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EPA's Risk-Screening Environmental Indicators (RSEI) Methodology

RSEI Version 2.3.9

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Executive Summary

ES-1. Introduction

EPA's Risk-Screening Environmental Indicators (RSEI) is a screening-level, multi-media model that incorporates EPA's Toxics Release Inventory (TRI) information together with other data sources and risk factor concepts to assess the potential chronic human health impacts of TRI chemicals. To help provide context on the relative hazard and potential for risks posed by certain waste management activities of TRI chemicals (e.g., from releases to the environment), RSEI produces hazard estimates and unitless risk scores, which represent harm and relative risks to human health following chronic exposure to a TRI chemical. RSEI can be used to quickly and easily screen large amounts of chemicals and chemical emissions data from the TRI database, saving time and resources. RSEI is particularly useful for examining trends that compare potential relative risks from year to year, or for ranking and prioritizing chemicals, industry sectors, or geographic regions for strategic planning. In conjunction with other data sources and information, RSEI can ultimately be used to help policy makers, researchers, and communities establish priorities for further investigation and to look at changes in potential human health impacts over time.

Using estimates of pounds of chemical releases to investigate potential health and environmental impacts is limited by the assumptions that all chemicals are equally toxic and that all people are equally exposed. Formal risk assessments are more accurate, but are complicated and time consuming to prepare, requiring detailed data that are not always available, and the results are often limited in scope and geographic area. The RSEI approach augments estimates of chemical pounds released with toxicity and exposure considerations, but does not address all of the potential factors that would have to be included in a full risk assessment. Thus, RSEI is not a stand-alone source of information for making conclusions or decisions about the risks posed by any particular facility or environmental release of a TRI chemical.

RSEI considers the following information: the amount of chemical released, the toxicity of the chemical, its fate and transport through the environment, the route and extent of human exposure, and the number of people affected. This information is used to create numerical values that can be added and compared in limitless ways to assess the relative risks of chemicals, facilities, industries, regions, and many other factors. The values generated are for comparative purposes and only meaningful when compared to other values produced by RSEI. It should be emphasized that the results are *not* a detailed or quantitative risk assessment, *however, RSEI results do offer a screening-level, risk-related perspective for relative comparisons of certain waste management activities of TRI chemicals.*

The RSEI approach is very flexible and can be implemented in many ways. The use of the model is not limited to any specific set of chemicals; in principle, the adaptable method can model any chemical if toxicity data, physicochemical properties, waste management quantities, and release and transfer locations are known or can be estimated.

As an indication of improvements in environmental quality over time, RSEI provides a valuable tool to measure general trends based upon relative risk-related impacts of TRI chemicals. Although RSEI results do not capture all environmental releases of concern, they generally relate changes in releases to relative changes in chronic human health impacts from a large number of toxic chemicals of concern to the Agency. Importantly, RSEI provides an ability to analyze the relative contribution of chemicals, facilities, and industrial sectors to human health impacts, and RSEI results serve as an analytical basis for setting priorities for further risk analyses, pollution prevention, regulatory initiatives, enforcement targeting, and chemical testing requirements.

ES-2. General Description of the RSEI Model

The RSEI model calculates values that reflect the risk-related impacts on chronic human health of modeled TRI chemical releases and transfers. These values do not provide absolute measures of risk and can only be interpreted as relative measures to be compared with other such values (reflecting the direction and the general magnitude of changes at different points in time when analyzing trends, or screening for situations of potential concern).

The model uses the reported quantities of TRI chemical releases and transfers to estimate the risk-related impacts associated with certain types of waste management activities of TRI covered facilities. The risk-related impacts potentially posed by a chemical are a function of chemical toxicity, the fate and transport of the chemical in the environment after it is released, the pathway of human exposure, and the number of people exposed.[1]

All RSEI results are designed to be additive so that users can combine and disaggregate results by chemical, facility, industry, region, etc. For instance, the score for a facility is the sum of the scores for all of the modeled releases and transfers from that facility. The sum of the scores for all of the facilities in a state is the score for that state. In this way, users can rank by one dimension, such as by state, and then drill down into the list of facility scores in that state to see which facilities account for the majority of the score. Users can examine results for groups of chemicals or facilities, for one year or over a certain period of time. All of the results, including pounds-based results and hazard-based results, are proportional and work in the same way.

RSEI does not perform a detailed or quantitative risk assessment, but offers a screening-level, risk-related perspective for relative comparisons of certain waste management activities (e.g., releases to the environment) of TRI chemicals. The RSEI model does not estimate actual risk to individuals. RSEI results are only meaningful when compared to other results produced by RSEI. The current version of the model calculates risk-related results for the air and surface water exposure pathways only (i.e., stack and fugitive air releases, direct surface water discharges, and transfers off-site to wastewater treatment and incineration). Hazard-based results are available for other kinds of waste management activities for chemicals and chemical categories with toxicity data.[2] In cases where toxicity data are not available, only pounds-based results can be viewed.

ES-2.1 Geographic Basis of the Model

The RSEI model relies on the ability to locate facilities and people geographically, and to attribute characteristics of the physical environment such as meteorology and areas surrounding the facilities once they are located. To locate the facilities and the attribute data to those facilities, the model describes the U.S. and its territories[3] as an 810 meter (m) by 810 meter grid

[1] The method is focused on the general population; individuals, particularly highly exposed or susceptible individuals, are not the focus of the model.

[2] Chemicals and chemical categories with toxicity data account for 99% of the total release and transfer quantities reported to TRI in 2019.

[3] The model also includes Puerto Rico, the U.S. Virgin Islands, Guam, American Samoa, and the Northern Mariana

system. For each cell in the grid, a location "address" in terms of (*x*,*y*) coordinates is assigned based on latitude and longitude (lat/long).

In order to estimate potential human exposure, TRI facilities and the U.S. population must be geographically located on the model grid. TRI facilities are located using the facilities' lat/long coordinates. To locate population, the model uses decennial U.S. census data for 1990, 2000, and 2010 at the block level. These data[4] are used to create detailed age-sex-defined population groups for each of the census blocks in the U.S. for 1990, 2000, and 2010. The following population groups are used in the model:

- Males Aged 0 through 9 years
- Males Aged 10 through 17 years
- Males Aged 18 through 44 years
- Males Aged 45 through 64 years
- Males Aged 65 Years and Older
- Females Aged 0 through 9 years
- Females Aged 10 through 17 years
- Females Aged 18 through 44 years
- Females Aged 45 through 64 years
- Females Aged 65 Years and Older

Because the census block boundaries change between decennial census years, each set of census block level data is first transposed onto the model grid, which is unchanging, using an area-weighted method. Once populations for 1990, 2000, and 2010 are placed on the grid system, the model uses a linear interpolation for each grid cell to create annual estimates of the population sizes for each year between 1990 and 2000, and again between 2000 and 2010. The straight-line plot between 1990 and 2000 is extrapolated backward to estimate population for 1988-89 and the straight-line plot between 2000 and 2010 is extrapolated forward to estimate population for the years after 2010.

Once facilities and people are located on the model's grid system, three main components are used to compute risk-related impacts in the model. These components are:

- The quantity of chemicals released or transferred,
- Adjustments for chronic human health toxicity, and
- Adjustments for exposure potential and population size.

Islands. 1990 U.S. census data were provided by GeoLytics, Inc., East Brunswick, NJ.

[4] For 1990, not all of the variables were available at the block level for the Continental U.S, Alaska and Hawaii. For those variables that were only available at the block group level, block group ratios were calculated and applied to the data at the block level. For 2000 and 2010, all of the required data were available at the block level. For the U.S. Virgin Islands and the territories, data from larger geographic units (block groups or county-equivalents) were used. For Puerto Rico, block group data were used for 1990 and block-level data for 2000 and 2010.

These components and the method used to combine them are described in the following sections.

Chemical Releases and Transfers. The model uses information on facilities' chemical releases and transfers from these facilities to off-site facilities (such as sewage treatment plants and incinerators) to model risk-related impacts. Other kinds of waste management activities, such as underground injection or transfers off-site to recycling, are not modeled, but users can view hazard-based results (toxicity-weighted pounds) or pounds-based results for these activities. These quantities are reported by facilities to EPA's TRI program, as mandated by the Emergency Planning and Community Right-to-Know Act. As of the 2019 reporting year, there are over 600 TRI chemicals and chemical categories listed.

Adjustments for Chronic Human Health Toxicity. The model is based on current EPA methodologies for assessing toxicity. The method EPA has chosen for assigning toxicity weights to chemicals is clear and reproducible, based upon easily accessible and publicly available information, and uses expert EPA-wide judgments to the greatest extent possible. RSEI reflects the toxicities of chemicals relative to one another using a continuous system of numerical weights. Toxicity weights for chemicals increase as their inherent ability to cause adverse health effect(s) increase. Hazard-based results provide an alternative perspective to pounds-based results or full risk-related results, and are especially valuable when necessary data for risk-related modeling are not available.

Values developed by EPA experts are used to differentiate the degrees and types of toxicity of chemicals. Oral Slope Factors (OSFs) and Inhalation Unit Risks (IURs)[5] provide information pertaining to toxicity for chemicals that may cause cancer. Reference Doses (RfDs) and Reference Concentrations (RfCs) provide toxicity information related to non-cancer effects.[6] Where these values are not available from EPA, other data sources may be used.

The following data sources are used, in the order of preference:

- EPA's Integrated Risk Information System (IRIS);
- EPA's National Air Toxics Assessment (NATA), which generally obtains data from the other sources listed in this list, but in some cases uses values derived by EPA's Office of Air Quality Planning and Standards (OAQPS);
- EPA's Office of Pesticide Programs' (OPP) Acute and Chronic Reference Doses Table, List of Chemicals Evaluated for Carcinogenic Potential, and Pesticide Reregistration Eligibility Documents;

[5] The Oral Slope Factor represents the upper-bound (approximating a 95% confidence limit) estimate of the slope of the dose-response curve in the low-dose region for carcinogens. The units of the slope factor are usually expressed as (mg/kg-day) $^{-1}$. The Inhalation Unit Risk is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air.

[6] RfDs and RfCs are estimates (with uncertainty spanning perhaps an order of magnitude) of daily exposure [RfD], or continuous inhalation exposure [RfC], to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime.

