820	125	0.32	5.4	0.001	1	0.216	0.0001327	0.33040	4.38E-05
NNW2e	340,031	125	0.32	5.4	0.001	1	0.216	0.0001327	0.38665	5.13E-05
NNW2w	38,196	125	0.32	5.4	0.001	1	0.216	0.0001327	0.56165	7.45E-05
NNW3	9,611,600	125	0.037	2.2	0.11	1	1.11925	0.0006874	0.18762	1.29E-04

Table A-7. USLE Erosion Parameters (Cont.)*

Soil Parcel	Area	Rainfall/ Erosivity Index[a]	Soil Erodibility Index[a]	Length-Slope Factor[a]	Cover Mgmt Factor[a]	Supporting Practices Factor[a]	Unit Soil Loss[b]		Sediment Delivery Ratio[c]	Calculated (Adjusted) Erosion Rate[d]
	m^2	R (100 ft-ton/ac)	K (ton/ac/(100 ft-ton/acre))	LS (USCS)	C (USCS)	P	A (ton/ac/yr)	A ($kg/m^2/d$)	SDR	calculated (adjusted) erosion rate ($kg/m^2/d$)
NNW4	165,843,092	125	0.032	5.4	0.001	1	0.0216	0.0000133	0.11265	1.49E-06
NW1	3,049,789	125	0.037	2.2	0.001	1	0.010175	0.0000062	0.21657	1.35E-06
NW2	7,387,449	125	0.037	2.2	0.001	1	0.010175	0.0000062	0.19389	1.21E-06
NW3	126,334,123	125	0.037	2.2	0.001	1	0.010175	0.0000062	0.11654	7.28E-07
S1	1,768,932	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.31462	4.83E-05
S2	142,826,053	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.11477	1.76E-05
S3	28,312,955	125	0.43	---	0.003	1	0.115[e]	0.0000706	0.14050	9.92E-06
SE1	393,244	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.37968	5.83E-05
SE2	7,835,857	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.19247	2.96E-05
SE3	84,872,112	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.12249	1.88E-05
SE4n	4,347,596	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.20718	3.18E-05
SE4s	2,097,360	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.30800	4.73E-05
SE5	45,631,552	125	0.43	---	0.001	1	0.25[e]	0.0001535	0.13236	2.03E-05
Source	714,066	125	0.39	1.5	0.2	1	35.1	0.02156	0.35240	0.00E+00
SW1	10,272,513	125	0.37	3.32	0.001	1	0.15355	0.0000943	0.18607	1.75E-05
SW2	32,293,781	125	0.37	3.32	0.003	1	0.46065	0.0002829	0.13821	3.91E-05
SW3	55,275,322	125	0.37	3.32	0.001	1	0.15355	0.0000943	0.12923	1.22E-05
W1	5,516,937	125	0.32	5.4	0.001	1	0.216	0.0001327	0.20110	2.67E-05

Table A-7. USLE Erosion Parameters (Cont.)*

Soil Parcel	Area	Rainfall/ Erosivity Index[a]	Soil Erodibility Index[a]	Length-Slope Factor[a]	Cover Mgmt Factor[a]	Supporting Practices Factor[a]	Unit Soil Loss[b]		Sediment Delivery Ratio[c]	Calculated (Adjusted) Erosion Rate[d]
	m^2	R (100 ft-ton/ac)	K (ton/ac/(100 ft-ton/acre))	LS (USCS)	C (USCS)	P	A (ton/ac/yr)	A (kg/m^2/d)	SDR	calculated (adjusted) erosion rate (kg/m^2/d)
W2	14,501,479	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.17822	1.11E-05
W3n	5,333,202	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.20195	1.26E-05
W3s	2,168,442	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.30672	1.92E-05
W4	27,245,681	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.14118	8.82E-06
W5	34,264,723	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.13719	8.57E-06
WNW1	4,208,581	125	0.37	2.2	0.003	1	0.30525	0.0001875	0.20802	3.90E-05
WNW2n	235,254	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.44748	2.80E-05
WNW2s	991,985	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.33821	2.11E-05
WNW3	14,464,874	125	0.37	2.2	0.003	1	0.30525	0.0001875	0.17827	3.34E-05
WNW4	8,391,775	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.19083	1.19E-05
WNW5	52,557,694	125	0.37	2.2	0.003	1	0.30525	0.0001875	0.13005	2.44E-05
WSW1	1,162,068	125	0.32	5.4	0.001	1	0.216	0.0001327	0.33159	4.40E-05
WSW2	3,051,907	125	0.32	5.4	0.003	1	0.648	0.0003980	0.21655	8.62E-05
WSW3n	459,880	125	0.32	5.4	0.001	1	0.216	0.0001327	0.37233	4.94E-05
WSW3s	707,648	125	0.32	5.4	0.001	1	0.216	0.0001327	0.35280	4.68E-05
WSW4	14,537,125	125	0.37	2.2	0.003	1	0.30525	0.0001875	0.17816	3.34E-05
WSW5	7,870,758	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.19236	1.20E-05
WSW6	48,298,321	125	0.37	2.2	0.001	1	0.10175	0.0000625	0.13143	8.21E-06

*All values shown were refined for this site-specific assessment (versus the values used in the Tiers 1 and 2 screening assessments)

[a] USDA Web Soil Survey, unless otherwise noted.

[b] =R*K*LS*C*P, with proper unit and time conversions, unless otherwise noted.

[c] Calculated using SD = a * $(AL)^{-b}$; where a is the empirical intercept coefficient (based on the size of the watershed), AL is the total watershed area receiving deposition (m^2), and b is the empirical slope coefficient (always 0.125).

[d] Calculated as A*SDR*E, where E = enrichment ratio for inorganics = 1.

[e] Derived using Ohio EPA (2009) weighted average KSLP for Beech Fork in the absence of LS data in USDA Web Soil Survey Data

Table A-8. Terrestrial Plant Placement

Surface Soil Volume Element	Grasses/ Herbs	Deciduous Forest	None
E1	x		
E2		x	
Farm_NNW_Tilled			x
Farm_NNW_Untilled			x
Farm_SE_Tilled			x
Farm_SE_Untilled			x
Farm_WSW_Tilled			x
Farm_WSW_Untilled			x
N1		x	
N2		x	
N3e		x	
N3w		x	
N4		x	
NE1		x	
NNW1		x	
NNW2e		x	
NNW2w			x
NNW3		x	
NNW4		x	
NW1		x	
NW2		x	
NW3		x	
S1		x	
S2		x	
S3	x		
SE1		x	
SE2		x	
SE3		x	
SE4n		x	

Table A-8. Terrestrial Plant Placement (Cont.)

Surface Soil Volume Element	Grasses/ Herbs	Deciduous Forest	None
SE4s		x	
SE5		x	
Source			x
SW1	x		
SW2		x	
SW3	x		
W1		x	
W2		x	
W3n		x	
W3s		x	
W4		x	
W5		x	
WNW1		x	
WNW2n	x		
WNW2s		x	
WNW3		x	
WNW4	x		
WNW5		x	
WSW1	x		
WSW2		x	
WSW3n	x		
WSW3s		x	
WSW4		x	
WSW5	x		
WSW6		x	

Table A-9. Terrestrial Plant Parameters*

Parameter Name	Units	Grass/Herbs[1]	Deciduous Forest	Reference
Leaf Compartment Type				
Allow exchange	1=yes, 0=no	seasonal[2]	seasonal[2]	-
Average leaf area index	m^2[leaf]/ m^2[area]	5[a]	3.4[b]	[a]Mid-range of 4–6 for old fields, Scurlock et al. 2001 [b]CDIAC 2010 (Harvard Forest, dom. red oak and red maple).
Calculate wet dep interception fraction (Boolean)	1=yes, 0=no	0	0	Professional judgment.
Correction exponent, octanal to lipid	unitless	0.76	0.76	Trapp 1995 (from roots).
Degree stomatal opening	unitless	1	1	Set to 1 for daytime based on professional judgment (stomatal diffusion is turned off at night using a different property, IsDay).
Density of wet leaf	kg/m^3	820	820	Paterson et al. 1991.
Leaf wetting factor	m	3.00E-04	3.00E-04	Muller and Prohl 1993 (1E-04 to 6E-04 for different crops and elements).
Length of leaf	m	0.05	0.1	Professional judgment.
Lipid content	kg/kg wet weight	0.00224	0.00224	Riederer 1995 (European beech).
Litterfall rate	1/day	seasonal[3]	seasonal[3]	-

Table A-9. Terrestrial Plant Parameters (Cont.)*

Parameter Name	Units	Grass/Herbs[1]	Deciduous Forest [1]	Reference
Leaf Compartment Type				
Stomatal area normalized effective diffusion path length	1/m	200	200	Wilmer and Fricker 1996.
Vegetation attenuation factor	m^2/kg	2.9	2.9	Baes et al. 1984 (Grass/hay).
Water content	unitless	0.8	0.8	Paterson et al. 1991.
Wet dep interception fraction	unitless	Calculated within TRIM.FaTE	Calculated within TRIM.FaTE	Calculated based on the meteorology data used within TRIM.FaTE
Wet mass of leaf per soil area	kg[fresh leaf]/m^2[area]	0.6[a]	0.6[b]	[a]Calculated from leaf area index and Leith 1975. [b]Simonich and Hites 1994 (Calculated from leaf area index, leaf thickness, density of wet foliage).
Particle on Leaf Compartment Type				
Allow exchange	1=yes, 0=no	seasonal[2]	seasonal[2]	-
Volume particle per area leaf	m^3[leaf particles]/m^2[leaf]	1.00E-09	1.00E-09	Coe and Lindberg 1987 (based on particle density and size distribution for atmospheric particles measured on an adhesive surface).

Table A-9. Terrestrial Plant Parameters (Cont.)*

Parameter Name	Units	Grass/Herbs[1]	Deciduous Forest[1]	Reference
Root Compartment Type – Nonwoody Only				
Allow exchange	1=yes, 0=no	seasonal[2]	seasonal[2]	-
Correction exponent, octanol to lipid	unitless	0.76	-	Trapp 1995.
Lipid content of root	kg/kg wet weight	0.011	-	Calculated.
Water content of root	kg/kg wet weight	0.8	-	Professional judgment.
Wet density of root	kg/m^3	820	-	Paterson et al. 1991 (soybean).
Wet mass per soil area	kg/m^2	1.4	-	Jackson et al. 1996 (temperate grassland).
Stem Compartment Type – Nonwoody Only				
Allow exchange	1=yes, 0=no	seasonal[2]	seasonal[2]	-
Correction exponent, octanol to lipid	unitless	0.76	-	Trapp 1995.
Density of phloem fluid	kg/m^3	1,000	-	Professional judgment.
Density of xylem fluid	kg/cm^3	900	-	Professional judgment.
Flow rate of transpired water per leaf area	m^3[water]/ m^2[leaf]	0.0048	-	Crank et al. 1981.
Fraction of transpiration flow rate that is phloem rate	unitless	0.05	-	Paterson et al. 1991.
Lipid content of stem	kg/kg wet weight	0.00224	-	Riederer 1995 (European beech).
Water content of stem	unitless	0.8	-	Paterson et al. 1991.
Wet density of stem	kg/m^3	830	-	Professional judgment.
Wet mass per soil area	kg/m^2	0.24[a]	-	[a]Calculated from leaf and root biomass density based on professional judgment.

[*] Shaded values indicate where refined values were developed for this site-specific assessment. All other values (unshaded) were unchanged from the Tiers 1 and 2 screening assessments.

[1] See separate table for assignment of plant types to surface soil compartments.

[2] Begins April 10 (set to 1), ends after October 1 (set to 0). Based on local frost/freeze data.

[3] Begins October 1, ends after October 30; rate = 0.15/day during this time (value assumes 99 percent of leaves fall in the 30 days beginning with the last day of allow-exchange).

Table A-10. Surface Water Parameters*

Parameter Name	Units	Value				Reference
		Goodfellows Park Lake	Mountwood Park Lake	Veto Lake	Wolf Run Lake	
Algal carbon content (fraction)	unitless	0.465	0.465	0.465	0.465	APHA 1995.
Algal density in water column	g[algae]/L [water]	0.0025	0.0025	0.0025	0.0025	Millard et al. 1996 as cited in ICF 2005.
Algal growth rate	1/day	0.7	0.7	0.7	0.7	Hudson et al. 1994 as cited in Mason et al. 1995b.
Algal radius	µm	2.5	2.5	2.5	2.5	Mason et al. 1995b.
Algal water content (fraction)	unitless	0.9	0.9	0.9	0.9	APHA 1995.
Average algal cell density (per vol cell, not water)	g[algae]/m^3 [algae]	1,000,000	1,000,000	1,000,000	1,000,000	Mason et al. 1995b; Mason et al. 1996.
Boundary layer thickness above sediment	m	0.02	0.02	0.02	0.02	Cal EPA 1993.
Chloride concentration	mg/L	13	12	13	11	USGS Water Alert Data.