- Final, published Minimal Risk Levels (MRLs) from the Agency for Toxic Substances and Disease Registry (ATSDR);
- Final, published toxicity values from the California Environmental Protection Agency (CalEPA), Office of Environmental Health Hazard and Assessment;
- EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs), which include toxicity values that have been developed by EPA's Office of Research and Development (ORD), Center for Public Health and Environmental Assessment (CPHEA), formerly known as the National Center for Environmental Assessment (NCEA), Superfund Health Risk Technical Support Center (STSC);
- EPA's Health Effects Assessment Summary Tables (HEAST); and
- Final Derived/Interim Derived Toxicity Weights estimated by EPA's Office of Pollution Prevention and Toxics (OPPT).

RSEI collects the following four values for each chemical, where possible:

- Oral Slope Factors (OSFs) in risk per mg/kg-day,
- Inhalation Unit Risks (IURs) in risk per mg/m^3,
- Reference Doses (RfDs) in mg/kg-day, and
- Reference Concentrations (RfCs) in mg/m^3

Each value is transformed into a toxicity weight, so that as the toxicity weight increases, the toxic effect(s) increase. The algorithms used to assign toxicity weights are shown below in Exhibit ES.1.

Exhibit ES.1
Algorithms for Assigning Toxicity Weights

		Route of Exposure	
		Inhalation	**Oral**
Type of Effect	**Cancer***	IUR / 2.8e-7	OSF/ 1e-6
	Non-cancer	3.5 / RfC	1 / RfD
*If the Weight of Evidence (WOE) Category is equal to C, each weight is divided by an additional factor of 10 to account for uncertainty.			

Each chemical is assigned up to four toxicity weights, according to the availability of its RfC, RfD, IUR, and OSF. The RSEI results may use different toxicity weights, depending on the data.

RSEI Hazard and RSEI Score use the higher cancer or non-cancer toxicity weight for each exposure route (i.e., oral and inhalation), and if one exposure route is missing both toxicity weights, then the other exposure route's toxicity weight is used. Cancer hazard and cancer score results use only the cancer toxicity weights (i.e., the IUR for the inhalation exposure route or the OSF for the oral exposure route), and do not use the RfC- or RfD-based toxicity weights even if the IUR or OSF is missing. Similarly, the non-cancer hazard and non-cancer score results only use the RfC- or RfD-based toxicity weights.

In addition, the RSEI score, cancer score, and non-cancer score all use the inhalation route toxicity weight (RfC or IUR as appropriate) for the portion of the Publicly Owned Treatment Works (POTW) transfer that volatilizes during wastewater treatment and the oral route toxicity weight (RfD or OSF as appropriate) for the portion of the POTW transfer that is released from the POTW as effluent.[7] The three hazard-based results do not account for partitioning, and use the oral toxicity weight (RfD or OSF as appropriate) for the entire chemical transfer. Exhibit ES.2 below summarizes the selection of toxicity weights for each kind of RSEI result.

Exhibit ES.2
Selection of Toxicity Weights for Each RSEI Result

RSEI Result	Air Releases	Water Releases	Transfers to POTWs	Fill in Toxicity Data Gaps?
Score	Higher of IUR tox weight or RfC tox weight.	Higher of OSF tox weight or RfD tox weight.	For portion of transfer that volatilizes during wastewater treatment use higher of IUR tox weight or RfC tox weight. For portion of transfer that is released from POTW as effluent use higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no tox weight in one exposure route, use tox weight from other exposure route. For instance, if a chemical has no IUR or RfC tox weight, use higher of RfD or OSF tox weight for air releases.
Cancer Score	IUR tox weight.	OSF tox weight.	For volatilized portion use IUR tox weight. For POTW effluent release portion use OSF.	No. If no route-specific cancer tox weight, then cancer score is zero.
Non-Cancer Score	RfC tox weight.	RfD tox weight.	For volatilized portion use RfC tox weight. For POTW effluent release portion use RfD tox weight.	No. If no route-specific non-cancer tox weight, then non-cancer score is zero.
Hazard	Higher of IUR tox weight or RfC tox weight.	Higher of OSF tox weight or RfD tox weight.	Higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no tox weight in one exposure route, use data from other exposure route.
Cancer Hazard	IUR tox weight.	OSF tox weight.	OSF tox weight.	No. If no route-specific cancer tox weight, then cancer hazard is zero.
Non-Cancer Hazard	RfC tox weight.	RfD tox weight.	RfD tox weight.	No. If no route-specific non-cancer tox weight, then non-cancer hazard is zero.

[7] Chemical-specific POTW removal and within-POTW partitioning rates are used to determine the portion of each transfer to a POTW that biodegrades, adsorbs to sludge, or volatilizes. The remainder is assumed to be released from the POTW as effluent.

The distribution of toxicity values for TRI chemicals corresponds to a range of toxicity weights of approximately 0.02 to 1,400,000,000. However, toxicity weights are not bounded. Continuous toxicity weights are expressed as values with two significant figures.

There are over 600 chemicals and chemical categories on the 2019 TRI Chemical List. Toxicity weights are available for over 400 of these chemicals and chemical categories.[8] Chemicals and chemical categories with toxicity weights account for 99% of the reported quantities for all releases and transfers to modeled media in 2019.

Adjustments for Exposure Potential and Population Size. Quantitatively, exposure potential is estimated using a "surrogate" dose. To estimate the surrogate dose, a separate exposure evaluation is conducted for each pathway-specific waste management activity. The exposure evaluations use models that incorporate data on pathway-specific chemical releases and transfers, physicochemical properties, and where available, site characteristics to estimate the ambient chemical concentrations in the environmental medium into which the chemical is released or transferred. The ambient concentrations are combined with human exposure assumptions and estimates of exposed population size specific to age and sex.

The algorithms for calculating surrogate doses rely on the ability to locate facilities and people geographically on the 810m by 810m grid cell system described earlier. While this method uses the EPA exposure assessment paradigm to evaluate exposure potential, the results should not be construed as an actual numerical dose resulting from TRI chemical waste management activities. Limited facility-specific data and the use of modeling that relies on default values and assumptions for many input parameters prevent the calculations of an actual numerical dose. The purpose of this methodology, rather, is to generate as accurate a surrogate dose as possible without conducting an in-depth and resource-intensive risk assessment. The estimates of surrogate doses resulting from certain waste management activities of TRI chemicals are *relative to the surrogate doses resulting from other waste management activities included in the model*. Please note that not all chemical waste management activities and resulting exposures from these activities are currently modeled.

[8] Elemental metals and metal compound categories (e.g., "lead" and "lead compounds") are separately listed for TRI reporting purposes. RSEI combines these separate listings into one category (e.g., "lead and lead compounds").

ES-2.2 RSEI Results

Because of the multi-functional nature of the model, a variety of results can be generated. The three main kinds of results are described below.

Exhibit ES.3
Description of RSEI Results

Risk-related results (scores)	Surrogate Dose **x** Toxicity Weight **x** Population
Hazard-based results	Pounds **x** Toxicity Weight
Pounds-based results	Waste management activity quantities

Risk-related results (scores). The exposure route-specific chemical toxicity weight, surrogate dose, and population components are multiplied to obtain a risk-related score. The surrogate dose is determined through pathway-specific modeling of the fate and transport of the chemical through the environment, combined with population-specific exposure factors. The final score generated is a unitless measure that is *not* independently meaningful, but is a risk-related estimate that can be compared to other risk-related estimates calculated using the same methodology. If toxicity data or other data required for modeling are zero, or if the exposure pathway is not currently modeled, then the risk-related score generated is zero. RSEI risk-related scores are only calculated for certain types of TRI chemical releases and transfers (modeled media).

- **RSEI Score-** Product of surrogate dose, population, and the higher toxicity weight for each exposure route (see Exhibit ES.2 for details).
- **Cancer Score**- Product of surrogate dose, population, and the IUR or OSF toxicity weight (see Exhibit ES.2 for details).
- **Non-Cancer Score**- Product of surrogate dose, population, and the RfC or RfD toxicity weight (see Exhibit ES.2 for details).

Hazard-based results. Hazard-based results ("Hazard") are calculated by multiplying the TRI chemical quantities (in pounds) by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure-specific pathway). The inhalation toxicity weight is used for releases of fugitive air and stack air, and transfers to off-site incineration. The oral toxicity weight is used for surface water releases and transfers to POTWs. For these results, no exposure modeling or population estimates are involved. If there is no toxicity weight available for the chemical, then the hazard score is zero. Hazard can be calculated for modeled media (modeled hazard) or for any TRI waste management quantity.

- **RSEI Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Table ES.2 for details).
- **RSEI Modeled Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Table ES.2 for details). Same as RSEI hazard, but calculated for modeled media only.
- **Cancer Hazard**- Product of TRI Pounds and the IUR toxicity weight or the OSF toxicity weight (see Table ES.2 for details).
- **Non-Cancer Hazard**- Product of TRI Pounds and the RfC toxicity weight or the RfD toxicity weight (see Table ES.2 for details).

Pounds-based results. These results ("TRI Pounds") reflect only the number of pounds reported to TRI for each waste management activity, and are available for all TRI-reported quantities.

Once all of the results are calculated, they can be combined in many different ways. All of the results are additive, so a result for a specific set of variables is calculated by summing the scores for all of the relevant waste management activity quantities.[9]

This method is very flexible, allowing for countless variation in the resulting outputs. For example, results can be generated for various subsets of variables (e.g., chemical, facility, exposure pathway) and compared to each other to assess the relative contribution of each subset to the total potential impact. Or, results for the same subset of variables for different years can be produced, to assess the general trend in pounds-based, hazard-based, or risk-related impacts over time.

It must be reiterated that while changes in results over the years would imply that there have been changes in hazard- or risk-related environmental impacts, the actual magnitude of any specific change or the reason may not be obvious. Although the value itself may be useful in identifying chemicals, facilities, or geographic locations with the highest potential for hazard or risk, the score itself does not represent a quantitative estimate or provide an exact indication of the magnitude of associated individual hazard or risk.

ES-2.3 Adjusting RSEI Results for Changes in TRI Reporting

When a change occurs in the number of or reporting requirements for chemicals and/or facilities regulated by the TRI program, the numerical value of RSEI results will be altered if no adjustments are made to the method of calculation to account for the changes respective to trend analyses. However, such changes would not necessarily represent a large change in actual environmental impact, but rather would reflect a broader understanding of the impacts that may have always existed. To maintain comparability in the weights over time, the results must be adjusted in some manner when such changes in TRI reporting occur.