Table A-10. Surface Water Parameters (Cont.)*

Parameter Name	Units	Value				Reference
		Goodfellows Park Lake	Mountwood Park Lake	Veto Lake	Wolf Run Lake	
Chlorophyll concentration	mg/L	0.0197	0.0075944	0.0197	0.0017	USGS 1984; Fulmer 1990.
Depth	m	2.23[a]	4.57[b]	2.23[a]	10.5[c]	[a]USGS 1984 (Veto used as surrogate for Goodfellows) [b]West Virginia DNR [c]Fulmer 1990
Dimensionless viscous sublayer thickness	unitless	4	4	4	4	Ambrose et al. 1995.
Drag coefficient for water body	unitless	0.0011	0.0011	0.0011	0.0011	Ambrose et al. 1995.
Flush rate	1/year	4.87	9.358976	19.022	0.595238	Calculated.
Fraction sand	unitless	0.25	0.25	0.25	0.25	Professional judgment.
Organic carbon fraction in suspended sediments	unitless	0.02	0.02	0.02	0.02	Professional judgment.

Table A-10. Surface Water Parameters (Cont.)*

Parameter Name	Units	Value				Reference
		Goodfellows Park Lake	Mountwood Park Lake	Veto Lake	Wolf Run Lake	
pH	unitless	7.33[a]	7.3[b]	7.33[a]	7.85[a]	[a]USGS Water Alert Data [b]Default; professional judgment
Suspended sediment deposition velocity	m/day	2	2	2	2	U.S. EPA 1997.
Total suspended sediment concentration	kg[sediment]/ m^3[water column]	0.042[a]	0.05[b]	0.042[a]	0.001[c]	[a]USGS 1984 and USGS Water Alert Data [b]U.S. EPA 2005b [c]USGS Water Alert Data
Water temperature	degrees K	291.85[a]	298[b]	291.85[a]	288.05[c]	[a]USGS 1984 [b]U.S. EPA 2005b [c]USGS WaterAlert Data

[*] Shaded values indicate where refined values were developed for this site-specific assessment. All other values (unshaded) were unchanged from the Tiers 1 and 2 screening assessments.

Table A-11. Sediment Parameters*

Parameter Name	Units	Value				Reference
		Goodfellows Park Lake	Mountwood Park Lake	Veto Lake	Wolf Run Lake	
Depth[1]	m	0.05[a]	1.09728[b]	0.05[a]	0.05[a]	[a]McKone et al. 2001 (Table 3). [b]EPA 1998b
Fraction Sand	unitless	0.25	0.25	0.25	0.25	Professional judgment.
Organic carbon fraction	unitless	0.02	0.02	0.02	0.02	Professional judgment.
Porosity of the sediment zone	volume[total pore space]/volume[sediment compartment]	0.6	0.6	0.6	0.6	U.S. EPA 1998a.
Solid material density in sediment	kg[sediment]/m^3[sediment]	2600	2600	2600	2600	McKone et al. 2001 (Table 3)
pH	unitless	7.33	7.2	7.33	7.85	Same as surface water.
Sediment resuspension velocity	m/day	8.28388E-05	9.6426E-05	8.2424E-05	1.9265E-06	Calculated from water balance model.

[*] Shaded values indicate where refined values were developed for this site-specific assessment. All other values (unshaded) were unchanged from the Tiers 1 and 2 screening assessments.

[1] Set using the volume element properties named "top" and "bottom."

Table A-12. Aquatic Animals Food Chain, Density, and Mass*

Aquatic Biota (Consuming Organism)	Fraction Diet								Biomass (kg/m^2)	Body Weight (kg)	Reference
	Algae	Zooplankton	Benthic Invertebrate	Water Column Herbivore	Benthic Omnivore	Water Column Omnivore	Benthic Carnivore	Water Column Carnivore			
Benthic invertebrate	0%	0%	0%	0%	0%	0%	0%	0%	0.020	2.55E-04	Professional judgment.
Water column herbivore	0%	100%	0%	0%	0%	0%	0%	0%	0.002	0.025	Professional judgment.
Benthic omnivore	0%	0%	100%	0%	0%	0%	0%	0%	0.002	0.25	Professional judgment.
Water column omnivore	0%	0%	0%	100%	0%	0%	0%	0%	0. 0005	0.25	Professional judgment.
Benthic carnivore	0%	0%	50%	0%	50%	0%	0%	0%	0.001	2.0	Professional judgment.
Water column carnivore	0%	0%	0%	0%	0%	100%	0%	0%	0.0002	2.0	Professional judgment.
Zooplankton	100%	0%	0%	0%	0%	0%	0%	0%	0.0064	5.70E-08	Professional judgment.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

Table A-13. Cadmium Chemical-Specific Parameters*

Parameter Name[a]	Units	Value	Reference
CAS number[b]	unitless	7440-43-9	-
Diffusion coefficient in pure air	m^2[air]/day	0.71	U.S. EPA 1999 (Table A-2-35).
Diffusion coefficient in pure water	m^2[water]/day	8.16E-05	U.S. EPA 1999 (Table A-2-35).
Henry's Law constant	Pa-m^3/mol	1.00E-37	U.S. EPA 1999 (Table A-2-35; assumed to be zero).
Melting point	degrees K	594	ATSDR 1999.
Molecular weight	g/mol	112.41	ATSDR 1999.
Octanol-air partition coefficient (K_{oa})	m^3[air]/m^3[octanol]	-	-
Octanol-carbon partition coefficient (K_{oc})	m^3[carbon]/m^3[octanol]	-	-
Octanol-water partition coefficient (K_{ow})	L[water]/kg[octanol]	-	-

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] All parameters in this table are TRIM.FaTE chemical properties.

[b] CAS numbers apply to elemental Cd; however, the cations of cadmium are being modeled.

Table A-14. Mercury Chemical-Specific Parameters*

Parameter Name[a]	Units	Value			Reference
		Hg(0)[b]	Hg(2)[b]	MHg[b]	
CAS number	unitless	7439-97-6	14302-87-5	22967-92-6	-
Diffusion coefficient in pure air	m^2[air]/day	0.478	0.478	0.456	U.S. EPA 1997.
Diffusion coefficient in pure water	m^2[water]/day	5.54E-05	5.54E-05	5.28E-05	U.S. EPA 1997.
Henry's Law constant	Pa-m^3/mol	719	7.19E-05	0.0477	U.S. EPA 1997.
Melting point	degrees K	234	5.50E+02	443	CARB 1994.
Molecular weight	g/mol	201	201	216	U.S. EPA 1997.
Octanol-water partition coefficient (K_{ow})	L[water]/kg[octanol]	4.15	3.33	1.7	Mason et al. 1996.
Vapor washout ratio	m^3[air]/m^3[rain]	1,200	1.6E+06	0	U.S. EPA 1997, based on Petersen et al. 1995.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] All parameters in this table are TRIM.FaTE chemical properties.

[b] On this and all following tables, Hg(0) = elemental mercury, Hg(2) = divalent mercury, and MHg = methyl mercury.

Table A-15. PAH Chemical-Specific Parameters*

Parameter Name[a]	Units	Value						
		2Methyl	**Acenaphthene**	**Acenaphthylene**	**BaA**	**BaP**	**BbF**	**BghiP**
CAS number	unitless	91-57-6	83-32-9	208-96-8	56-55-3	50-32-8	205-99-2	191-24-2
Diffusion coefficient in pure air	m^2/day	0.451	0.009	0.388	0.441	0.372	0.009	0.190
Diffusion coefficient in pure water	m^2/day	6.70E-05	8.64E-05	6.03E-05	7.78E-05	7.78E-05	8.64E-05	4.54E-05
Henry's Law constant	Pa-m^3/mol	50.56	18.50	12.70	1.22	0.07	0.05	0.03
Melting point	degrees K	307.75	366.15	365.65	433	452	441	550.15
Molecular weight	g/mol	142.20	154.21	152.20	228.29	252.32	252.32	276.34
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	7.24E+03	8.32E+03	1.00E+04	6.17E+05	9.33E+05	6.03E+05	4.27E+06

Table A-15. PAH Chemical-Specific Parameters (Cont.)*

Parameter Name[a]	**Units**	**Value**					
		BkF	**Chr**	**DahA**	**Fluoranthene**	**Fluorene**	**IcdP**
CAS number	unitless	207-08-9	218-01-9	53-70-3	206-44-0	86-73-7	193-39-5
Diffusion coefficient in pure air	m^2/day	0.009	0.009	0.009	0.009	0.009	0.009
Diffusion coefficient in pure water	m^2/day	8.64E-05	8.64E-05	8.64E-05	8.64E-05	8.64E-05	8.64E-05
Henry's Law constant	Pa-m^3/mol	0.04	0.53	0.01	1.96	9.81	0.03
Melting point	degrees K	490	531	539	383.15	383.15	437
Molecular weight	g/mol	252.32	228.29	278.33	202.26	166.20	276.34
Octanol-water partition coefficient (K_{ow})	L[water]/L [octanol]	8.71E+05	5.37E+05	3.16E+06	1.45E+05	1.51E+04	5.25E+06

Table A-15. PAH Chemical-Specific Parameters (Cont.)*

Parameter Name[a]	Units	Reference
CAS number	unitless	-
Diffusion coefficient in pure air	m^2/day	U.S. EPA 2005b. Exceptions include Siemens 2007 (2-Methylnaphthalene, Acenaphthylene, and Benzo(g,h,i)perylene).
Diffusion coefficient in pure water	m^2/day	U.S. EPA 2005b. Exceptions include Siemens 2007 (2-Methylnaphthalene, Acenaphthylene, and Benzo(g,h,i)perylene).
Henry's Law constant	Pa-m^3/mol	U.S. EPA 2005b. Exceptions include U.S. EPA 2003 (2-Methylnaphthalene), HSDB 2001a (Acenaphthylene), and HSDB 2001b (Benzo(g,h,i)perylene).
Melting point	degrees K	Budavari 1996. Exceptions include U.S. EPA 2003 (2-Methylnaphthalene), HSDB 2001a (Acenaphthylene), HSDB 2001b (Benzo(g,h,i)perylene), and U.S. EPA 2005b (Acenaphthene, Fluoranthene, and Fluorene).
Molecular weight	g/mol	Budavari 1996. Exceptions include U.S. EPA 2003 (2-Methylnaphthalene), HSDB 2001a (Acenaphthylene), HSDB 2001b (Benzo(g,h,i)perylene), and U.S. EPA 2005b (Acenaphthene, Fluoranthene, and Fluorene).
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	Hansch et al. 1995. Exceptions include Passivirta et al. 1999 (Acenaphthylene, Benzo(k)fluoranthene, and Indeno(1,2,3-cd)pyrene), and Sangster 1993 (Benzo(b)fluoranthene).

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] All parameters in this table are TRIM.FaTE chemical properties.