[9] Separate results can also be calculated for each exposure pathway component of an environmental release, such as the drinking water exposure or fish ingestion components of a surface water release; however, in most user-facing applications the RSEI model results are presented at the overall environmental release level.

A change in the number of chemicals and/or facilities subject to TRI reporting can occur through several mechanisms. The addition to or deletion of chemicals from the TRI chemical list will occur as EPA responds to petitions or initiates its own regulatory action through the chemical listing or delisting process. The largest revision to the list occurred in November 1994, when the Agency added 245 chemicals and chemical categories to the existing TRI chemical list, effective for the reporting year 1995. Other revisions have occurred since. To allow for meaningful trend analyses, the RSEI model maintains a list of "core chemicals" which have been reported on since 1987, and for which their reporting requirements have not changed.

Compliance with TRI reporting has changed over time, which has led to more facilities reporting. Increases in the number of reporting facilities may also occur as a result of changes in reporting requirements. For instance, chemical activity threshold requirements for facilities were decreased over the first few years of TRI reporting, in addition to lowered thresholds for Persistent Bioaccumulative Toxic chemicals (PBTs). The TRI program has also expanded the set of industrial facilities required to report to include electric utilities, mining facilities, commercial hazardous waste facilities, solvent recovery facilities, and wholesale chemical and petroleum terminal facilities. All of these modifications can act to alter the total quantities reported to the TRI program and in turn result in alterations to the model's estimate of the associated relative risk-based impacts.

When deletions from the TRI chemical list occur, RSEI's chemical database is modified to remove all results from previous reporting years. Also, the yearly TRI data in the TRI database are subject to ongoing quality control review and correction by both EPA and by TRI-reporting facilities. As a result, yearly comparisons could be flawed if such revisions to reported data were not included in each previous year's results. Therefore, RSEI results are recomputed for all years on an annual basis in order to incorporate chemical deletions and modifications to the reported data.

ES-2.4 RSEI Data Products

Users can access RSEI model results in a variety of ways. RSEI results are included in EPA data tools such as Envirofacts[10] and the TRI National Analysis. RSEI results are also currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet browser[11] or through https://www.epa.gov/rsei. The EasyRSEI dashboard allows users to view and query all RSEI model results for TRI reporting years 2007-2019 for modeled media. Pounds- and hazard-based results for non-modeled media, including waste management activities reported in Section 8 of the TRI Form R, are also available. A separate Qlik Sense dashboard is

[10] RSEI results are located in TRI Search, a query built into the TRI section of Envirofacts (https://www.epa.gov/enviro/tri-search), under the heading "Risk-Screening."

[11] EasyRSEI is available at https://edap.epa.gov/public/extensions/EasyRSEI/EasyRSEI.html. The All Years version is available at https://edap.epa.gov/public/extensions/EasyRSEI_AllYears/EasyRSEI_AllYears.html.

available for users who are interested in the full TRI time series (1988-2019), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download.[12]

Users of the EasyRSEI dashboard can quickly and easily view trends and rankings and filter by dimensions such as state, chemical, industry, year, etc., with no downloading required. Preformatted reports are also available for printing. Results can be used for screening-level ranking and prioritization for strategic planning purposes, risk-related targeting, and trends analyses. Considerable resources can be saved by conducting preliminary analyses with RSEI to identify risk-related situations of high potential concern, which warrant further investigation and evaluation.

As noted above, users can evaluate RSEI information using a number of variables, such as chemical, environmental medium, geographic area, or industry. For instance, the following types of questions can be investigated:

- How do industry sectors compare to one another from a risk-related perspective?
- What is the relative contribution of chemicals within a given industry sector?
- What exposure pathways for a particular chemical pose the greatest potential risk-related impacts?

Users can view pounds-based, hazard-based, and other results, to investigate the relative influence of toxicity and population components on the risk-related results, which also incorporate exposure modeling.

Information regarding the RSEI project is available on the RSEI web site at https://www.epa.gov/rsei. Complete documentation, frequently asked questions, and contact information are all posted on the site. Periodic updates and troubleshooting information are also available for users.

ES-2.5 How the RSEI Chronic Human Health Toxicity Weightings Differ from EPCRA Section 313 (TRI) Statutory Criteria

As described above, the RSEI model uses TRI chemical reporting data. However, it is important that the public not confuse the use of the model as a screening-level tool for investigating relative risk-based impacts related to the releases and transfers of TRI chemicals, with the very different and separate regulatory activity of listing/delisting chemicals on the TRI chemical list using statutory criteria.

The goal of the RSEI model is to use data reported to the Agency to investigate the relative risk-based impacts of certain waste management activities (e.g., releases to the environment) of TRI chemicals on the general, non-worker population. The model differentiates the relative toxicity of listed chemicals and ranks them in a consistent and transparent manner. The ranking of each chemical reflects its toxicity only relative to other chemicals that are included in the model.

[12] RSEI Queries and other data products are available at https://www.epa.gov/rsei/ways-get-rsei-results.

Toxicity is not compared to some benchmark or absolute value as is required when adding or removing a chemical from the TRI chemical list.

In contrast, the EPCRA statutory criteria used for listing and delisting chemicals consider both acute and chronic human toxicity, as well as environmental toxicity, and consider multiple effects and the severity of those effects. The criteria also address the "absolute" chronic toxicity of chemicals on the TRI chemical list relative to a benchmark value.

Because of these differences, *the toxicity weightings used in the model cannot be used as a scoring system for evaluating listing/delisting decisions*. The RSEI model does not attempt to reflect the statutory criteria for these TRI chemicals and chemical categories.

ES-3. Important Caveats Regarding the RSEI Model

The RSEI model is a screening tool that provides a relative risk-related perspective in assessing the environmental impacts of certain waste management activities of TRI chemicals. Risk-related results are available for certain environmental exposure pathways (i.e., air and water), and pounds- and hazard-based results are available for other waste management activities. RSEI scores combine estimates of chemical toxicity, exposure level, and the exposed population to provide relative risk-related comparisons, but do not provide a detailed or quantitative assessment of risk. These resulting scores are also not designed as a substitute for more comprehensive, inclusive, and site-specific risk assessments. There are a number of important caveats associated with each component of the RSEI model, as described in the following sections.

Release Component. The following caveat should be considered regarding the TRI data and information incorporated into the model:

- The RSEI model uses facility-reported TRI data, which are known to contain some reporting issues and errors. The TRI program does not change any reported data in the official database until the reporting facility submits an official correction to their reporting form. In certain instances, reporting errors by facilities result in RSEI scores so large as to overwhelm annual RSEI values. In these cases where a reporting error has clearly been made, the reporting error (e.g., chemical release quantity) is retained in the RSEI data, but the hazard and scores are set to zero.

Toxicity Component. The following caveats should be considered regarding the toxicity component of the model:

- The toxicity weights used are not designed to (and may not) correlate with ECPRA Section 313 statutory criteria used for listing and delisting chemicals on the TRI chemical list. RSEI risk-related model results account for estimated exposure and may not correlate with listing/delisting decisions.
- The RSEI model only addresses chronic human toxicity (cancer and non-cancer effects, such as developmental toxicity, reproductive toxicity, neurotoxicity, etc.) associated with

long-term exposure and does not address concerns for either acute human toxicity or environmental toxicity.

- Toxicity weights are based upon the single, most sensitive chronic human health endpoint for inhalation or oral exposure pathways, and do not reflect severity of effects or multiple health effects.
- Estimated RfDs and RfCs for non-cancer effects incorporate uncertainty factors which are reflected in the toxicity weights that are based upon these values.
- Toxicity weights for TRI-listed chemical categories are based on the toxicity of the most toxic member of the chemical category. One exception to this is for the polycyclic aromatic compounds (PACs) chemical category, where the toxicity weight is based on 18% of the toxicity for benzo(a)pyrene, its most toxic member. This is based on speciation information and follows the method used by EPA's National Air Toxics Assessment (NATA) evaluation for polycyclic organic matter (POM).[13]
- Several significant assumptions are made regarding metals and metal compounds, because important data regarding these chemicals are not subject to TRI reporting. Metals and metal compounds are assumed to have the same toxicity weight, although the chronic toxicity of some metal compounds may be lower or higher. Metals and metal compounds are assumed to be released in the valence (or oxidation state) associated with the highest chronic toxicity. There are two exceptions to this: (1) For chromium and chromium compounds, it is assumed that facilities may release some combination of hexavalent chromium and trivalent chromium. Facility-specific and industry-level estimates specific to 4- or 6-digit North American Industry Classification System (NAICS) codes from the 2014 National Emissions Inventory (NEI) are used to estimate the fraction of each type.[14] As trivalent chromium has a very low toxicity, only the hexavalent chromium fraction is modeled, using a toxicity weight specifically for that valence state; and (2) For mercury and mercury compounds, toxicity for the oral pathway is based on methyl mercury, and toxicity for the inhalation pathway is based on elemental mercury.
- Being that the physical form of released metals or metal compounds can affect toxicity, reasonable assumptions are made regarding the most likely form of releases (e.g., the non-cancer toxicity weight for chromic acid mists and dissolved hexavalent chromium aerosols is much higher than for hexavalent chromium particulates, but releases of these chemicals as mists and acid aerosols are not expected to be typical so the toxicity weight for the inhalation of hexavalent chromium particulates is used). Users need to consider these assumptions, and whether the gathering of additional data is warranted, when examining model results for metals and metal compounds.

[13] The documentation on modeling polycyclic organic matter (POM) from EPA's NATA model can be found in the Technical Methods Document at https://www.epa.gov/national-air-toxics-assessment/2005-national-air-toxics-assessment. RSEI assumes that PAC emissions reported to TRI are most like NATA's "7-PAH" category.

[14] A default of 34% hexavalent, 66% trivalent is used where NAICS-based data are unavailable. The NEI is available at https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data.

Exposure Component. The following caveats should be considered regarding the exposure component of the model:

- Like other exposure models, RSEI estimates exposure levels. It does not yield actual exposures. The RSEI model provides estimated air concentrations in each grid cell and surface water concentrations.
- The model uses some generic assumptions for facility air releases: default median stack heights, stack diameters, and exit gas velocities related to 4- or 6-digit NAICS codes or a nationwide median are used when facility-specific data are unavailable. For large facilities with multiple stacks, the median height for all stacks is used as the stack height for the entire facility.
- In the current version of the RSEI model, only air and surface water exposures are generated as modeled media.
- The model does not account for population activity scenarios or patterns.
- The model does not account for indirect exposure such as air deposition of pollutants to other media, or absorption of pollutants through the skin.

Population Component. The following caveats should be considered regarding the population component of the model:

- Population values for non-decennial years are estimated based on linear interpolations at the block level between the 1990 and 2000 and between the 2000 and 2010 U.S. census datasets, and on extrapolation back to 1988 and forward to 2019.
- Drinking water populations are estimated by using the total drinking water populations associated with individual downstream drinking water intakes. Estimated populations for the fish ingestion pathway are based upon U.S. Fish and Wildlife Service surveys.
- Because RSEI results reflect changing population size at the local level, a facility's relative contribution could increase or decrease even without changes in its waste management quantities over time. While the model is designed to reflect the overall risk-related impacts on the local population, such population changes should be considered when examining a facility's environmental management practices.

ES-4. New Features in Version 2.3.9

- Includes TRI data and information from reporting years 1988 to 2019.
- Toxicity weights have been updated with the most recent toxicity data.

1. Introduction

EPA's Risk-Screening Environmental Indicators (RSEI) is a screening-level tool that assesses the potential impact of certain waste management activities of TRI chemicals (e.g., from releases to the environment) from pounds-based, hazard-based, and risk-related perspectives. RSEI can be used to quickly and easily screen large amounts of chemicals and chemical emissions data from the TRI database, saving time and resources. RSEI is particularly useful for examining trends that compare potential relative risks from year to year, or for ranking and prioritizing chemicals, industry sectors, or geographic regions for strategic planning. In conjunction with other data sources and information, RSEI can ultimately be used to help policy makers, researchers, and communities establish priorities for further investigation and to look at changes in potential human health impacts over time.

Using estimates of pounds of chemical releases to investigate potential health and environmental impacts is limited by the assumptions that all chemicals are equally toxic and that all people are equally exposed. Formal risk assessments are more accurate, but are complicated and time consuming to prepare, requiring detailed data that are not always available, and the results are often limited in scope and geographic area. The RSEI approach augments estimates of chemical pounds released with toxicity and exposure considerations, but does not address all of the potential factors that would have to be included in a full risk assessment.

RSEI considers the following information: the amount of chemical released, the toxicity of the chemical, its fate and transport through the environment, the route and extent of human exposure, and the number of people affected. This information is used to create numerical values that can be added and compared in limitless ways to assess the relative risks of chemicals, facilities, industries, regions, and many other factors. The values generated are for comparative purposes and only meaningful when compared to other values produced by RSEI. It should be emphasized that the results are *not* a detailed or quantitative risk assessment, *however, RSEI results do offer a screening-level, risk-related perspective for relative comparisons of certain waste management activities of TRI chemicals.*

RSEI can help users can investigate the following types of questions: How do industry sectors compare to one another from a risk-related perspective? What is the relative contribution of chemicals within a given industry sector? What release pathway for a particular chemical poses the greatest risk-related impacts? Users can view pounds-based, hazard-based, and other results, to investigate the relative influence of toxicity and population on the risk-related results, which also incorporate exposure modeling.

The RSEI approach is very flexible and can be implemented in many ways. The use of the model is not limited to any specific set of chemicals; in principle, the adaptable method can model any chemical if toxicity data, physicochemical properties, waste management quantities, and release and transfer locations are known or can be estimated.

1.1 Background

In 1989, the EPA outlined goals for establishing strategic planning processes at the Agency (EPA, 1990c). Underlying these goals was the Agency's desire to set priorities and direct resources to areas with the greatest opportunity to achieve health and environmental risk reductions. As part of this initiative, the Administrator set forth a plan to develop indicators to track changes in human health and environmental impacts over time. Tracking these changes would allow the Agency to measure its progress in implementing environmental protection and pollution prevention programs. In addition, comparing the relative contributions of particular chemicals, industries, and geographic regions through the indicators would allow the Agency (and other users and stakeholders) to establish priorities for improving human health and the environment.

To efficiently track changes in human health and environmental impacts over time, the Agency should take advantage of existing data sources that reflect multi-media trends in environmental contaminant releases. The Toxic Chemical Release Inventory (i.e., Toxics Release Inventory (TRI)) is one of the Agency's most relevant source of continuous data for developing indicators of change in environmental impacts over time. Reporting to the TRI is required by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA, or Title III of the Superfund Amendments and Reauthorization Act of 1986), Public Law 99 499. Reporting is required to provide information to the public on releases and other waste management of EPCRA Section 313 chemicals in their communities and to provide EPA with release and other waste management information to assist the Agency in determining the need for future regulations. Subject facilities must report the quantities of routine and accidental releases, and releases resulting from catastrophic or other one-time events of EPCRA Section 313 chemicals, as well as the maximum amount of the EPCRA Section 313 chemical on-site during the calendar year and the amount contained in wastes managed on-site or transferred off-site.

In response to the need for environmental indicators, and to take advantage of the rich data source offered by the TRI, the Office of Toxic Substances (OTS), known currently as the Office of Pollution Prevention and Toxics (OPPT), convened a workgroup to explore the development of an indicator or indicators based on the TRI that could track changes in human health and environmental impacts. Specifically, the approach would integrate hazard, exposure, and population considerations into the risk-related evaluation of environmental releases of toxic chemicals. The RSEI model was subsequently developed in response to this initiative.

When evaluating impacts of chemicals, it is important to not only consider the quantities of a chemical released to the environment, but also the toxicity of the chemical, its exposure potential, and the size of the receptor population. RSEI integrates these factors and provides a relative risk-based perspective of certain chemical releases and transfers. To the extent possible, the RSEI model is based on existing EPA approaches, guidelines, data, and models, to minimize duplication of effort and to maximize consistency with other Agency efforts to evaluate human health and environmental impacts.

The current version of the RSEI model tracks changes in chronic human health impacts. Ultimately, the model may be expanded to track acute human health and acute and chronic ecological impacts.

This document explains how the RSEI model is constructed, and describes the conceptual method, data sources, and the computational approach. The aim is to explain the model to a variety of agencies, stakeholders, and users that may wish to use or adopt the model or the RSEI methodology in general, to suit their own needs. In addition, this document describes the advantages of the RSEI approach in terms of flexibility, power, and usefulness as an analytical basis for setting priorities for further risk analyses, pollution prevention, regulatory initiatives, enforcement targeting, and chemical testing requirements.

1.2 RSEI Data Products

Users can access RSEI model results in a variety of ways. RSEI results are included in EPA data tools such as Envirofacts[15] and the TRI National Analysis. RSEI results are also currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet browser[16] or through https://www.epa.gov/rsei. The EasyRSEI dashboard allows users to view and query all RSEI results for TRI reporting years 2007-2019 for modeled media. Pounds- and hazard-based results for non-modeled media, including waste management activities reported in Section 8 of the TRI Form R, are also available. A separate Qlik Sense dashboard is available for users who are interested in the full TRI time series (1988-2019), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download.[17]

RSEI also produces geographically disaggregated data, called the Geographic Microdata. These are very large datasets that present results for the air exposure pathway at the 810m x 810m grid cell level. The RSEI Geographic Microdata results include score, chemical concentration, and toxicity-weighted concentration for each air release for each grid cell. There is also an aggregated version of the Microdata that sums the score, chemical concentration, and toxicity-weighted concentration over all of the air releases for each cell.

Information regarding the RSEI project is available on the RSEI web site, at https://www.epa.gov/rsei.

1.3 Organization of this Document

Chapter 2 of this document gives a brief description of the RSEI methodology and model, as well as a discussion of their overall strengths and limitations. Chapter 3 describes the TRI data used in the model. Chapter 4 describes the methods used to adjust the data for chemical toxicity, and Chapter 5 provides a discussion of the geographic basis of the model, as well as pathway-specific descriptions of adjustments made for exposure potential and population size. Chapter 6 presents the equations for calculating RSEI results, and Chapter 7 describes issues pertinent to the current implementation of the RSEI method.

There are also six Technical Appendices that accompany this methodology document and provide additional information on the data used in the model. The Appendices are as follows:

Technical Appendix A - Toxicity Weights for TRI Chemicals and Chemical Categories
Technical Appendix B - Physicochemical Properties for TRI Chemicals and Chemical Categories
Technical Appendix C - Derivation of Model Exposure Parameters

[15] RSEI results are located in TRI Search, a query built into the TRI section of Envirofacts (https://www.epa.gov/enviro/tri-search), under the heading "Risk-Screening."

[16] EasyRSEI is available at https://edap.epa.gov/public/extensions/EasyRSEI/EasyRSEI.html. The All Years version is available at https://edap.epa.gov/public/extensions/EasyRSEI_AllYears/EasyRSEI_AllYears.html.

[17] RSEI Queries and other data products are available at https://www.epa.gov/rsei/ways-get-rsei-results.

Technical Appendix D - Locational Data for TRI Reporting Facilities and Off-site Facilities
Technical Appendix E - Derivation of Stack Parameter Data
Technical Appendix F - Summary of Differences between RSEI Data and the TRI National Analysis

In addition, two documents containing background and supporting information are available on the project web site. *Analyses Performed for the Risk-Screening Environmental Indicators* contains three parts: Part A describes the result of a ground-truthing analysis performed to determine the accuracy of the air pathway modeling; Part B contains additional analyses performed on the air pathway to determine optimal modeling parameters; and Part C describes the results of an analysis of SIC code-based stack parameter data. *Developing the Risk-Screening Environmental Indicators* describes the development of the model, and outlines options that were considered for several important aspects of the method. These background documents are available on the RSEI web site, at https://www.epa.gov/rsei.

The RSEI web site also contains complete methodological information, a document archive, answers to frequently asked questions, contact information, and a glossary.

2. General Description of the RSEI Model

2.1 General Description

The RSEI model is a screening-level tool that assesses the potential impact of certain waste management activities of TRI chemicals (e.g., from releases to the environment) from pounds-based, hazard-based, and risk-related perspectives. A basic outline of the modeling approach is illustrated in Exhibit 2.1.