Table A-16. Dioxin Chemical-Specific Parameters*

Parameter Name[1]	Units	Value						
		1,2,3,4,6,7,8-HpCDD	**1,2,3,4,7,8-HxCDF**	**1,2,3,7,8-PeCDF**	**2,3,7,8-TCDD**	**1,2,3,4,6,7,8,9-OCDD**	**1,2,3,4,6,7,8,9-OCDF**	**1,2,3,4,6,7,8-HpCDF**
CAS number	unitless	35822-46-9	70648-26-9	57117-41-6	1746-01-6	3268-87-9	39001-02-0	67562-39-4
Diffusion coefficient in pure air	m^2/day	0.782	0.183	0.192	0.899	0.0883	0.123	0.129
Diffusion coefficient in pure water	m^2/day	6.91E-05	6.91E-05	6.91E-05	4.84E-05	3.08E-06	3.15E-05	3.33E-05
Henry's Law constant	Pa-m^3/mol	1.22	1.45	0.507	3.33	0.68	0.19	1.43
Melting point	degrees K	538[a]	499[a]	499[b]	578[a]	603	259	236.5
Molecular weight	g/mol	425.2[a]	374.87[a]	340.42[b]	322[a]	460.0	443.76	409.31
Octanol-water partition coefficient (K_{ow})	L[water]/ L[octanol]	1.00E+08	1.00E+07	6.17E+06	6.31E+06	1.58E+08	1.00E+08	2.51E+07

Table A-16. Dioxin Chemical-Specific Parameters (Cont.)*

Parameter Name[1]	Units	Value					
		1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8-PeCDD
CAS number	unitless	57653-85-7	57117-44-9	19408-74-3	72918-21-9	60851-34-5	40321-76-4
Diffusion coefficient in pure air	m^2/day	0.0958	0.135	0.0958	0.135	0.135	0.101
Diffusion coefficient in pure water	m^2/day	3.43E-05	3.53E-05	3.43E-05	3.53E-05	3.53E-05	3.65E-05
Henry's Law constant	Pa-m^3/mol	1.08	0.74	1.08	0.74	0.74	3.33
Melting point	degrees K	558.0	506.0	517.0	509.0	512.5	513.0
Molecular weight	g/mol	390.84	374.9	390.8	374.9	374.9	356.4
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	1.62E+08	8.24E+07	1.62E+08	3.80E+07	8.31E+07	4.37E+06

Table A-16. Dioxin Chemical-Specific Parameters (Cont.)*

Parameter Name[1]	Units	Value				Reference
		2,3,4,7,8-PeCDF	1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8-HxCDD	2,3,7,8-TCDF	
CAS number	unitless	57117-31-4	55673-89-7	39227-28-6	51207-31-9	-
Diffusion coefficient in pure air	m^2/day	0.142	0.129	0.0958	0.149	U.S. EPA 2005b.
Diffusion coefficient in pure water	m^2/day	3.76E-05	3.33E-05	3.43E-05	4.04E-05	U.S. EPA 2005b.
Henry's Law constant	Pa-m^3/mol	0.5	1.43	1.08	1.46	U.S. EPA 2005.
Melting point	degrees K	469.3	222	546	500.0	[a]Mackay et al. 2000. [b]ATSDR 1998.
Molecular weight	g/mol	340.4	409.31	391.0	306.0	[a]Mackay et al. 2000. [b]ATSDR 1998.
Octanol-water partition coefficient (K_{ow})	L[water]/L[octanol]	3.16E+06	7.94E+06	6.31E+07	1.26E+06	Mackay et al. 1992 as cited in U.S. EPA 2000.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[1] All parameters in this table are TRIM.FaTE chemical properties.

Table A-17. Cadmium Chemical-Specific Parameters for Abiotic Compartments*

Parameter Name	Units	Value	Reference
Air Compartment Type			
Particle dry deposition velocity	m/day	260	Calculated from Muhlbaier and Tisue 1981.
Washout ratio	m^3[air]/m^3[rain]	200,000	MacKay et al. 1986.
Surface Soil Compartment Type			
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	Professional judgment.
Root Zone Soil Compartment Type			
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	Professional judgment.
Surface Water Compartment Type			
Ratio of concentration in water to concentration in algae to concentration dissolved in water	L[water]/g[algal wet wt]	1.87	McGeer et al. 2003.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

Table A-18. Mercury Chemical-Specific Parameters for Abiotic Compartments

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Air Compartment Type					
Particle dry deposition velocity	m/day	500	500	500	McKone et al. 2001 (CalTOX value).
Demethylation rate	1/day	N/A	N/A	0	Professional judgment.
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	0.00385	0	0	U.S. EPA 1997 (low end of half-life range (6 months to 2 years)).
Reduction rate	1/day	0	0	0	Professional judgment.
Washout ratio	m^3[air]/m^3[rain]	200,000	200,000	200,000	Professional judgment.
Surface Soil Compartment Type					
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	0	0	Professional judgment.
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	U.S. EPA 1997.
Vapor dry deposition velocity	m/day	50[a]	2500[b]	0	[a]Lindberg et al. 1992 . [b]Estimate by U.S. EPA using the Industrial Source Complex (ISC) Model [See Vol. III, App. A of the Mercury Study Report (U.S. EPA 1997)].
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari, P. and M. Verta. 1995.

Table A-18. Mercury Chemical-Specific Parameters for Abiotic Compartments (Cont.)

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Surface Soil Compartment Type					
Methylation rate	1/day	0	0.001	0	Professional judgment.
Oxidation rate	1/day	0	0	0	U.S. EPA 1997.
Reduction rate	1/day	0	1.25E-5	0	Professional judgment.
Root Zone Soil Compartment Type					
Use input characteristic depth (Boolean)	0 = no, Else = yes	0	0	0	Professional judgment.
Soil-water partition coefficient	L[water]/kg[soil wet wt]	1,000	58,000	7,000	U.S. EPA 1997.
Demethylation rate	1/day	N/A	N/A	0.06	Range reported in Porvari and Verta 1995 is 3E-2 to 6E-2 /day; value is average maximum potential demethylation rate constant under anaerobic conditions.
Methylation rate	1/day	0	0.001	0	Range reported in Porvari and Verta 1995 is 2E-4 to 1E-3 /day; value is average maximum potential methylation rate constant under anaerobic conditions.
Oxidation rate	1/day	0	0	0	U.S. EPA 1997.
Reduction rate	1/day	0	3.25E-06	0	U.S. EPA 2005a

Table A-18. Mercury Chemical-Specific Parameters for Abiotic Compartments (Cont.)

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Surface Water Compartment Type					
Algal surface area-specific uptake rate constant	nmol/[µm^2-day-nmol]	0	2.04E-10	3.60E-10	Assumes radius = 2.5mm, Mason et al. 1995b, Mason et al. 1996; Hg(0) assumed same as Hg(2).
Dow ("overall K_{ow}")	L[water]/kg[octanol]	0	-[1]	-[2]	Mason et al. 1996.
Solids-water partition coefficient	L[water]/kg[solids wet wt]	1,000	100,000	100,000	U.S. EPA 1997.
Vapor dry deposition velocity	m/day	N/A	2500		U.S. EPA 1997 (Vol. III, App. A).
Demethylation rate	1/day	N/A	N/A	0.013	Gilmour and Henry 1991 (average of range of 1E-3 to 2.5E-2/day).
Methylation rate	1/day	0	0.001	0	U.S. EPA 1997; Gilmour and Henry 1991 (range is from 1E-4 to 3E-4/day).
Oxidation rate	1/day	0	0	0	Professional judgment.
Reduction rate	1/day	0	0.0075	0	U.S. EPA 1997; reported values range from less than 5E-3/day for depths greater than 17m, up to 3.5/day (Xiao et al. 1995; Vandal et al. 1995; Mason et al. 1995a; Amyot et al. 1997).
Sediment Compartment Type					
Solids-water partition coefficient	L[water]/kg[solids wet wt]	3,000	50,000	3,000	U.S. EPA 1997.
Demethylation rate	1/day	N/A	N/A	0.0501	Gilmour and Henry 1991 (average of range of 2E-4 to 1E-1/day).
Methylation rate	1/day	0	1.0E-4	0	U.S. EPA 1997; Gilmour and Henry 1991 (range is from 1E-5 to 1E-3/day).
Oxidation rate	1/day	0	0	0	Professional judgment.
Reduction rate	1/day	0	1.00E-06	0	U.S. EPA 1997; Vandal et al. 1995; (inferred value based on presence of Hg(0) in sediment porewater).

[1] TRIM.FaTE Formula Property, which varies from 0.025 to 1.625 depending on pH and chloride concentration.
[2] TRIM.FaTE Formula Property, which varies from 0.075 to 1.7 depending on pH and chloride concentration.

Table A-19. PAH Chemical-Specific Parameters for Abiotic Compartments*

Parameter Name	Units	Values							
		2Methyl	Acenaphthene	Acenaphthylene	BaA	BaP	BbF	BghiP	BkF
Air Compartment Type									
Particle dry deposition velocity	m/day	500	500	500	500	500	500	500	500
Half-life	day	0.154	0.3	0.208	0.125	0.046	0.596	0.215	0.458
Washout ratio	m3[air]/m3 [rain]	200000	200000	200000	200000	200000	200000	200000	200000
Surface Soil Compartment Type									
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0	0	0
Half-life	day	18	56	66.5	680	530	610	415	2140
Root Zone Soil Compartment Type									
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0	0	0
Half-life	day	18	56	66.5	680	530	610	415	2140
Surface Water Compartment Type									
Ratio of concentration in algae to concentration dissolved in water	(g[chem]/kg [algae]) / (g[chem]/ L[water])	2.6	3	3.7	325	510	317	1539	473
Half-life	day	78	25	184	0.375	0.138	90	1670	62.4
Sediment Compartment Type									
Half-life	day	2290	2290	2290	2290	2290	2290	2290	2290

Table A-19. PAH Chemical-Specific Parameters for Abiotic Compartments (Cont.)*

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Air Compartment Type							
Particle dry deposition velocity	m/day	500	500	500	500	500	McKone et al. 2001.
Half-life	day	0.334	0.178	0.46	0.46	0.262	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), U.S. EPA 2005b (Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001c (Acenaphthene), HSDB 2001a (Acenaphthylene), and Spero et al. 2000 (Fluorene).
Washout ratio	m3[air]/m3 [rain]	20000 0	200000	200000	200000	200000	Mackay et al. 1986.
Surface Soil Compartment Type							
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	Professional judgment.
Half-life	day	1000	940	275	33	730	MacKay et al. 2000 / average of range. Exceptions include ATSDR 2005 (2-Methylnaphthalene), U.S. EPA 2005b (Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001c (Acenaphthene), HSDB 2001a (Acenaphthylene), and HSDB 2001d (Fluorene).
Root Zone Soil Compartment Type							
User input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	Professional judgment.

Table A-19. PAH Chemical-Specific Parameters for Abiotic Compartments (Cont.)*

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Root Zone Soil Compartment Type							
Half-life	day	1000	940	275	33	730	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include ATSDR 2005 (2-Methylnaphthalene), U.S. EPA 2005b (Benzo(g,h,i)perylene, and Fluoranthene) / average of range, HSDB 2001c (Acenaphthene), HSDB 2001a (Acenaphthylene), and HSDB 2001d (Fluorene).
Surface Water Compartment Type							
Ratio of concentration in algae to concentration dissolved in water	(g[chem]/kg[algae]) / (g[chem]/L[water])	280	1388	67.4	5.8	1653	K_{ow} from Del Vento and Dachs 2002.
Half-life	day	1.626	97.8	160	8.5	750	Howard et al. 1991 / upper bound measured or estimated value. Exceptions include HSDB 2005 (2-Methylnaphthalene), HSDB 2001c (Acenaphthene), HSDB 2001a (Acenaphthylene), and HSDB 2001b (Benzo(g,h,i)perylene), Montgomery 2000 (Fluoranthene), and Boyle 1985 (Fluorene).
Sediment Compartment Type							
Half-life	day	2290	2290	2290	2290	2290	Mackay et al. 1992 (PAH values are the mean half-life of the log class that Mackay et al. assigned for sediment, except for BbF and IcdP, which were not on Table 2.3).

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

Table A-20. Dioxin Chemical-Specific Parameters for Abiotic Compartments*

Parameter Name	Units	Value					
		1,2,3,4,6,7,8,9-OCDD	**1,2,3,4,6,7,8,9-OCDF**	**1,2,3,4,6,7,8-HpCDD**	**1,2,3,4,6,7,8-HpCDF**	**1,2,3,4,7,8,9-HpCDF**	**1,2,3,4,7,8-HxCDD**
Air Compartment Type							
Deposition velocity	m/day	500	500	500	500	500	500
Half-life	day	162	321	64	137	122	42
Washout ratio	m^3[air]/m^3[rain]	91000	22000	64000	32000	32000	9000
Surface Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Half-life	day	1008	1008	1008	1008	1008	1008
Surface Water Compartment Type							
Ratio of concentration in algae to concentration dissolved in water	(g[chem]/g [algae])/(g[chem]/L[water])	5.31	4.54	4.54	2.83	1.9	3.88
Half-life	day	0.67	0.58	47	0.58	0.58	6.3
Sediment Compartment Type							
Half-life	day	1095	1095	1095	1095	1095	1095

Table A-20. Dioxin Chemical-Specific Parameters for Abiotic Compartments (Cont.)*

Parameter Name	Units	Value					
		1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-HxCDF	1,2,3,7,8-PeCDD
Air Compartment Type							
Deposition Velocity	m/day	500	500	500	500	500	500
Half-life	day	78	28	55	28	51	18
Washout ratio	m^3[air]/m^3[rain]	10000	9000	10000	9000	10000	18000
Surface Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type							
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650	3650
Half-life	day	1008	1008	1008	1008	1008	1008
Surface Water Compartment Type							
Ratio of concentration in algae to concentration dissolved in water	(g[chem]/g[algae])/(g[chem]/L[water])	2.06	5.36	4.25	5.36	3.26	1.55
Half-life	day	0.58	6.3	0.58	6.3	0.58	2.7
Sediment Compartment Type							
Half-life	day	1095	1095	1095	1095	1095	1095

Table A-20. Dioxin Chemical-Specific Parameters for Abiotic Compartments (Cont.)*