Three main components are used in the model to calculate results:[18]

- The TRI database, maintained by EPA, provides the data on the **quantities of TRI-listed chemicals** released to air, water, disposed of to land, and transferred off-site to facilities for further waste management activities for more than 600 toxic chemicals and chemical categories. Reporting by facilities to the TRI program began in 1987, and has continued each year since then (RSEI uses TRI reporting data beginning in reporting year 1988). Waste management activity quantities (e.g., releases to the environment) are reported to the TRI program in pounds per year.
- **Toxicity weights** are assigned to each chemical for which adequate toxicity data are available. These weights are assigned using quantitative toxicity values developed by EPA scientists and additional qualitative assessments.
- **Exposure and population modeling** are performed for the air and surface water pathways to model the movement of each chemical release through the environment to the exposed population. A surrogate dose, the amount of chemical that a human contacts, is then estimated. The estimation of a surrogate dose allows comparisons across exposure pathways. Then the population exposed to each chemical release is estimated using decennial U.S. census data.

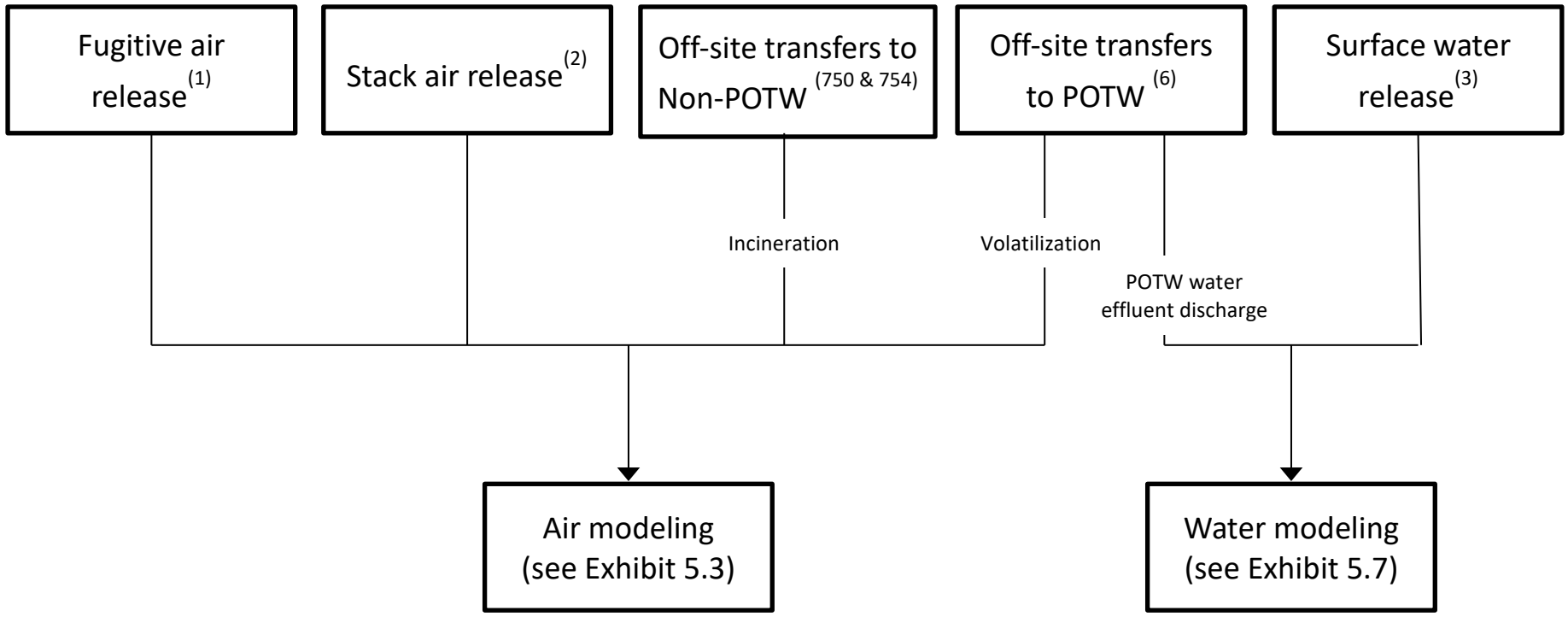
RSEI produces three main kinds of results; risk-related, hazard-based, and pounds-based. Risk-related scores require the most information to calculate (e.g., environmental fate and transport, toxicity, chemical release quantities, and population exposure information) and are not available for all kinds of waste management activities reported to TRI. Hazard-based results are calculated using only chemical release and transfer quantities and toxicity information, and are available for all waste management activities. Pounds-based results are simply the waste management activity quantities reported to TRI and require no additional information or data.

All RSEI results are designed to be additive so that users can combine and disaggregate results by chemical, facility, industry, region, etc. For instance, the score for a facility is the sum of the scores for all of the modeled releases and transfers from that facility. The sum of the scores for all of the facilities in a state is the score for that state. In this way, users can rank by one dimension, such as by state, and then drill down into the list of facility scores in that state to see

[18] The method is focused on the general population; individuals, particularly highly exposed or susceptible individuals, are not the focus of the model. Furthermore, worker exposures are not addressed.

which facilities account for the majority of the score. Users can examine results for groups of chemicals or facilities, for one year or over a certain period of time. All of the results, including pounds-based results and hazard-based results, are proportional and work in the same way.

Exhibit 2.1
RSEI Modeling Approach



(1) indicates media code 1: Fugitive (non-point) Air Emissions
(2) indicates media code 2: Stack (point) Air Emissions
(750) indicates media code 750: Off-site Transfers to Incineration (Thermal Treatment)
(754) indicates media code 754: Off-site Transfer to Incineration (Insignificant Fuel Value)
(6) indicates media code 6: Transfers to POTW
(3) indicates media code 3: Direct Surface Water Discharge

Exhibit 2.2
Description of RSEI Results

Risk-related results (scores)	Surrogate Dose **x** Toxicity Weight **x** Population
Hazard-based results	Pounds **x** Toxicity Weight
Pounds-based results	TRI Pounds Released/Transferred

Risk-related results (scores). The exposure route-specific chemical toxicity weight, surrogate dose, and population components are multiplied to obtain a risk-related score. The surrogate dose is determined through pathway-specific modeling of the fate and transport of the chemical through the environment, combined with population-specific exposure factors. The final score generated is a unitless measure that is *not* independently meaningful, but is a risk-related estimate that can be compared to other risk-related estimates calculated using the same methodology. If toxicity data or other data required for modeling are zero, or if the exposure pathway is not currently modeled, then the risk-related score generated is zero. RSEI risk-related scores are only calculated for certain types of TRI chemical releases and transfers (modeled media).

- **RSEI Score-** Product of surrogate dose, population, and the higher toxicity weight for each exposure route (see Exhibit 4.4 for details).
- **Cancer Score**- Product of surrogate dose, population, and the IUR or OSF toxicity weight (see Exhibit 4.4 for details).
- **Non-Cancer Score**- Product of surrogate dose, population, and the RfC or RfD toxicity weight (see Exhibit 4.4 for details).

Hazard-based results. Hazard-based results ("Hazard") are calculated by multiplying the TRI chemical quantities released or transferred (in pounds) by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure-specific pathway). The inhalation toxicity weight is used for releases of fugitive air and stack air, and transfers to off-site incineration. The oral toxicity weight is used for surface water releases and transfers to POTWs. For these results, no exposure modeling or population estimates are involved. If there is no toxicity weight available for the chemical, then the hazard score is zero. Hazard can be calculated for modeled media (modeled hazard) or for any TRI release and transfer quantity.

- **RSEI Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Exhibit 4.4 for details).
- **RSEI Modeled Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Exhibit 4.4 for details). Same as RSEI hazard, but calculated for modeled media only.

- **Cancer Hazard**- Product of TRI Pounds and the IUR toxicity weight or the OSF toxicity weight (see Exhibit 4.4 for details).
- **Non-Cancer Hazard**- Product of TRI Pounds and the RfC toxicity weight or the RfD toxicity weight (see Exhibit 4.4 for details).

Pounds-based results. These results reflect only the number of pounds reported to TRI for each waste management activity, and are available for all TRI-reported quantities. In some user-facing applications, there can be more than one pounds value reported: The "TRI Pounds" value counts all of the pounds reported to TRI for all waste management activities, while the "RSEI Modeled Pounds" value only counts the pounds reported for the specific releases and transfers modeled by RSEI.

All RSEI results are designed to be additive so that users can combine and disaggregate results by chemical, facility, industry, region, etc. For instance, the score for a facility is the sum of the scores for all of the modeled releases and transfers from that facility. The sum of the scores for all of the facilities in a state is the score for that state. In this way, users can rank by one dimension, such as by state, and then drill down into the list of facility scores in that state to see which facilities account for the majority of the score. Users can examine results for groups of chemicals or facilities, for one year or over a certain period of time. All of the results, including pounds-based results and hazard-based results, are proportional and work in the same way.

It must be reiterated that while changes in results over the years would imply that there have been changes in hazard- or risk-related environmental impacts, the actual magnitude of any specific change or the reason may not be obvious. Although the value itself may be useful in identifying chemicals, facilities, or geographic locations with the highest potential for hazard or risk, the score itself does not represent a quantitative estimate or provide an exact indication of the magnitude of associated individual hazard or risk.

2.2 Summary of the Strengths and Limitations of the RSEI Model

2.2.1 Strengths

The following are strengths of the model:

- The model provides important hazard-based and risk-related perspectives regarding the impacts of certain TRI chemical waste management activities (e.g., releases to the environment) on chronic human health.
- The model quickly organizes and evaluates complex and large streams of data. For example, the air exposure model is combined with U.S. census data to directly estimate the size of exposed populations and the magnitude of their exposure, rather than assuming that all individuals surrounding a facility are equally exposed.
- The model allows for greatly increased speed in performing screening analyses, thereby conserving resources for conducting more precise, site-specific risk evaluations. In addition, its use as a priority-setting tool allows resources to be focused in areas that will provide the greatest potential risk reduction.

- The model can perform single- and multi-media analyses.
- Custom-tailored and *ad hoc* selections can be made based upon a wide range of parameters.
- This adaptable method can model any chemical if toxicity data, physicochemical properties, waste management quantities, and release and transfer locations are known or can be estimated.
- The model considers both cancer and non-cancer chronic human health endpoints.
- The RSEI method has been subject to repeated expert scientific peer review.
- The model's methodology and assumptions are transparent. Complete and detailed documentation of the RSEI model is available and made available to the public.

2.2.2 Limitations

The following are limitations of the model:

- RSEI results do not provide users with quantitative risk estimates (such as excess cases of cancer).
- RSEI results do not evaluate individual risk.
- The model does not account for all sources of toxic chemicals; it only accounts for the TRI chemicals and chemical categories reported by facilities to the TRI program.
- The model also does not generate scores for all TRI-listed chemicals and chemical categories. With that said, TRI chemicals without toxicity weights account for a very small percentage of total releases and of total risk-related impacts.
- The model assumes that air concentrations of TRI chemicals are the same for indoor and outdoor exposures, and that populations are continuously exposed.
- Dermal and food ingestion pathways (other than fish consumption), and some other indirect exposure pathways are not evaluated in the model.
- Acute health effects associated with short-term, periodic exposures to higher levels of these same chemicals are not addressed in the model.
- Ecological effects of these same chemicals are not addressed in the model.

3. TRI Data Used in the Model

The RSEI model uses information on certain waste management activity quantities (e.g., releases to the environment) reported by facilities to the TRI. The TRI database is a publicly available EPA database that contains information on toxic chemical releases and other waste management activities reported annually by federal facilities and facilities in certain industry sectors. The TRI program operates under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). EPCRA was passed in response to concerns regarding the environmental and safety hazards posed by the storage and handling of toxic chemicals. To reduce the likelihood of chemical emergencies in the United States, Congress imposed requirements for federal, state, and local governments, tribes, and industry. These requirements covered emergency planning and "Community Right-to-Know" reporting on hazardous and toxic chemicals. The Community Right-to-Know provisions help increase the public's knowledge and access to information on chemicals at individual facilities, their uses, and releases into the environment. States and communities, working with facilities, can use the information to improve chemical safety and protect public health and the environment.

Sections 311 and 312 of EPCRA require facilities that handle or store any hazardous chemicals to submit inventory forms, as well as Material Safety Data Sheets (MSDSs) or Safety Data Sheets (SDSs) to state and local officials and to local fire departments. EPCRA Section 313 established the TRI, which required EPA to annually collect data on waste management activity quantities of toxic chemicals from facilities, and to make the data available to the public. In 1990, Congress passed the Pollution Prevention Act (PPA) which required that additional information on waste management and source reduction activities be reported to the TRI. The mission of the TRI program is to provide the public with information about TRI chemicals, including releases, other waste management (e.g., recycling), and pollution prevention from TRI-reporting facilities. It is through this provided data and other information that helps support informed decision making at all levels by industry, government, non-governmental organizations, and the public.

EPA compiles the TRI data each year in the TRI database and makes it available through several data access tools, including several through EPA's Envirofacts.[19] Subject TRI facilities must report the quantities of routine and accidental releases, and releases resulting from catastrophic or other one-time events of EPCRA Section 313 chemicals, as well as the maximum amount of the EPCRA Section 313 chemical on-site during the calendar year and the amount contained in wastes managed on-site or transferred off-site. The TRI release and transfer data reported each year are the initial source of quantitative data used for evaluating potential human exposure in the RSEI model.

EPA has a data quality policy that allows facilities reporting to the TRI to submit changes and corrections to their TRI reporting forms at any time. To limit the effects of these continuous changes on RSEI modeling results, the RSEI model extracts TRI release and transfer data during a period each year when EPA "freezes" the TRI data. This "TRI data freeze" is a cutoff point in

[19] This program description is taken from the TRI web site, https://www.epa.gov/tri. The web site provides additional information, including reporting criteria and requirements for facilities.

time that the Agency uses so that it can prepare official EPA analyses of TRI data such as for the TRI National Analysis and other deliverables. Changes to TRI reporting forms and submitted data during this data freeze will continue to be processed by EPA, but will not be reflected in some of the public data access tools or official EPA analyses until the end of the data freeze and/or until the next update to the TRI access points occur.[20] To ensure that each RSEI model update is current on all revisions submitted to the TRI, data for all years are extracted once a year during this TRI data freeze period, and added to the model, replacing the previous data.

Even though the TRI National Analysis and the RSEI model both use the annual TRI data freeze, there still are some important differences between the two data sets:

- RSEI performs considerable processing on the set of on-site and off-site facilities, including quality-assuring their locations, and identifying duplicate records of off-site facilities.

- The TRI National Analysis adjusts its data to account for "double counting" of waste management quantities[21], where the RSEI model does not make that adjustment. However, beginning with Version 2.3.5, RSEI does adjust transfers to off-site incineration for possible double counting, by dropping any facility off-site transfers to incineration to a receiving facility that also reports to the TRI and is in NAICS code 562211 (Hazardous Waste Treatment and Disposal).[22]

- Each year there may be several corrections to individual facility releases that may be made in one database but not the other.

For more detail on these differences and any year-specific differences, please see Technical Appendix F, "Summary of Differences between RSEI Data and the TRI National Analysis."

[20] For the first time, RSEI data was updated with the spring TRI update in reporting year 2018. Because most revisions are for recent years, only the last five years were updated. So for 2018, there are two data sets, "rsei2018" and "rsei2018_spring". Microdata and user-facing tools like EasyRSEI were updated with the spring dataset, and that should be considered the final 2018 RSEI data.

[21] Some quantities are counted twice for TRI aggregate total waste management activity calculations, where "double counting" is when the waste quantities are reported as both transferred off-site by a facility and also managed on-site by another facility (e.g., a TRI industrial facility sending chemical waste off-site for disposal to a RCRA-regulated chemical treatment, storage, and disposal facility (TSDF) that also reports those waste quantities to TRI as disposed of on-site).

[22] See section 5.6 for more information.

4. Methods for Calculating Toxicity Weights

The EPCRA Section 313 criteria list several human toxicity endpoints that EPA must consider when evaluating a chemical for addition to the TRI chemical list, including acute toxicity, cancer or teratogenic effects, serious or irreversible reproductive dysfunctions, neurological disorders, heritable genetic mutations, or other chronic health effects. EPCRA also considers environmental toxicity endpoints. Some chemicals have toxicity data for only one adverse effect, while other chemicals have evidence of adverse effects within several of these toxicity endpoints. The toxicity endpoints and their definitions as prescribed in EPCRA Section 313 are presented in Exhibit 4.1.

The RSEI model focuses on carcinogenicity and other types of toxic endpoints that are typically associated with chronic exposures.[23] The RSEI method relies heavily on current EPA methodologies for assessing toxicity, and will be continually updated to reflect any changes in these methods.

Exhibit 4.1
Toxicity Endpoints

Endpoint	Definition
Carcinogenicity	The ability of a chemical to produce cancer in animals or humans.
Heritable Genetic and Chromosomal Mutation	The failure to transmit genetic information. This can involve at least three separate modes of action: the gain or loss of whole chromosomes (aneuploidization), rearrangement of parts of chromosomes (clastogenesis), and addition or deletion of a small number of base pairs (mutagenesis).
Developmental Toxicity	Any detrimental effect produced by exposures to developing organisms during embryonic stages of development, resulting in: prenatal or early postnatal death, structural abnormalities, altered growth, and functional deficits (reduced immunological competence, learning disorders, etc.).
Reproductive Toxicity	Interference with the development of normal reproductive capacity. Chemicals can affect gonadal function, the estrous cycle, mating behavior, conception, parturition, lactation, and weaning.
Acute Toxicity	The potential for a short-term exposure (typically hours or days) by inhalation, oral, or dermal routes to cause acute health effect or death.
Chronic Toxicity	The potential for any adverse effects other than cancer observed in humans or animals resulting from long-term exposure (typically months or years) to a chemical.

[23] Chronic effects are those that generally persist over a long period of time whether or not they occur immediately after exposure or are delayed. Chronic exposure refers to multiple exposures occurring over an extended period of time, or a significant fraction of an individual's lifetime.

Exhibit 4.1
Toxicity Endpoints

Endpoint	Definition
Neurotoxicity	Changes to the central and/or peripheral nervous system, which may be morphological (biochemical changes in the system or neurological diseases) or functional (behavioral, electrophysiological, or neurochemical effects).

4.1 Toxicity Weighting Scheme for Carcinogens and Non-carcinogens

The RSEI method uses a proportional system of numerical weights that reflect the toxicities of chemicals relative to one another. The toxicity weights of chemicals increase as the toxicological potential to cause chronic human health effects increases. The method EPA has chosen for assigning toxicity weights to chemicals is clear, transparent, and reproducible, based upon easily accessible and publicly available information, and uses expert EPA-wide judgments to the greatest extent possible.

Factors that could be used to weight a chemical's toxicity include: the number of adverse effects that the chemical causes; the relative severity of the effect(s); the potency of the chemical to elicit the effect(s); and the uncertainty inherent in characterizing the effect(s). The RSEI method focuses on the latter two factors (potency and uncertainty inherent in characterizing effect(s)), and thus considers both quantitative and qualitative elements to judge the relative toxicity of chemicals. The types of data required and the method used to combine these data into toxicity weights are described below.

4.1.1 Qualitative Data

Uncertainty reflecting the quality and adequacy of the data are incorporated into the underlying toxicity values or in the toxicity weights themselves. The RSEI method is intended to differentiate the relative toxicity of TRI chemicals in a uniform manner.

When evaluating the potential toxicity of a chemical to humans, toxicologists and risk assessors use a variety of data, including epidemiological data, *in vivo* acute and chronic animal studies, and *in vitro* and *in silico* toxicity testing methods. Together, these data form a body of evidence regarding the potential for toxic chemicals to cause particular adverse health effect(s). Experts can judge qualitatively the strengths of this body of evidence when evaluating the probability of the occurrence of the effect(s) happening in humans. Based on this scientific judgment, the chemical is assigned a weight-of-evidence (WOE) classification. Weight-of-evidence schemes can be designed to indicate whether a chemical either causes specific health effect(s) in general, or specifically in humans.