Parameter Name	Units	Value				
		1,2,3,7,8-PeCDF	**2,3,4,6,7,8-HxCDF**	**2,3,4,7,8-PeCDF**	**2,3,7,8-TCDD**	**2,3,7,8-TCDF**
Air Compartment Type						
Deposition velocity	m/day	500	500	500	500	500
Half-life	day	31	59	33	12	19
Washout ratio	m^3[air]/m^3[rain]	13000	10000	14000	18000	19000
Surface Soil Compartment Type						
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth (Boolean)	0 = No, Else = Yes	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650
Root Zone Soil Compartment Type						
Input characteristic depth	m	0.08	0.08	0.08	0.08	0.08
Use input characteristic depth	0 = No, Else = Yes	0	0	0	0	0
Half-life	day	3650	3650	3650	3650	3650
Surface Water Compartment Type						
Ratio of concentration in algae to concentration dissolved in water	(g[chem]/g[algae])/(g[chem]/L[water])	1.75	4.26	1.39	1.76	0.71
Half-life	day	0.19	0.58	0.19	2.7	0.18
Sediment Compartment Type						
Half-life	day	1095	1095	1095	1095	1095

Table A-20. Dioxin Chemical-Specific Parameters for Abiotic Compartments (Cont.)*

Parameter Name	References
Air Compartment Type	
Deposition Velocity	McKone et al. 2001.
Half-life	Atkinson 1996 as cited in U.S. EPA 2000; vapor-phase reaction with hydroxyl radical.
Washout ratio	Vulykh et al. 2001.
Surface Soil Compartment Type	
Input characteristic depth	Not used (model set to calculate value).
Use input characteristic depth (boolean)	Professional judgment.
Half-life	Mackay et al. 2000; the degradation rate was cited by multiple authors, value is for 2,3,7,8-TCDD.
Root Zone Soil Compartment Type	
Input characteristic depth	Not used (model set to calculate value).
Use input characteristic depth	Professional judgment.
Half-life	Mackay et al. 2000; the degradation rate was cited by multiple authors, value is for 2,3,7,8-TCDD.
Half-life	Average value of the range presented in Mackay et al. 2000; based on estimated unacclimated aerobic biodegradation half-life, value is for 2,3,7,8-TCDD.
Surface Water Compartment Type	
Ratio of concentration in algae to concentration dissolved in water	Estimated from K_{ow} value using model from Del Vento and Dachs 2002.
Half-life	Kim and O’Keefe 1998 as cited in U.S. EPA 2000.
Sediment Compartment Type	
Half-life	Estimation based on Adriaens and Grbic-Galic 1992,1993 and Adriaens et al. 1995 as cited in U.S. EPA 2000.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used)

Table A-21. Cadmium Chemical-Specific Parameters for Plant Compartments*

Parameter Name	Units	Value	Reference
Leaf Compartment Type			
Transfer factor to leaf particle	1/day	0.002	Professional judgment.
Particle on Leaf Compartment Type			
Transfer factor to leaf	1/day	0.200	Professional judgment.
Root Compartment Type - Grasses/Herbs[a]			
Root to root soil partition - alpha of steady state	unitless	0.95	Henning et al. 2001.
Root to root soil partition - partitioning coefficient	m^3[bulk root soil]/m^3[root]	0.23	Nriagu 1980 (based on average value calculated from various agricultural plant species).
Root to root soil partition - time to reach alpha	day	28	Henning et al. 2001.
Stem Compartment Type - Grasses/Herbs[a]			
Transpiration stream concentration factor (TSCF)	m^3[soil pore water]/m^3[xylem fluid]	0.45	Tsiros et al. 1999.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Table A-22. Mercury Chemical-Specific Parameters for Plant Compartments*

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Leaf Compartment Type					
Transfer factor to leaf particle	1/day	0.002	0.002	0	Professional judgment (assumed 1% of transfer factor from leaf particle to leaf).
Demethylation rate	1/day	N/A	N/A	0.03	Calculated from Bache et al. 1973.
Methylation rate	1/day	0	0	0	Assumed from Gay 1975, Bache et al. 1973.
Oxidation rate	1/day	1.0E+06	0	0	Professional judgment; assumed close to instantaneous.
Reduction rate	1/day	0	0	0	Professional judgment.
Particle on Leaf Compartment Type					
Transfer factor to leaf	1/day	0.2	0.2	0.2	Professional judgment.
Demethylation rate	1/day	N/A	N/A	0	Professional judgment.
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	0	0	0	Professional judgment.
Reduction rate	1/day	0	0	0	Professional judgment.
Root Compartment Type - Grasses/Herbs[a]					
Alpha for root-root zone bulk soil	unitless	0.95	0.95	0.95	Selected value.
Root/root-zone-soil-water partition coefficient	m^3[bulk root soil]/ m^3[root]	0	0.18[a]	1.2[b]	[a]Geometric mean Leonard et al. 1998, John 1972, Hogg et al. 1978 [b]MHg- assumed, based on Hogg et al. 1978.
t-alpha for root-root zone bulk soil	day	21	21	21	Professional judgment.
Demethylation rate	1/day	N/A	N/A	0	Professional judgment.

Table A-22. Mercury Chemical-Specific Parameters for Plant Compartments (Cont.)*

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Root Compartment Type - Grasses/Herbs[a]					
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	0	0	0	Professional judgment.
Reduction rate	1/day	0	0	0	Professional judgment.
Stem Compartment Type - Grasses/Herbs[a]					
Transpiration stream concentration factor (TSCF)	m^3[soil pore water]/ m^3[xylem fluid]	0	0.5	0.2	Bishop et al. 1998 (Norway spruce, Scots pine).
Demethylation rate	1/day	N/A	N/A	0.03	Calculated from Bache et al. 1973.
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	0	0	0	Professional judgment.
Reduction rate	1/day	0	0	0	Professional judgment.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Table A-23. PAH Chemical-Specific Parameters for Plant Compartments*

Parameter Name	Units	Value							
		2Methyl	Acenaphthene	Acenaphthylene	BaA	BaP	BbF	BghiP	BkF
Leaf Compartment Type									
Transfer factor to leaf particle	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Half-life	day	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Particle on Leaf Compartment Type									
Transfer factor to leaf	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Half-life	day	2.31	2.31	2.31	1.84	2.31	3.56	2.31	17.80
Root Compartment Type - Grasses/Herbs[a]									
Half-life	day	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60
Root soil water interaction - alpha	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Stem Compartment Type - Grasses/Herbs[a]									
Half-life	day	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50

Table A-23. PAH Chemical-Specific Parameters for Plant Compartments (Cont.)*

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Leaf Compartment Type							
Transfer factor to leaf particle	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	Professional judgment.
Half-life	day	3.50	3.50	3.50	3.50	3.50	Edwards 1988 (as cited in Efroymson 1997)/ calculated from metabolic rate constant.
Particle on Leaf Compartment Type							
Transfer factor to leaf	1/day	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	Professional judgment.
Half-life	day	4.12	17.80	2.31	2.31	17.80	Calculated as 2 times the measured photolysis half-life from Mackay et al. 1992. Exceptions include values that have been set equal to Benzo(a)pyrene (2-Methylnaphthalene; Acenaphthene; Acenaphthylene; Benzo(ghi)perylene; Fluoranthene; and Fluorene)
Root Compartment Type - Grasses/Herbs[a]							
Half-life	day	34.60	34.60	34.60	34.60	34.60	Edwards 1988 (as cited in Efroymson 1997)/ calculated from metabolic rate constant.
Root soil water interaction - alpha	unitless	0.95	0.95	0.95	0.95	0.95	Professional judgment.
Stem Compartment Type - Grasses/Herbs[a]							
Half-life	day	3.50	3.50	3.50	3.50	3.50	Edwards 1988 (as cited in Efroymson 1997)/ calculated from metabolic rate constant.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

Table A-24. Dioxin Chemical-Specific Parameters for Plant Compartments*

Parameter Name	Units	Value	Reference
		All Dioxins	
Leaf Compartment Type			
Transfer factor to leaf particle	1/day	0.003	Calculated as 1 percent of transfer factor to leaf; highly uncertain.
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba et al. 1995 (soybean root cell culture metabolism test data for DDE).
Particle on Leaf Compartment Type			
Transfer factor to leaf	1/day	0.3	Professional judgment based on U.S. EPA 2000 (an estimate for mercury) and Trapp 1995 (highly uncertain).
Half-life	day	4.4	McCrady and Maggard 1993 (photodegradation sorbed to grass foliage in sunlight; assumed 10 sunlight per day).
Root Compartment Type - Grasses/Herbs[a]			
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba, et al. 1995 (soybean root cell culture metabolism test data for DDE).
Root soil water interaction - alpha	unitless	0.95	Professional judgment.
Stem Compartment Type - Grasses/Herbs[a]			
Half-life	day	70	Arjmand and Sandermann 1985, as cited in Komoba, et al. 1995 (soybean root cell culture metabolism test data for DDE).

[a] Roots and stems are not modeled for deciduous or coniferous forest in the current version of TRIM.FaTE.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

Table A-25. Cadmium Chemical-Specific Parameters for Aquatic Species*

Parameter Name	Units	Value	Reference
Zooplankton Compartment Type			
Absorption rate constant	L[water]/ kg[fish wet wt]-day	1500	Goulet 2007.
Assimilation efficiency from algae	unitless	0.5	Goulet 2007.
Elimination rate constant	1/day	0.03	Goulet 2007.
Benthic Invertebrate Compartment Type			
Sediment partitioning - alpha of equilibrium	unitless	0.95	Professional judgment.
Sediment partitioning - partition coefficient	kg[bulk sed/kg[invertebrate wet wt]	0.27	Professional judgment.
Sediment partitioning - time to reach alpha of equilibrium	day	21	Hare et al. 2001.
Benthic Omnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Absorption rate constant	unitless	1.23	Calculated based on body weight from regression in Hendriks & Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Professional judgment.
Benthic Carnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Absorption rate constant	unitless	0.66	Calculated based on body weight from regression in Hendriks & Heikens 2001.
Elimination rate constant	unitless	1.68E-03	Professional judgment.
Water-column Herbivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Professional judgment based on Yan and Wang 2002.

Table A-25. Cadmium Chemical-Specific Parameters for Aquatic Species (Cont.)[A]

Parameter Name	Units	Value	Reference
Water-column Herbivore Compartment Type			
Assimilation efficiency from plants	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Absorption rate constant	unitless	2.46	Calculated based on body weight from regression in Hendriks & Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Professional judgmentr.
Water-column Omnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Assimilation efficiency from plants	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Absorption rate constant	unitless	1.23	Calculated based on body weight from regression in Hendriks & Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Professional judgment.
Water-column Carnivore Compartment Type			
Assimilation efficiency from food	unitless	0.1	Professional judgment based on Yan and Wang 2002.
Absorption rate constant	unitless	0.66	Calculated based on body weight from regression in Hendriks & Heikens 2001.
Elimination rate constant	unitless	1.73E-02	Professional judgment.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

Table A-26. Mercury Chemical-Specific Parameters for Aquatic Species*

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
Zooplankton Compartment Type					
AssimilationEfficiencyFromAlgae	unitless	0.2	0.015	0.5	Environment Canada 2002.
Half-life	day	1.0E+09	1.0E+09	1.0E+09	Professional judgment.
HowMuchFasterHgEliminationIsThanForMHg	unitless	3	3	1	Professional judgment.
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	0	1.0E+06	0	Professional judgment.
Reduction rate	1/day	0	0	0	Professional judgment.
Benthic Invertebrate Compartment Type					
Alpha of equilibrium for sediment partitioning	unitless	0.95	0.95	0.95	Selected value.
Benthic invertebrate-bulk sediment partition coefficient	kg[bulk sediment]/ kg[invertebrate wet wt]	0.0824[a]	0.0824[b]	5.04[b]	[a]Assumed based on Hg(2) value. [b]Saouter et al. 1991.
t-alpha for equilibrium for sediment partitioning	day	14	14	14	Saouter et al. 1991 (experiment duration).
All Fish Compartments Types[1]					
Elimination adjustment factor	unitless	3	3	1	Trudel and Rasmussen 1997.
Assimilation efficiency from food	unitless	0.06	0.06	0.5	Williams et al. 2010. The 0.5 value was used for MHg (instead of 0.8) to calibrate the model to match the ratio of Hg concentrations at different trophic levels within the same food web from published literature.