For **cancer** effects, the WOE system presented in this RSEI method relies on categorical definitions from the 1986 EPA Guidelines for Carcinogenic Risk Assessment (EPA, 1986a), which are related to the potential for a chemical to be carcinogenic to humans.[24] The Cancer Guidelines define the six WOE categories shown in Exhibit 4.2 in which WOE categories A, B1, and B2 (known and probable carcinogens) are combined in the RSEI model. The combination of the A and B categories represents a modification of the Hazard Ranking System (HRS), which is used by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) to rank hazardous waste sites for inclusion in the National Priorities List (NPL). Under the HRS scheme, A, B, and C categories are each considered separately. This revision reduces the dichotomy between the A and B categories, a dichotomy that may be inappropriate in the context of assigning toxicity weights. Also, combining categories A and B stabilizes the model results against changes induced by chemicals switching between the A and B designations. Class C chemicals (possible carcinogens) are assigned toxicity weights by dividing the calculated toxicity weights by a factor of 10 (see Section 4.1.3), because evidence that they cause cancer in humans is less certain. The choice of applying an uncertainty factor is based on the advice of expert peer review and the HRS, where an order of magnitude difference is an arbitrary uncertainty factor. Categories D and E are not considered in this toxicity weighting scheme (i.e., no toxicity weights are assigned).

Exhibit 4.2
Weight-of-Evidence Categories for Carcinogenicity

Category	Weight-of-Evidence
A	Sufficient evidence from epidemiological studies to support a causal relationship between exposure to the agent and cancer.
B1	Limited evidence from epidemiological studies and sufficient animal data.
B2	Sufficient evidence from animal studies but inadequate or no evidence or no data from epidemiological studies.
C	Limited evidence of carcinogenicity in animals and an absence of evidence or data in humans.
D	Inadequate human and animal evidence for carcinogenicity or no data.
E	No evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiological and animal studies, coupled with no evidence or data in epidemiological studies.

Source: 51 FR 33996

[24] EPA's Cancer Guidelines were updated in 2005 (EPA, 2005). The 2005 EPA WOE categories are not grouped by letter as are the EPA's 1986 WOE categories. The new 2005 categories are translated into 1986 designations in the following way:

- Carcinogenic to humans: **A**
- Likely to be carcinogenic to humans: **B**
- Suggestive evidence of carcinogenic potential: **C**
- Inadequate information to assess carcinogenic potential: **D**
- Not likely to be carcinogenic to humans: **E**

For **non-cancer** effects, WOE is considered qualitatively in the hazard identification step of determining an RfD or an RfC. The WOE evaluation for non-cancer effects is different from the WOE evaluation for carcinogenic effects. The WOE judgment for non-cancer effects focuses on the dose or concentration where chemical exposure would be relevant to humans (Dourson, 1993). That is, the focus of the WOE evaluation and the expression of the level of confidence in the RfD or RfC is a judgment of the accuracy with which the dose or concentration relevant to humans has been estimated. The WOE evaluation is included qualitatively in the RfD or RfC, but does not affect its numerical calculation. Since WOE has been considered in developing RfDs and RfCs, RSEI does not consider WOE separately for non-cancer effects.

4.1.2 Quantitative Data

Quantitative data on the relative toxic potencies of chemicals are needed for toxicity weighting. These data generally result from analyses done during the dose-response assessment step of a risk assessment. This step involves describing how the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to a chemical (the dose provided). Risk posed by exposure to a chemical cannot be described without quantitative dose-response data. Dose-response data are derived from animal studies or, less frequently, from studies in exposed human populations. There may be many different dose-response relationships for a chemical if the chemical produces different toxic effects under different conditions of exposure.

For **cancer risk assessment**, EPA has developed standard methods for predicting the incremental lifetime risk of cancer per exposure of a chemical. EPA quantitatively models the dose-response function of a potential carcinogen and typically provides estimates of Oral Slope Factors (OSFs) or Inhalation Unit Risks (IURs). The OSF represents the upper-bound estimate of the slope of the dose-response curve in the low-dose region for carcinogens, and is a measure of cancer potency. The units of the slope factor are usually expressed as $(mg/kg\text{-}day)^{-1}$. The IUR is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at a concentration of 1 $\mu g/m^3$ in air (RSEI model toxicity weights are based on this value when expressed as risk per mg/m^3). Although the level of conservatism inherent in the OSFs and Unit Risks varies by chemical, OSFs and IURs nonetheless are the best readily available values that allow for a comparison of the relative cancer potency of chemicals.

RSEI's oral cancer toxicity weight (OTWc) represents how toxic a chemical is relative to a chemical that produces a 1 in 1 million risk[25] (above background, over a lifetime) at an average lifetime daily dose of 1 mg/kg-day. If the OSF is greater than this arbitrary slope factor (i.e., the chemical is more toxic than the arbitrary slope factor), the OTWc is greater than 1.

$$OTWc = \frac{OSF\ kg\text{–}day/mg}{10^{-6}\,kg\text{–}day/mg} \qquad \text{(Eq. 4.1)}$$

[25] EPA programs commonly use a risk management range corresponding to an excess individual lifetime risk of cancer of 1 in 10^{-6} to 10^{-4} (EPA, 1999a).

For **non-cancer risk assessment,** data on dose-response are typically (though not always) more limited; generally, a risk assessor evaluates dose compared to a Reference Dose (RfD) and a concentration compared to a Reference Concentration (RfC). Both the RfD and RfC are defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure [oral exposure for RfD or continuous inhalation exposure for RfC] to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious [non-cancer] effects during a lifetime" (EPA, 1988a; EPA, 1990b). The units of RfD are mg/kg-day, while the units of the RfC are mg/m^3. A chemical's RfD or RfC is typically based on a No-Observed-Adverse-Effect Level (NOAEL) or Lowest-Observed-Adverse-Effect Level (LOAEL), combined with appropriate uncertainty factors to account for intraspecies variability in sensitivity, interspecies extrapolation, extrapolation from LOAELs to NOAELs, and extrapolation from subchronic to chronic data. In addition, a modifying factor can be applied to reflect EPA's best professional judgment on the quality of the entire toxicity data reference for the chemical. By definition, exposures below the RfD/RfC are unlikely to produce an adverse effect; above this value, an exposed individual may be at risk for the effect. Empirical evidence generally shows that as the dosage of a toxicant increases, the measured response (e.g., severity and/or incidence of effect) also increases (EPA, 1988a), but for a given exposure level above the respective RfD or RfC, the specific probability or severity of an effect is not known. For purposes of the RSEI model, it is assumed that non-cancer risk varies as the ratio of the estimated exposure dose or concentration to its respective RfD or RfC.

RSEI's oral non-cancer toxicity weight (OTWnc) represents how toxic a chemical is relative to an arbitrary dose of 1 mg/kg-day. If the RfD is greater than this arbitrary dose (i.e. the chemical is less toxic than the arbitrary dose), the OTWnc is less than 1.

$$OTWnc = \frac{1\,mg/kg\text{–}day}{RfD\,mg/kg\text{–}day} \qquad \text{(Eq. 4.2)}$$

4.1.3 Method for Calculating Toxicity Weights

The RSEI method uses several different algorithms in assigning chemical toxicity weights. RSEI model toxicity weights are designed to be proportional to a chemical's toxicity. The more toxic a chemical is, the higher its toxicity weight.

Toxicity values for the inhalation pathway are typically expressed in units of exposure, that is, milligram (mg) of chemical per cubic meter (m^3) of air. The RSEI toxicity weighting method uses standard adult human exposure factors for inhalation rate (20 m^3/day) and body weight (70 kilogram (kg)) to modify toxicity values expressed in units of exposure. This adjustment means that different constants are used to calculate the toxicity weights when inhalation toxicity values

are used rather than oral toxicity values[26] (3.5 versus 1.0 for non-carcinogens, and $2.8*10^{-7}$ versus $1*10^{-6}$ for carcinogens). All RSEI toxicity weights are expressed as reciprocal units of mg/kg-day.

As these calculations show, non-cancer toxicity weights are proportional to the reciprocal of the RfD or RfC for the oral and inhalation exposure pathways, respectively. Cancer toxicity weights are proportional to the OSF or IUR, for the oral and inhalation exposure pathways, respectively. When multiplied by the surrogate dose estimated by RSEI, the risk-related scores calculated by the model are unitless, and should be used only for comparative purposes within RSEI.

Exhibit 4.3 below shows the algorithms used to calculate RSEI chemical toxicity weights. Chemicals classified as WOE category C are assigned the same algorithm as those in WOE categories A and B, but the OSF or IUR is divided by an additional uncertainty factor of 10 because the evidence of cancer causation in humans is uncertain.

Exhibit 4.3
Algorithms for Assigning Toxicity Weights

		Exposure Route	
		Inhalation	**Oral**
Type of Effect	**Cancer***	IUR / 2.8e-7	OSF/ 1e-6
	Non-Cancer	3.5 / RfC	1 / RfD
*If the Weight of Evidence (WOE) Category is equal to C, each weight is divided by an additional factor of 10 to account for uncertainty.			

4.2 Selecting the Final Toxicity Weights

Each chemical is assigned up to four toxicity weights, according to the availability of the RfC, RfD, IUR, and OSF. The RSEI model results may use different toxicity weights, depending on the data.

RSEI Hazard and RSEI Score use the higher cancer or non-cancer toxicity weight for each exposure route (i.e., oral and inhalation), and if one exposure route is missing both toxicity weights, then the other exposure route's toxicity weight is used. Cancer hazard and cancer score results use only the cancer toxicity weights (i.e., the IUR for the inhalation exposure route or the OSF for the oral exposure route), and do not use the RfC- or RfD-based toxicity weights even if the IUR or OSF is missing. Similarly, the non-cancer hazard and non-cancer score results only use the RfC- or RfD-based toxicity weights.

In addition, the RSEI score, cancer score, and non-cancer score all use the inhalation route toxicity weight (RfC or IUR as appropriate) for the portion of the Publicly Owned Treatment Works (POTW) transfer that volatilizes during wastewater treatment and the oral route toxicity

[26] Non-carcinogens are multiplied by 3.5, derived from the inhalation rate and body weight adjustment (70/20). Carcinogens are multiplied by 1/3.5, which, when multiplied by 1e-6, equals 2.8e-7.

weight (RfD or OSF as appropriate) for the portion of the POTW transfer that is released from the POTW as effluent.[27] The three hazard-based results do not account for partitioning, and use the oral toxicity weight (RfD or OSF as appropriate) for the entire chemical transfer. The table below summarizes the selection of toxicity weights for each kind of RSEI result.