Table A-26. Mercury Chemical-Specific Parameters for Aquatic Species (Cont.)*

Parameter Name	Units	Value			Reference
		Hg(0)	Hg(2)	MHg	
All Fish Compartments Types[1]					
Demethylation rate	1/day	N/A	N/A	0	Professional judgment.
Methylation rate	1/day	0	0	0	Professional judgment.
Oxidation rate	1/day	1.0E+06	0	0	Professional judgment.
Reduction rate	1/day	0	0	0	Professional judgment.
Water-column Herbivore Compartment Type					
Assimilation efficiency from plankton	unitless	0.06	0.06	0.5	Williams et al. 2010. The 0.5 value was used for MHg (instead of 0.8) to calibrate the model to match the ratio of Hg concentrations at different trophic levels within the same food web from published literature.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[1] Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

Table A-27. PAH Chemical-Specific Parameters for Aquatic Species*

Parameter Name	Units	Value							
		2Methyl	**Acenaphthene**	**Acenaphthylene**	**BaA**	**BaP**	**BbF**	**BghiP**	**BkF**
Zooplankton Compartment Type									
Absorption rate constant	L[water]/ kg[fish wet wt]-day	790	42231	42302.2	42650.8	42652.8	42650.7	42655.8	42653
Assimilation efficiency from algae	unitless	0.5	0.5	0.5	0.46	0.25	0.25	0.25	0.25
Elimination rate constant	1/day	169.68	148.07	123.44	2.073	1.3864	2.12	0.33	1.48
Half-life	day	0.00779	0.00239	0.00239	1.284	16.5	17	17	17
Benthic Invertebrate Compartment Type									
Clearance constant	unitless	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6
V_d (ratio of concentration in benthic invertebrates to concentration in water)	mL/g	7235	7235	7235	7235	7235	7235	7235	7235
Half-life	day	0.722	0.722	0.722	1.284	16.5	17	17	17
All Fish Compartment Types[a]									
Gamma fish	unitless	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Assimilation efficiency from food	unitless	0.5	0.5	0.32	0.15	0.15	0.15	0.15	0.15
Half-life	day	0.2	0.2	0.2	0.408	1.925	2	2	2

Table A-27. PAH Chemical-Specific Parameters for Aquatic Species (Cont.)*

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Zooplankton Compartment Type							
Absorption rate constant	L[water]/ kg[fish wet wt]-day	42650	42655.5	142000	15000	42655.9	K_{ow} from Arnot et al. 2004. Exception is Berrojalbiz et al. 2009 (2-Methylnaphthalene, Fluoranthene, and Fluorene).
Assimilation efficiency from algae	unitless	0.46	0.25	0.49	0.5	0.25	K_{ow} from Arnot et al. 2004. Exception is maximum value from Wang and Wang 2006 (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, and Indeno(1,2,3-cd)pyrene).
Elimination rate constant	1/day	2.3746	0.4331	8.678	81.87	0.269	K_{ow} from Arnot et al. 2004.
Half-life	day	0.495	17	0.00239	0.000248	17	McElroy 1990. Exceptions include Berrojalbiz et al. 2009 (2-Methylnaphthalene, Fluoranthene, and Fluorene) and Moermond et al. 2007 (Benz(a)anthracene and Benzo(a)pyrene).

Table A-27. PAH Chemical-Specific Parameters for Aquatic Species (Cont.)*

Parameter Name	Units	Value					Reference
		Chr	DahA	Fluoranthene	Fluorene	IcdP	
Benthic Invertebrate Compartment Type							
Clearance constant	unitless	100.6	100.6	100.6	100.6	100.6	Stehly et al. 1990.
V_d (ratio of concentration in benthic invertebrates to concentration in water)	mL/g	7235	7235	7235	7235	7235	Stehly et al. 1990.
Half-life	day	0.495	17	0.722	0.722	17	Moermond et al. 2007.
All Fish Compartment Types[a]							
Gamma fish	unitless	0.2	0.2	0.2	0.2	0.2	Thomann 1989.
Assimilation efficiency from food	unitless	0.15	0.15	0.14	0.14	0.15	Lemair et al. 1992. Exceptions include Barber 2008 & Wang and Wang 2006 (2-Methylnaphthalene and Acenaphthene) and Niimi and Palazzo 1986 (Acenaphthylene, Fluoranthene, and Fluorene).
Half-life	day	0.533	2	0.165	0.2	2	Moermond et al. 2007.

*All values were unchanged from the Tiers 1 and 2 Screening assessments (no site-specific values used).

[a] Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

Table A-28. Dioxin Chemical-Specific Parameters for Aquatic Species*

Parameter Name	Units	Value								
		1,2,3,4,6,7,8,9-OCDD	1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7, 8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF
Benthic Invertebrate Compartment										
Clearance constant	unitless	0	0	0	0	0	0	0	0	0
Sediment partitioning partition coefficient	kg/kg	0.0013	0.0017	0.0055	0.0012	0.042	0.033	0.0081	0.013	0.02
Sediment partitioning alpha of equilibrium	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Sediment partitioning time to reach alpha of equilibrium	days	120	42	120	42	42	120	42	120	42
V_d (ratio of concentration in benthic invertebrates to concentration in water)	mL/g	0	0	0	0	0	0	0	0	0
Half-life	day	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2
Zooplankton Compartment Type										
Assimilation efficiency from food	unitless	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Absorption rate constant	L/kg(ww)/day	380.0	380.0	380.0	380.0	380.0	380.0	380.0	380.0	380.0
Elimination rate constant	/day	5.5E-4	5.5E-4	5.5E-4	5.5E-4	5.5E-4	5.5E-4	5.5E-4	5.5E-4	5.5E-4
Half life	day	1E09	1E09	1E09	1E09	1E09	1E09	1E09	1E09	1E09
All Fish Compartments[a]										
Assimilation efficiency from food	unitless	0.03	0.03	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chemical uptake rate via gill	L[water]/kg[fish wet wt]/day	142	N/A[b]	14	N/A[b]	N/A[b]	127	N/A[b]	127	N/A[b]
Gamma_fish	unitless	N/A[b]	0.2	N/A[b]	0.2	0.2	N/A[b]	0.2	N/A[b]	0.2
Half-life	day	693.15	346.57	346.57	346.57	346.57	495.11	495.11	495.11	495.11
Water Column Herbivore Compartment										
Assimilation efficiency from plants	unitless	0.03	0.03	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Water Column Omnivore Compartment										
Assimilation efficiency from plants	unitless	0.03	0.03	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table A-28. Dioxin Chemical-Specific Parameters for Aquatic Species (Cont.)*

Parameter Name	Units	Value							
		1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-HxCDF	1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF	2,3,4,6,7,8-HxCDF	2,3,4,7,8-PeCDF	2,3,7,8-TCDD	2,3,7,8-TCDF
Benthic Invertebrate Compartment									
Clearance constant	unitless	0	0	0	0	0	0	0	0
Sediment partitioning partition coefficient	kg/kg	0.015	0.067	0.098	0.024	0.072	0.17	0.205	0.056
Sediment partitioning alpha of equilibrium	unitless	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Sediment partitioning time to reach alpha of equilibrium	days	120	42	120	42	42	42	120	42
V_d (ratio of concentration in benthic invertebrates to concentration in water)	mL/g	0	0	0	0	0	0	0	0
Half-life	day	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2	5776.2
All Fish Compartments[a]									
Assimilation efficiency from food	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chemical uptake rate via gill	L[water]/kg[fish wet wt]/day	127	N/A[b]	700	N/A[b]	N/A[b]	N/A[b]	380	N/A[b]
Gamma_fish	unitless	N/A[b]	0.2	N/A[b]	0.2	0.2	0.2	N/A[b]	0.2
Half-life	day	495.11	495.11	420.09	420.09	495.11	420.09	5251.1	5251.1
Water Column Herbivore Compartment									
Assimilation efficiency from plants	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Water Column Omnivore Compartment									
Assimilation efficiency from plants	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table A-28. Dioxin Chemical-Specific Parameters for Aquatic Species (Cont.)*

Parameter Name	Units	Reference
Benthic Invertebrate Compartment		
Clearance constant	unitless	Professional judgment.
Sediment partitioning partition coefficient	kg/kg	TCDD data for sandworm in Rubenstein et al. 1990; dry weight sediment. PeCDF, multiplied TCDD partition coefficient for sandworm by congener-specific bioaccumulation equivalency factor in GLWQI from U.S. EPA 1999.
Sediment partitioning alpha of equilibrium	unitless	Professional judgment.
Sediment partitioning time to reach alpha of equilibrium	days	TCDD: professional judgment; PeCDF: Rubinstein et al. 1990; data for TCDF in sandworm.
V_d (ratio of concentration in benthic invertebrates to concentration in water)	mL/g	Professional judgment.
Half-life	day	Change source to f-pass
Zooplankton Compartment Type		
Assimilation efficiency from food	unitless	Morrison et al. 1999.
Absorption rate constant	L/kg(ww)-day	Based on fish value in Muir et al. 1986
Elimination rate constant	/day	Professional judgment based on water column herbivore value.
Half Life	day	Professional judgment.
All Fish Compartments[a]		
Assimilation efficiency from food	unitless	TCDD: calculated from data in Kleeman et al. 1986b trout data as cited in U.S. EPA 1993; PeCDF: used assimilation efficiency for TCDD in trout.
Chemical uptake rate via gill	L[water]/kg[fish wet wt]-day	Muir et al. 1986.
Gamma_fish	unitless	Thomann 1989
Half-life	day	Change source to f-pass
Water Column Herbivore Compartment		
Assimilation efficiency from plants	unitless	TCDD: calculated from data in Kleeman et al. 1986b trout data as cited in U.S. EPA 1993; PeCDF: used assimilation efficiency for TCDD in trout.
Water Column Omnivore Compartment		
Assimilation efficiency from plants	unitless	TCDD: calculated from data in Kleeman et al. 1986b trout data as cited in U.S. EPA 1993; PeCDF: used assimilation efficiency for TCDD in trout.

*All values were unchanged from the Tiers 1 and 2 screening assessments (no site-specific values used).

[a] Ferroalloys scenario includes: Benthic Omnivore, Benthic Carnivore, Water-column Herbivore, Water-column Omnivore, and Water-column Carnivore.

[b] N/A = not applicable. This parameter is used in calculating the uptake when measured data are unavailable.

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Appendix B

Modeled Media Concentrations

This appendix provides the concentrations of PB-HAPs estimated in TRIM.FaTE compartments. The values are the annual average for the 50th year of the simulation; these outputs were used in the risk characterization estimates.

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Table B-1. Concentration Estimates and Speciations for Mercury

Location and Medium		Units	Total Hg	Divalent Hg		Elemental Hg		Methyl Hg[a]	
			Value	Value	% Total Hg	Value	% Total Hg	Value	% Total Hg
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	9.87E-03	9.62E-03	97.49%	8.75E-05	0.89%	1.60E-04	1.62%
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.96E-02	1.93E-02	98.36%	3.67E-06	0.02%	3.18E-04	1.62%
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	2.01E-02	1.96E-02	97.58%	1.60E-04	0.80%	3.27E-04	1.63%
	Untilled Surface Soil	µg g^{-1} [dry weight]	3.88E-02	3.81E-02	98.35%	4.68E-06	0.01%	6.34E-04	1.64%
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	2.62E-03	2.55E-03	97.41%	2.54E-05	0.97%	4.26E-05	1.62%
	Untilled Surface Soil	µg g^{-1} [dry weight]	7.06E-03	6.94E-03	98.35%	1.74E-06	0.02%	1.15E-04	1.63%
Wolf Run Lake	Surface water	mg L^{-1}	2.97E-08	2.45E-08	82.54%	4.57E-09	15.40%	6.12E-10	2.06%
	Macrophyte	mg kg^{-1} [wet weight]	4.30E-08	4.09E-08	95.17%	4.30E-17	0.00%	2.08E-09	4.83%
	Zooplankton	mg kg^{-1} [wet weight]	3.17E-04	1.48E-04	46.63%	0.00E+00	0.00%	1.69E-04	53.37%
	Water Column Herbivore	mg kg^{-1} [wet weight]	6.84E-04	5.99E-05	8.76%	0.00E+00	0.00%	6.24E-04	91.24%

Table B-1. Concentration Estimates and Speciations for Mercury (Cont.)

Location and Medium		Units	Total Hg	Divalent Hg		Elemental Hg		Methyl Hg[a]	
			Value	Value	% Total Hg	Value	% Total Hg	Value	% Total Hg
Wolf Run Lake	Water Column Omnivore	mg kg^{-1} [wet weight]	3.11E-03	2.57E-05	0.82%	0.00E+00	0.00%	3.09E-03	99.18%
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.73E-02	1.41E-05	0.08%	0.00E+00	0.00%	1.73E-02	99.92%
	Sediment	µg g^{-1} [dry weight]	1.01E-03	1.01E-03	99.19%	6.13E-06	0.60%	2.07E-06	0.20%
	Benthic Invertebrate	mg kg^{-1} [wet weight]	5.92E-05	5.24E-05	88.51%	3.19E-07	0.54%	6.49E-06	10.95%
	Benthic Omnivore	mg kg^{-1} [wet weight]	4.97E-05	2.51E-05	50.46%	3.23E-12	0.00%	2.46E-05	49.54%
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.35E-04	2.22E-05	9.43%	2.05E-12	0.00%	2.13E-04	90.57%
Veto Lake	Surface water	mg L^{-1}	1.06E-07	1.02E-07	96.79%	3.02E-09	2.86%	3.70E-10	0.35%
	Macrophyte	mg kg^{-1} [wet weight]	3.14E-08	3.11E-08	99.04%	4.77E-17	0.00%	3.02E-10	0.96%
	Zooplankton	mg kg^{-1} [wet weight]	1.55E-04	1.31E-04	84.32%	0.00E+00	0.00%	2.43E-05	15.68%
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.43E-04	5.29E-05	36.92%	0.00E+00	0.00%	9.03E-05	63.08%
	Water Column Omnivore	mg kg^{-1} [wet weight]	4.78E-04	2.27E-05	4.75%	0.00E+00	0.00%	4.55E-04	95.25%
	Water Column Carnivore	mg kg^{-1} [wet weight]	2.51E-03	1.25E-05	0.50%	0.00E+00	0.00%	2.50E-03	99.50%

Table B-1. Concentration Estimates and Speciations for Mercury (Cont.)

Location and Medium		Units	Total Hg	Divalent Hg		Elemental Hg		Methyl Hg[a]	
			Value	Value	% Total Hg	Value	% Total Hg	Value	% Total Hg
Veto Lake	Sediment	µg g^{-1} [dry weight]	1.90E-03	1.90E-03	99.63%	3.10E-06	0.16%	3.89E-06	0.20%
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.11E-04	9.88E-05	88.91%	1.61E-07	0.15%	1.22E-05	10.94%
	Benthic Omnivore	mg kg^{-1} [wet weight]	9.15E-05	4.54E-05	49.60%	2.80E-12	0.00%	4.61E-05	50.40%
	Benthic Carnivore	mg kg^{-1} [wet weight]	4.40E-04	4.00E-05	9.10%	1.05E-12	0.00%	4.00E-04	90.90%
Mountwood Park Lake	Surface water	mg L^{-1}	1.10E-08	1.01E-08	92.37%	7.94E-10	7.25%	4.24E-11	0.39%
	Macrophyte	mg kg^{-1} [wet weight]	5.12E-09	5.09E-09	99.41%	9.92E-18	0.00%	3.02E-11	0.59%
	Zooplankton	mg kg^{-1} [wet weight]	1.32E-05	1.08E-05	82.11%	0.00E+00	0.00%	2.36E-06	17.89%

Table B-1. Concentration Estimates and Speciations for Mercury (Cont.)

Location and Medium		Units	Total Hg	Divalent Hg		Elemental Hg		Methyl Hg[a]	
			Value	Value	% Total Hg	Value	% Total Hg	Value	% Total Hg
Mountwood Park Lake	Water Column Herbivore	mg kg^{-1} [wet weight]	1.30E-05	4.31E-06	33.07%	0.00E+00	0.00%	8.73E-06	66.93%
	Water Column Omnivore	mg kg^{-1} [wet weight]	4.55E-05	1.83E-06	4.02%	0.00E+00	0.00%	4.37E-05	95.98%
	Water Column Carnivore	mg kg^{-1} [wet weight]	2.28E-04	9.74E-07	0.43%	0.00E+00	0.00%	2.27E-04	99.57%
	Sediment	µg g^{-1} [dry weight]	1.04E-04	1.03E-04	99.33%	4.83E-07	0.47%	2.06E-07	0.20%
	Benthic Invertebrate	mg kg^{-1} [wet weight]	6.02E-06	5.36E-06	88.99%	2.51E-08	0.42%	6.37E-07	10.59%
	Benthic Omnivore	mg kg^{-1} [wet weight]	4.80E-06	2.42E-06	50.35%	7.70E-13	0.00%	2.38E-06	49.65%
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.18E-05	2.10E-06	9.64%	7.57E-13	0.00%	1.97E-05	90.36%

[a] Methyl mercury concentrations represent the mass of mercury as methyl mercury.

Table B-2. Concentration Estimates for Cadmium

Location and Medium		Units	Values
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	1.10E-02
	Untilled Surface Soil	µg g^{-1} [dry weight]	9.09E-03
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	5.33E-02
	Untilled Surface Soil	µg g^{-1} [dry weight]	7.18E-02
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	3.94E-02
	Untilled Surface Soil	µg g^{-1} [dry weight]	2.94E-02
Wolf Run Lake	Surface water	mg L^{-1}	1.84E-06
	Macrophyte	mg kg^{-1} [wet weight]	1.83E-04
	Zooplankton	mg kg^{-1} [wet weight]	1.17E-01
	Water Column Herbivore	mg kg^{-1} [wet weight]	5.82E-02
	Water Column Omnivore	mg kg^{-1} [wet weight]	2.02E-02
	Water Column Carnivore	mg kg^{-1} [wet weight]	5.77E-03
	Sediment	µg g^{-1} [dry weight]	4.55E-03
	Benthic Invertebrate	mg kg^{-1} [wet weight]	7.75E-04
	Benthic Omnivore	mg kg^{-1} [wet weight]	3.99E-04
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.38E-03

Table B-2. Concentration Estimates for Cadmium (Cont.)

Location and Medium		Units	Values
Veto Lake	Surface water	mg L^{-1}	1.98E-06
	Macrophyte	mg kg^{-1} [wet weight]	1.89E-04
	Zooplankton	mg kg^{-1} [wet weight]	1.27E-01
	Water Column Herbivore	mg kg^{-1} [wet weight]	7.73E-02
	Water Column Omnivore	mg kg^{-1} [wet weight]	3.28E-02
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.17E-02
	Sediment	µg g^{-1} [dry weight]	2.32E-03
	Benthic Invertebrate	mg kg^{-1} [wet weight]	3.95E-04
	Benthic Omnivore	mg kg^{-1} [wet weight]	2.98E-04
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.02E-03
Mountwood Park Lake	Surface water	mg L^{-1}	2.38E-07
	Macrophyte	mg kg^{-1} [wet weight]	2.26E-05
	Zooplankton	mg kg^{-1} [wet weight]	1.69E-02
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.45E-02
	Water Column Omnivore	mg kg^{-1} [wet weight]	8.50E-03
	Water Column Carnivore	mg kg^{-1} [wet weight]	4.39E-03
	Sediment	µg g^{-1} [dry weight]	1.73E-04
	Benthic Invertebrate	mg kg^{-1} [wet weight]	2.93E-05
	Benthic Omnivore	mg kg^{-1} [wet weight]	3.26E-05
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.49E-04

Table B-3. Concentration Estimates for PAH Congeners

Location and Medium		Units	Values						
			Acenaphthene	**Acenaphthylene**	**Benzo(A)anthracene**	**Benzo(A)pyrene**	**Benzo(B)flouranthene**	**Benzo(g,h,i)perylene**	**Benzo(K)fluoranthene**
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	1.17E-07	1.04E-06	5.57E-05	1.14E-04	8.12E-04	9.62E-05	1.10E-03
	Untilled Surface Soil	µg g^{-1} [dry weight]	2.25E-06	5.12E-05	7.07E-04	1.47E-03	9.72E-03	1.35E-03	6.88E-03
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	1.56E-07	1.65E-06	6.97E-05	1.45E-04	9.93E-04	1.23E-04	1.56E-03
	Untilled Surface Soil	µg g^{-1} [dry weight]	3.56E-06	6.34E-05	8.80E-04	1.81E-03	1.16E-02	1.65E-03	9.34E-03
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	9.56E-08	1.00E-06	2.15E-05	2.79E-05	3.03E-04	2.63E-05	4.26E-04
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.05E-06	1.81E-05	2.72E-04	3.89E-04	3.82E-03	4.02E-04	2.86E-03
Wolf Run Lake	Surface water	mg L^{-1}	1.53E-09	9.30E-09	1.96E-10	2.66E-11	2.51E-08	1.72E-09	6.77E-09
	Macrophyte	mg kg^{-1} [wet weight]	3.11E-08	2.28E-07	1.31E-07	1.74E-08	1.68E-05	7.69E-07	4.47E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values						
			Acenaphthene	Acenaphthylene	Benzo(A)anthracene	Benzo(A)pyrene	Benzo(B)flouranthene	Benzo(g,h,i)perylene	Benzo(K)fluoranthene
Wolf Run Lake	Zooplankton	mg kg^{-1} [wet weight]	1.50E-07	9.70E-07	5.87E-06	1.04E-06	6.12E-04	2.76E-04	2.44E-04
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.38E-06	9.27E-06	8.26E-07	4.21E-07	4.87E-04	1.70E-05	1.14E-04
	Water Column Omnivore	mg kg^{-1} [wet weight]	9.68E-07	5.93E-06	1.55E-07	8.66E-08	1.07E-04	2.13E-06	2.39E-05
	Water Column Carnivore	mg kg^{-1} [wet weight]	7.94E-07	4.85E-06	1.23E-07	6.32E-08	7.83E-05	1.39E-06	1.74E-05
	Sediment	µg g^{-1} [dry weight]	3.47E-08	3.78E-07	2.81E-06	5.82E-07	4.35E-04	5.54E-05	1.44E-04
	Benthic Invertebrate	mg kg^{-1} [wet weight]	6.54E-07	4.10E-06	1.09E-06	1.93E-07	2.91E-04	5.41E-06	6.71E-05
	Benthic Omnivore	mg kg^{-1} [wet weight]	9.63E-07	5.90E-06	1.57E-07	8.07E-08	1.01E-04	1.80E-06	2.26E-05
	Benthic Carnivore	mg kg^{-1} [wet weight]	7.93E-07	4.85E-06	1.25E-07	6.43E-08	8.02E-05	1.42E-06	1.78E-05

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values						
			Acenaphthene	Acenaphthylene	Benzo(A)anthracene	Benzo(A)pyrene	Benzo(B)flouranthene	Benzo(g,h,i)perylene	Benzo(K)fluoranthene
Veto Lake	Surface water	mg L^{-1}	4.69E-09	2.01E-08	2.40E-09	4.31E-10	8.53E-08	7.68E-09	2.67E-08
	Macrophyte	mg kg^{-1} [wet weight]	9.54E-08	4.90E-07	1.41E-06	2.13E-07	4.71E-05	2.24E-06	1.42E-05
	Zooplankton	mg kg^{-1} [wet weight]	4.60E-07	2.09E-06	7.26E-05	1.45E-05	1.95E-03	9.75E-04	8.95E-04
	Water Column Herbivore	mg kg^{-1} [wet weight]	4.22E-06	1.99E-05	8.94E-06	5.34E-06	1.39E-03	6.65E-05	3.73E-04
	Water Column Omnivore	mg kg^{-1} [wet weight]	2.97E-06	1.28E-05	1.65E-06	1.10E-06	3.10E-04	7.15E-06	7.84E-05
	Water Column Carnivore	mg kg^{-1} [wet weight]	2.43E-06	1.04E-05	1.29E-06	7.78E-07	2.22E-04	4.09E-06	5.54E-05
	Sediment	µg g^{-1} [dry weight]	3.47E-07	2.91E-06	3.76E-05	8.81E-06	1.39E-03	1.91E-04	5.12E-04
	Benthic Invertebrate	mg kg^{-1} [wet weight]	6.54E-06	3.16E-05	1.45E-05	2.91E-06	9.25E-04	1.87E-05	2.38E-04

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values						
			Acenaphthene	Acenaphthylene	Benzo(A)anthracene	Benzo(A)pyrene	Benzo(B)flouranthene	Benzo(g,h,i)perylene	Benzo(K)fluoranthene
Veto Lake	Benthic Omnivore	mg kg^{-1} [wet weight]	3.00E-06	1.29E-05	1.69E-06	1.02E-06	2.94E-04	5.46E-06	7.38E-05
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.45E-06	1.05E-05	1.33E-06	8.00E-07	2.30E-04	4.22E-06	5.75E-05
Mountwood Park Lake	Surface water	mg L^{-1}	1.50E-09	7.03E-09	4.05E-10	6.98E-11	1.22E-08	9.52E-10	3.56E-09
	Macrophyte	mg kg^{-1} [wet weight]	3.06E-08	1.72E-07	2.31E-07	3.26E-08	6.54E-06	2.61E-07	1.82E-06
	Zooplankton	mg kg^{-1} [wet weight]	1.49E-07	7.43E-07	1.59E-05	2.94E-06	3.42E-04	1.57E-04	1.50E-04
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.35E-06	6.95E-06	1.58E-06	9.07E-07	2.03E-04	1.35E-05	5.27E-05
	Water Column Omnivore	mg kg^{-1} [wet weight]	9.56E-07	4.48E-06	2.76E-07	1.84E-07	4.64E-05	1.25E-06	1.10E-05
	Water Column Carnivore	mg kg^{-1} [wet weight]	7.83E-07	3.66E-06	2.13E-07	1.21E-07	3.14E-05	5.01E-07	7.27E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values						
			Acenaphthene	Acenaphthylene	Benzo(A)anthracene	Benzo(A)pyrene	Benzo(B)flouranthene	Benzo(g,h,i)perylene	Benzo(K)fluoranthene
Mountwood Park Lake	Sediment	µg g^{-1} [dry weight]	5.69E-08	4.34E-07	1.01E-06	2.00E-07	3.06E-05	3.65E-06	1.05E-05
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.07E-06	4.70E-06	3.89E-07	6.58E-08	2.04E-05	3.55E-07	4.86E-06
	Benthic Omnivore	mg kg^{-1} [wet weight]	9.53E-07	4.46E-06	2.63E-07	1.43E-07	3.72E-05	5.72E-07	8.61E-06
	Benthic Carnivore	mg kg^{-1} [wet weight]	7.83E-07	3.66E-06	2.13E-07	1.18E-07	3.07E-05	4.71E-07	7.10E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values					
			Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Methylnaphthalene, 2-
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	5.14E-04	4.44E-05	4.64E-05	1.78E-07	1.21E-04	1.11E-07
	Untilled Surface Soil	µg g^{-1} [dry weight]	4.90E-03	4.46E-04	6.69E-04	3.70E-06	1.37E-03	8.30E-06
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	6.35E-04	5.85E-05	5.52E-05	2.01E-07	1.54E-04	1.23E-07
	Untilled Surface Soil	µg g^{-1} [dry weight]	5.94E-03	5.55E-04	8.78E-04	4.52E-06	1.65E-03	8.30E-06
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	2.21E-04	1.27E-05	2.80E-05	1.01E-07	3.55E-05	7.00E-08
	Untilled Surface Soil	µg g^{-1} [dry weight]	2.19E-03	1.46E-04	3.17E-04	1.62E-06	4.60E-04	2.63E-06
Wolf Run Lake	Surface water	mg L^{-1}	2.15E-09	3.23E-10	1.56E-08	2.01E-09	1.35E-09	2.59E-09
	Macrophyte	mg kg^{-1} [wet weight]	1.41E-06	1.51E-07	5.22E-06	7.51E-08	5.82E-07	4.58E-08

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values					
			Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Methylnaphthalene, 2-
Wolf Run Lake	Zooplankton	mg kg^{-1} [wet weight]	4.27E-05	4.06E-05	7.31E-06	1.16E-08	2.59E-04	1.64E-08
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.22E-05	3.03E-06	3.84E-05	2.50E-06	1.44E-05	2.16E-06
	Water Column Omnivore	mg kg^{-1} [wet weight]	2.37E-06	4.49E-07	7.56E-06	1.30E-06	1.56E-06	1.62E-06
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.87E-06	3.05E-07	6.07E-06	1.06E-06	9.75E-07	1.33E-06
	Sediment	µg g^{-1} [dry weight]	2.81E-05	9.86E-06	2.99E-05	1.10E-07	4.36E-05	6.34E-08
	Benthic Invertebrate	mg kg^{-1} [wet weight]	4.56E-06	1.77E-06	5.67E-05	1.32E-06	3.47E-06	9.42E-07
	Benthic Omnivore	mg kg^{-1} [wet weight]	2.32E-06	4.14E-07	7.60E-06	1.30E-06	1.26E-06	1.61E-06
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.87E-06	3.19E-07	6.11E-06	1.06E-06	9.92E-07	1.33E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values					
			Chrysene	**Dibenz[a,h]anthracene**	**Fluoranthene**	**Fluorene**	**Indeno(1,2,3-cd)pyrene**	**Methylnaphthalene, 2-**
Veto Lake	Surface water	mg L^{-1}	1.89E-08	1.39E-09	3.39E-08	9.44E-09	5.61E-09	6.00E-09
	Macrophyte	mg kg^{-1} [wet weight]	1.05E-05	4.93E-07	1.11E-05	3.52E-07	1.50E-06	1.06E-07
	Zooplankton	mg kg^{-1} [wet weight]	3.65E-04	1.61E-04	1.59E-05	5.59E-08	8.09E-04	4.29E-08
	Water Column Herbivore	mg kg^{-1} [wet weight]	9.10E-05	1.27E-05	8.08E-05	1.17E-05	5.11E-05	4.99E-06
	Water Column Omnivore	mg kg^{-1} [wet weight]	1.76E-05	1.63E-06	1.59E-05	6.08E-06	4.79E-06	3.75E-06
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.37E-05	1.01E-06	1.28E-05	4.96E-06	2.54E-06	3.08E-06
	Sediment	µg g^{-1} [dry weight]	2.76E-04	3.53E-05	1.36E-04	1.72E-06	1.40E-04	5.07E-07
	Benthic Invertebrate	mg kg^{-1} [wet weight]	4.47E-05	6.33E-06	2.58E-04	2.07E-05	1.11E-05	7.52E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values					
			Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Methylnaphthalene, 2-
Veto Lake	Benthic Omnivore	mg kg^{-1} [wet weight]	1.72E-05	1.41E-06	1.64E-05	6.11E-06	3.36E-06	3.78E-06
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.38E-05	1.07E-06	1.30E-05	4.97E-06	2.61E-06	3.10E-06
Mountwood Park Lake	Surface water	mg L^{-1}	3.09E-09	1.88E-10	1.04E-08	2.58E-09	7.19E-10	2.01E-09
	Macrophyte	mg kg^{-1} [wet weight]	1.65E-06	6.39E-08	3.37E-06	9.64E-08	1.79E-07	3.55E-08
	Zooplankton	mg kg^{-1} [wet weight]	7.59E-05	2.87E-05	5.18E-06	1.62E-08	1.34E-04	1.81E-08
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.50E-05	2.68E-06	2.45E-05	3.19E-06	1.10E-05	1.67E-06
	Water Column Omnivore	mg kg^{-1} [wet weight]	2.83E-06	2.91E-07	4.87E-06	1.67E-06	9.19E-07	1.26E-06
	Water Column Carnivore	mg kg^{-1} [wet weight]	2.17E-06	1.36E-07	3.89E-06	1.36E-06	3.23E-07	1.04E-06

Table B-3. Concentration Estimates for PAH Congeners (Cont.)

Location and Medium		Units	Values					
			Chrysene	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Methylnaphthalene, 2-
Mountwood Park Lake	Sediment	µg g^{-1} [dry weight]	7.20E-06	6.98E-07	8.36E-06	2.00E-07	2.88E-06	8.08E-08
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.17E-06	1.25E-07	1.59E-05	2.40E-06	2.28E-07	1.20E-06
	Benthic Omnivore	mg kg^{-1} [wet weight]	2.65E-06	1.59E-07	4.84E-06	1.66E-06	3.64E-07	1.26E-06
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.16E-06	1.30E-07	3.91E-06	1.36E-06	2.99E-07	1.04E-06

Table B-4. Concentration Estimates for Dioxin Congeners

Location and Medium		Units	Values					
			HeptaCDD, 1,2,3,4,6,7,8-	HexaCDF, 1,2,3,4,7,8-	PentaCDF, 1,2,3,7,8-	TetraCDD, 2,3,7,8-	OctaCDF, 1,2,3,4,6,7,8,9-	TetraCDF, 2,3,7,8-
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	3.00E-09	5.99E-10	8.70E-10	2.03E-10	5.47E-09	1.55E-10
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.39E-08	2.77E-09	4.01E-09	1.01E-09	2.52E-08	7.30E-10
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	4.61E-09	9.04E-10	1.34E-09	3.35E-10	8.30E-09	2.96E-10
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.92E-08	3.85E-09	5.78E-09	1.59E-09	3.44E-08	1.51E-09
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	9.03E-10	2.28E-10	3.26E-10	9.24E-11	1.61E-09	1.15E-10
	Untilled Surface Soil	µg g^{-1} [dry weight]	5.39E-09	1.29E-09	1.80E-09	5.06E-10	9.60E-09	4.55E-10
Wolf Run Lake	Surface water	mg L^{-1}	4.50E-15	2.04E-16	9.49E-17	3.65E-16	7.67E-16	5.85E-17
	Macrophyte	mg kg^{-1} [wet weight]	8.76E-11	5.06E-12	1.95E-12	7.62E-12	1.48E-11	3.99E-13
	Zooplankton	mg kg^{-1} [wet weight]	7.94E-10	1.03E-11	3.27E-12	1.27E-11	1.61E-10	4.88E-13
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.13E-09	2.13E-11	8.68E-12	3.94E-11	6.73E-11	2.36E-12
	Water Column Omnivore	mg kg^{-1} [wet weight]	1.24E-09	2.90E-11	1.44E-11	6.93E-11	2.00E-11	4.99E-12
	Water Column Carnivore	mg kg^{-1} [wet weight]	7.83E-10	4.58E-11	3.10E-11	1.53E-10	4.96E-12	1.37E-11
	Sediment	µg g^{-1} [dry weight]	1.24E-10	1.13E-12	3.45E-13	1.36E-12	2.05E-11	5.00E-14
	Benthic Invertebrate	mg kg^{-1} [wet weight]	4.04E-13	5.61E-15	5.00E-15	1.56E-13	2.20E-14	1.68E-15
	Benthic Omnivore	mg kg^{-1} [wet weight]	9.56E-12	2.49E-12	1.65E-12	1.30E-11	1.86E-13	1.34E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.35E-11	5.21E-12	4.09E-12	3.17E-11	2.14E-13	3.67E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values					
			HeptaCDD, 1,2,3,4,6,7,8-	**HexaCDF, 1,2,3,4,7,8-**	**PentaCDF, 1,2,3,7,8-**	**TetraCDD, 2,3,7,8-**	**OctaCDF, 1,2,3,4,6,7,8,9-**	**TetraCDF, 2,3,7,8-**
Veto Lake	Surface water	mg L^{-1}	2.98E-14	2.35E-15	1.27E-15	2.75E-15	1.07E-14	6.79E-16
	Macrophyte	mg kg^{-1} [wet weight]	2.54E-11	1.05E-11	6.66E-12	1.47E-11	8.70E-12	2.90E-12
	Zooplankton	mg kg^{-1} [wet weight]	2.18E-10	2.21E-11	1.15E-11	2.47E-11	9.41E-11	3.50E-12
	Water Column Herbivore	mg kg^{-1} [wet weight]	3.67E-10	4.99E-11	3.24E-11	8.13E-11	4.71E-11	1.70E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	4.91E-10	7.41E-11	5.65E-11	1.53E-10	1.77E-11	3.72E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	4.06E-10	1.48E-10	1.49E-10	4.18E-10	5.82E-12	1.24E-10
	Sediment	µg g^{-1} [dry weight]	4.76E-10	3.11E-11	1.49E-11	3.42E-11	1.63E-10	4.30E-12
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.53E-12	1.53E-13	2.14E-13	3.81E-12	1.73E-13	1.42E-13
	Benthic Omnivore	mg kg^{-1} [wet weight]	4.82E-12	5.09E-12	5.58E-12	3.07E-11	1.72E-13	8.93E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	5.59E-12	1.18E-11	1.51E-11	7.91E-11	1.65E-13	2.78E-11
Mountwood Park Lake	Surface water	mg L^{-1}	3.53E-15	3.30E-16	1.83E-16	3.60E-16	1.52E-15	1.07E-16
	Macrophyte	mg kg^{-1} [wet weight]	2.94E-12	1.55E-12	9.88E-13	1.95E-12	1.29E-12	4.44E-13
	Zooplankton	mg kg^{-1} [wet weight]	2.12E-11	2.68E-12	1.44E-12	2.85E-12	1.25E-11	5.14E-13
	Water Column Herbivore	mg kg^{-1} [wet weight]	5.04E-11	8.76E-12	5.57E-12	1.20E-11	1.03E-11	2.92E-12
	Water Column Omnivore	mg kg^{-1} [wet weight]	9.21E-11	1.76E-11	1.28E-11	2.82E-11	5.57E-12	7.70E-12
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.09E-10	5.38E-11	5.33E-11	1.17E-10	2.56E-12	4.01E-11

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values					
			HeptaCDD, 1,2,3,4,6,7,8-	HexaCDF, 1,2,3,4,7,8-	PentaCDF, 1,2,3,7,8-	TetraCDD, 2,3,7,8-	OctaCDF, 1,2,3,4,6,7,8,9-	TetraCDF, 2,3,7,8-
Mountwood Park Lake	Sediment	µg g^{-1} [dry weight]	9.10E-12	8.45E-13	4.22E-13	8.39E-13	4.13E-12	1.35E-13
	Benthic Invertebrate	mg kg^{-1} [wet weight]	2.84E-14	4.09E-15	5.92E-15	8.81E-14	4.40E-15	4.35E-15
	Benthic Omnivore	mg kg^{-1} [wet weight]	3.26E-13	6.30E-13	6.76E-13	2.83E-12	1.73E-14	1.24E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	5.69E-13	2.10E-12	2.79E-12	1.12E-11	2.17E-14	5.84E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values					
			PentaCDD, 1,2,3,7,8-	PentaCDF, 2,3,4,7,8-	HexaCDD, 1,2,3,4,7,8-	HexaCDD, 1,2,3,6,7,8-	HexaCDF, 1,2,3,6,7,8-	HexaCDF, 1,2,3,7,8,9-
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	2.10E-09	8.46E-10	1.41E-09	1.63E-09	1.52E-09	1.34E-09
	Untilled Surface Soil	µg g^{-1} [dry weight]	9.75E-09	3.89E-09	6.52E-09	7.57E-09	6.99E-09	6.17E-09
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	3.35E-09	1.36E-09	2.19E-09	2.55E-09	2.31E-09	2.02E-09
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.42E-08	6.06E-09	9.18E-09	1.06E-08	9.57E-09	8.41E-09
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	6.54E-10	3.71E-10	4.32E-10	4.84E-10	4.60E-10	4.32E-10
	Untilled Surface Soil	µg g^{-1} [dry weight]	3.81E-09	1.89E-09	2.57E-09	2.90E-09	2.74E-09	2.55E-09
Wolf Run Lake	Surface water	mg L^{-1}	1.55E-15	1.39E-16	1.39E-15	1.23E-15	2.36E-16	2.57E-16
	Macrophyte	mg kg^{-1} [wet weight]	4.25E-11	1.96E-12	3.28E-11	1.82E-11	5.00E-12	6.87E-12
	Zooplankton	mg kg^{-1} [wet weight]	1.17E-10	2.71E-12	1.95E-10	1.97E-10	3.70E-11	3.10E-11
	Water Column Herbivore	mg kg^{-1} [wet weight]	3.08E-10	8.90E-12	4.38E-10	3.75E-10	7.02E-11	5.96E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	5.09E-10	1.61E-11	5.58E-10	4.81E-10	8.95E-11	7.69E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.10E-09	3.66E-11	8.33E-10	7.23E-10	1.33E-10	1.16E-10
	Sediment	µg g^{-1} [dry weight]	1.44E-11	2.78E-13	3.02E-11	4.04E-11	5.79E-12	4.01E-12
	Benthic Invertebrate	mg kg^{-1} [wet weight]	7.84E-13	2.86E-14	5.71E-13	3.01E-13	7.07E-14	1.64E-13
	Benthic Omnivore	mg kg^{-1} [wet weight]	5.54E-11	3.37E-12	6.27E-12	8.80E-12	1.69E-12	2.62E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.36E-10	8.28E-12	1.25E-11	1.81E-11	3.45E-12	5.27E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values					
			PentaCDD, 1,2,3,7,8-	PentaCDF, 2,3,4,7,8-	HexaCDD, 1,2,3,4,7,8-	HexaCDD, 1,2,3,6,7,8-	HexaCDF, 1,2,3,6,7,8-	HexaCDF, 1,2,3,7,8,9-
Veto Lake	Surface water	mg L^{-1}	1.40E-14	1.75E-15	1.14E-14	1.18E-14	3.25E-15	3.35E-15
	Macrophyte	mg kg^{-1} [wet weight]	4.51E-11	9.82E-12	1.44E-11	6.33E-12	3.13E-12	6.29E-12
	Zooplankton	mg kg^{-1} [wet weight]	1.23E-10	1.37E-11	8.19E-11	6.26E-11	2.26E-11	2.87E-11
	Water Column Herbivore	mg kg^{-1} [wet weight]	3.55E-10	4.66E-11	2.10E-10	1.37E-10	4.72E-11	6.06E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	6.35E-10	8.74E-11	3.05E-10	2.01E-10	6.75E-11	8.68E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.71E-09	2.40E-10	5.95E-10	3.97E-10	1.32E-10	1.70E-10
	Sediment	µg g^{-1} [dry weight]	2.02E-10	1.70E-11	1.77E-10	1.87E-10	4.87E-11	4.93E-11
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.07E-11	1.72E-12	3.28E-12	1.37E-12	5.90E-13	2.00E-12
	Benthic Omnivore	mg kg^{-1} [wet weight]	7.61E-11	1.87E-11	8.07E-12	5.14E-12	1.98E-12	5.59E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.96E-10	4.87E-11	1.42E-11	1.02E-11	3.78E-12	1.02E-11
Mountwood Park Lake	Surface water	mg L^{-1}	1.78E-15	2.62E-16	1.34E-15	1.40E-15	4.51E-16	4.59E-16
	Macrophyte	mg kg^{-1} [wet weight]	5.87E-12	1.46E-12	1.75E-12	7.68E-13	4.63E-13	9.22E-13
	Zooplankton	mg kg^{-1} [wet weight]	1.32E-11	1.83E-12	7.79E-12	5.92E-12	2.58E-12	3.29E-12
	Water Column Herbivore	mg kg^{-1} [wet weight]	4.96E-11	8.06E-12	2.82E-11	1.79E-11	7.83E-12	1.02E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	1.12E-10	1.92E-11	5.41E-11	3.39E-11	1.50E-11	1.99E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	4.59E-10	8.18E-11	1.58E-10	9.85E-11	4.42E-11	5.92E-11

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values					
			PentaCDD, 1,2,3,7,8-	PentaCDF, 2,3,4,7,8-	HexaCDD, 1,2,3,4,7,8-	HexaCDD, 1,2,3,6,7,8-	HexaCDF, 1,2,3,6,7,8-	HexaCDF, 1,2,3,7,8,9-
Mountwood Park Lake	Sediment	µg g^{-1} [dry weight]	4.54E-12	5.00E-13	3.69E-12	3.89E-12	1.26E-12	1.28E-12
	Benthic Invertebrate	mg kg^{-1} [wet weight]	2.27E-13	4.97E-14	6.54E-14	2.71E-14	1.50E-14	5.11E-14
	Benthic Omnivore	mg kg^{-1} [wet weight]	6.27E-12	2.17E-12	3.72E-13	3.34E-13	1.48E-13	3.64E-13
	Benthic Carnivore	mg kg^{-1} [wet weight]	2.48E-11	8.75E-12	1.04E-12	1.02E-12	4.45E-13	1.06E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values				
			HexaCDD, 1,2,3,7,8,9 -	HexaCDF, 2,3,4,6,7,8-	HeptaCDF, 1,2,3,4,7,8,9-	OctaCDD, 1,2,3,4,6,7,8,9-	HeptaCDF, 1,2,3,4,6,7,8-
Farm_NNW	Tilled Surface Soil	µg g^{-1} [dry weight]	1.67E-09	2.05E-09	4.75E-10	2.76E-08	2.33E-09
	Untilled Surface Soil	µg g^{-1} [dry weight]	7.73E-09	9.44E-09	2.19E-09	1.27E-07	1.07E-08
Farm_SE	Tilled Surface Soil	µg g^{-1} [dry weight]	2.61E-09	3.11E-09	7.14E-10	4.28E-08	3.48E-09
	Untilled Surface Soil	µg g^{-1} [dry weight]	1.09E-08	1.29E-08	3.06E-09	1.78E-07	1.45E-08
Farm_WSW	Tilled Surface Soil	µg g^{-1} [dry weight]	4.95E-10	6.32E-10	1.87E-10	8.11E-09	7.95E-10
	Untilled Surface Soil	µg g^{-1} [dry weight]	2.96E-09	3.76E-09	1.04E-09	4.84E-08	4.66E-09
Wolf Run Lake	Surface water	mg L^{-1}	1.27E-15	3.34E-16	1.79E-16	4.61E-15	5.48E-16
	Macrophyte	mg kg^{-1} [wet weight]	1.88E-11	7.04E-12	4.11E-12	6.85E-11	1.53E-11
	Zooplankton	mg kg^{-1} [wet weight]	2.02E-10	5.24E-11	7.58E-12	1.01E-09	5.55E-11
	Water Column Herbivore	mg kg^{-1} [wet weight]	3.86E-10	9.94E-11	1.08E-11	6.49E-10	3.98E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	4.95E-10	1.27E-10	1.06E-11	2.93E-10	2.05E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	7.43E-10	1.89E-10	1.08E-11	1.14E-10	9.74E-12
	Sediment	µg g^{-1} [dry weight]	4.15E-11	8.20E-12	8.15E-13	1.48E-10	6.40E-12
	Benthic Invertebrate	mg kg^{-1} [wet weight]	3.57E-13	3.61E-13	2.12E-14	1.18E-13	4.81E-15
	Benthic Omnivore	mg kg^{-1} [wet weight]	9.12E-12	2.77E-12	6.39E-13	1.49E-12	8.78E-13
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.87E-11	5.35E-12	1.07E-12	1.87E-12	1.16E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values				
			HexaCDD, 1,2,3,7,8,9 -	**HexaCDF, 2,3,4,6,7,8-**	**HeptaCDF, 1,2,3,4,7,8,9-**	**OctaCDD, 1,2,3,4,6,7,8,9-**	**HeptaCDF, 1,2,3,4,6,7,8-**
Veto Lake	Surface water	mg L^{-1}	1.21E-14	4.54E-15	2.03E-15	6.33E-14	6.77E-15
	Macrophyte	mg kg^{-1} [wet weight]	6.48E-12	4.34E-12	9.99E-12	3.33E-11	1.75E-11
	Zooplankton	mg kg^{-1} [wet weight]	6.42E-11	3.15E-11	1.89E-11	4.77E-10	6.55E-11
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.40E-10	6.59E-11	3.03E-11	3.67E-10	5.44E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	2.06E-10	9.43E-11	3.39E-11	2.09E-10	3.35E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	4.06E-10	1.85E-10	4.41E-11	1.09E-10	2.02E-11
	Sediment	µg g^{-1} [dry weight]	1.92E-10	6.83E-11	2.59E-11	9.66E-10	9.79E-11
	Benthic Invertebrate	mg kg^{-1} [wet weight]	1.61E-12	2.97E-12	6.69E-13	7.65E-13	7.32E-14
	Benthic Omnivore	mg kg^{-1} [wet weight]	5.65E-12	6.58E-12	2.29E-12	1.15E-12	1.03E-12
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.10E-11	1.11E-11	3.64E-12	1.24E-12	1.40E-12
Mountwood Park Lake	Surface water	mg L^{-1}	1.45E-15	6.30E-16	2.92E-16	9.66E-15	9.60E-16
	Macrophyte	mg kg^{-1} [wet weight]	7.91E-13	6.44E-13	1.47E-12	5.18E-12	2.61E-12
	Zooplankton	mg kg^{-1} [wet weight]	6.10E-12	3.60E-12	2.35E-12	6.64E-11	8.05E-12
	Water Column Herbivore	mg kg^{-1} [wet weight]	1.84E-11	1.09E-11	5.85E-12	7.82E-11	1.13E-11
	Water Column Omnivore	mg kg^{-1} [wet weight]	3.49E-11	2.10E-11	9.19E-12	6.08E-11	1.02E-11
	Water Column Carnivore	mg kg^{-1} [wet weight]	1.01E-10	6.19E-11	1.77E-11	4.35E-11	8.68E-12

Table B-4. Concentration Estimates for Dioxin Congeners (Cont.)

Location and Medium		Units	Values				
			HexaCDD, 1,2,3,7,8,9 -	HexaCDF, 2,3,4,6,7,8-	HeptaCDF, 1,2,3,4,7,8,9-	OctaCDD, 1,2,3,4,6,7,8,9-	HeptaCDF, 1,2,3,4,6,7,8-
Mountwood Park Lake	Sediment	µg g^{-1} [dry weight]	4.00E-12	1.77E-12	7.01E-13	2.44E-11	2.56E-12
	Benthic Invertebrate	mg kg^{-1} [wet weight]	3.22E-14	7.59E-14	1.79E-14	1.91E-14	1.91E-15
	Benthic Omnivore	mg kg^{-1} [wet weight]	3.54E-13	3.29E-13	2.27E-13	1.16E-13	1.41E-13
	Benthic Carnivore	mg kg^{-1} [wet weight]	1.07E-12	8.67E-13	5.31E-13	1.70E-13	2.33E-13