[27] Chemical-specific POTW removal and within-POTW partitioning rates are used to determine the portion of each transfer to a POTW that biodegrades, adsorbs to sludge, or volatilizes. The remainder is assumed to be released from the POTW as effluent.

Exhibit 4.4
Selection of Toxicity Weights for Each RSEI Result

RSEI Result	Air Releases	Water Releases	Transfers to POTWs	Fill in Toxicity Data Gaps?
Score	Higher of IUR tox weight or RfC tox weight.	Higher of OSF tox weight or RfD tox weight.	For portion of transfer that volatilizes during wastewater treatment use higher of IUR tox weight or RfC tox weight. For portion of transfer that is released from POTW as effluent use higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no tox weight in one exposure route, use tox weight from other exposure route. For instance, if a chemical has no IUR or RfC tox weight, use higher of RfD or OSF tox weight for air releases.
Cancer Score	IUR tox weight.	OSF tox weight.	For volatilized portion use IUR tox weight. For POTW effluent release portion use OSF.	No. If no route-specific cancer tox weight, then cancer score is zero.
Non-Cancer Score	RfC tox weight.	RfD tox weight.	For volatilized portion use RfC tox weight. For POTW effluent release portion use RfD tox weight.	No. If no route-specific non-cancer tox weight, then non-cancer score is zero.
Hazard	Higher of IUR tox weight or RfC tox weight.	Higher of OSF tox weight or RfD tox weight.	Higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no tox weight in one exposure route, use data from other exposure route.
Cancer Hazard	IUR tox weight.	OSF tox weight.	OSF tox weight.	No. If no route-specific cancer tox weight, then cancer hazard is zero.
Non-Cancer Hazard	RfC tox weight.	RfD tox weight.	RfD tox weight.	No. If no route-specific non-cancer tox weight, then non-cancer hazard is zero.

RSEI Hazard and RSEI Score use the higher cancer or non-cancer toxicity weight for each exposure route (i.e., oral and inhalation), and if one exposure route is missing both toxicity weights, then the other exposure route's toxicity weight is used. If data are available for only one route, the same toxicity weight is applied for both routes, provided there is no evidence the

effects are route-specific or limited to the "portal of entry" into the body. In rare instances, toxicity studies are available to show that a given chemical causes no adverse effects via one route; in these instances, a toxicity weight is assigned only to the route that results in chronic human health adverse effects. Although assigning the same weight to both routes is not an ideal method, it is appropriate for a screening-level tool like the RSEI model.

Although a given chemical can cause several types of toxic effects, the RSEI model assigns the chemical's toxicity weight based on the single most sensitive adverse effect for the given exposure route (oral or inhalation). If the chemical exhibits both carcinogenic and non-carcinogenic adverse effects, the higher of the associated cancer and non-cancer toxicity weights is assigned as the final toxicity weight for the chemical for the given route for the RSEI score and RSEI hazard. For the other results, cancer and non-cancer effects are not mixed.

The approach of toxicity weighting based on the most sensitive adverse effect does not consider differences in the type, number, or molecular target of the adverse effects posed by the chemical. For example, liver toxicity is weighted in the same way that neurotoxicity is weighted; in principle, chemicals causing a certain type of adverse effect could be assigned additional weights if special concern(s) existed for that type of effect. However, applying such additional toxicity weights would require a subjective evaluation and assignment of the severity of the adverse health effects. Also, chemicals with a broad range of adverse health effects are weighted the same as a chemical causing only one adverse effect. This approach may appear to under-estimate the risk of chemicals with a wide spectrum of adverse effects relative to chemicals with one or few adverse effects. However, a chemical may only appear to demonstrate just one adverse effect because there are no data on other toxic endpoints; thus, applying an additional weight based on the number of endpoints may under-value some poorly-studied yet still hazardous chemicals. For these reasons, the options for applying additional toxicity weights based on the number and relative severity of toxic endpoints were not adopted.

Elemental metals and metal compound categories (e.g., "lead" and "lead compounds") are separately listed for TRI reporting purposes. RSEI combines these separate listings into one category (e.g., "lead and lead compounds").

4.3 Chemical Categories

Along with information for individually-listed TRI chemicals, the TRI program also collects information for some chemicals as part of a chemical category listing. For example, the TRI program has separate reporting requirements for both elemental metals and for metal compound categories, as well as reporting requirements for other chemical categories such as certain glycol ethers, diisocyanates, and polycyclic aromatic compounds (PACs). In the case of most metal compound categories, TRI regulations define the category members to include any unique chemical substance that contains the named metal (e.g., lead, antimony, nickel, etc.) as part of that chemical's composition, however, subject facilities do not need to disclose the specific category member's identity in their TRI reporting forms.

To simplify toxicity weight calculations due to the identity uncertainties behind the metal compound category members that are reported to the TRI program, the RSEI model combines TRI-listed metal compound categories (e.g., nickel compounds) together with separately listed

TRI elemental metals (e.g., nickel) into one RSEI chemical category (e.g., nickel and nickel compounds). Both nickel and nickel compounds are reported to TRI to reflect the quantities of the nickel parent metal that is ultimately released to the environment, where in some cases, reporting facilities may combine the two into a single report and reported their release quantities to TRI as nickel compounds. For RSEI modeling purposes, the model combines the reported metal release quantities into one entry listed as "nickel and nickel compounds" and assumes that the elemental metal and metal compound category members have the same toxicity weight. It is also assumed that elemental metals and metal compounds are released in the valence or oxidation state associated with the highest chronic toxicity value, although in reality it may be that certain metal compounds may have differing associated chronic toxicity values due to environmental releases of less toxic valence or oxidation states.

For both metal and non-metal TRI chemical categories, the RSEI model uses toxicity data for the most toxic member of the chemical category to represent the toxicity of the entire chemical category, with a few noted exceptions. The first exception is for chromium and chromium compounds, for which the RSEI model assumes that TRI reporting facilities may release some combination of both hexavalent chromium (Cr VI) and trivalent chromium (Cr III). Facility-specific and industry NAICS-code specific estimates derived from the 2014 NEI are used to estimate the speciation fraction of each type.28 As trivalent chromium has a very low toxicity, only the hexavalent fraction is modeled in RSEI, using a toxicity weight specifically for that valence state (Cr VI). The second exception is for mercury and mercury compounds. The toxicity for the oral pathway is based on methyl mercury, and the toxicity for the inhalation pathway is based on elemental mercury. The third exception is for polycyclic aromatic compounds (PACs), for which the RSEI model assumes that the overall toxicity for the chemical category is 18% of the toxicity for benzo(a)pyrene, the most toxic member of the group. This value is based on the methodology used by EPA's National Air Toxics Assessment (NATA) model for polycyclic organic matter (POM), which is based on emissions factors for representative processes used in industries that emit large amounts of POM. RSEI assumes that PACs emissions reported to TRI are most like NATA's "7-PAH" category.29

The fourth exception is for dioxin and dioxin-like compounds. EPA first required reporting of this chemical category beginning with reporting year 2000. Along with transfer information and waste management activity quantities, TRI reporting facilities were required to report total dioxin and dioxin-like compound quantities released (in units of grams) to each environmental medium, as a single representative distribution of the 17 members of the chemical category based on releases to all media combined or to a specific environmental medium. EPA changed the reporting requirements for reporting year 2008, where reporting facilities were then subject to provide more specific distributions of each individual member of the chemical category to each environmental release medium, transfer off-site, and waste management activity. These new

[28] The NEI is available at https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data.

[29] The documentation on modeling polycyclic organic matter (POM) from EPA's NATA model can be found in the Technical Methods Document at https://www.epa.gov/national-air-toxics-assessment/2005-national-air-toxics-assessment.

reporting requirements were reflected in TRI's Form R Schedule 1, which was submitted as an adjunct to the Form R if reporting facilities had this information.

Toxicity information is only available for one member of the dioxin and dioxin-like compounds chemical category, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). However, EPA has determined a toxic equivalence factor (TEF) for each congener member of the chemical category, based on its toxicity relative to TCDD30. The RSEI model combines the reported distributions of each individual member of the chemical category with EPA's TEFs to calculate a weighted average TEF for each waste management activity quantity (e.g., releases to the environment). When multiplied by the toxicity weight for TCDD, this provides a comparable toxicity weight for each dioxin and dioxin-like compound category member. For waste management activity quantities where the reported distributions of each category member are blank or invalid, the RSEI model adopts mean distribution TEFs for each category member using the reporting facility's 4-digit NAICS code. If a 4-digit NAICS code for the reporting facility is not available, the overall mean TEF for the specific environmental medium is used. Because the specific individual category member distributions to each environmental release medium, transfer off-site, and waste management activity are only available starting with reporting year 2008 and on, RSEI hazard and risk-related modeling results are only available for these years, however, users can examine RSEI pounds-based results for dioxin and dioxin-like compounds for reporting year 2000 and later.

4.4 Sources of Toxicity Data

Information regarding the toxicity data on TRI chemicals is compiled from the following sources:

IRIS. The primary (and most preferred) source of these data is EPA's Integrated Risk Information System (IRIS). The IRIS program is available on the internet (at https://www.epa.gov/iris), and supports EPA's mission by identifying and characterizing the health hazards of chemicals found in the environment. IRIS includes information on EPA evaluations of chemical toxicity for both cancer and non-cancer effects of chemicals. IRIS provides both background information on the studies used to develop the toxicity evaluations and the numerical toxicity values used by EPA to characterize risks from these chemicals. These values include upper-bound OSF or IUR values for chemicals with carcinogenic effects as well as RfDs or RfCs for chemicals with non-cancer effects. Data contained in IRIS have been peer-reviewed and represent Agency-wide expert scientific judgments. The peer-review process involves literature review and evaluation of a chemical by individual EPA program offices and intra-Agency work groups before inclusion in IRIS.

[30] TEFs are consensus estimates of compound-specific toxicity/potency relative to the toxicity/potency of an index chemical. TEFs are the result of expert scientific judgment using all of the available data and taking into account uncertainties in the available data. For more detail on the dioxin and dioxin-like compound TEFs, see https://www.epa.gov/risk/documents-recommended-toxicity-equivalency-factors-human-health-risk-assessments-dioxin-and.

NATA. EPA's National Air Toxics Assessment (NATA), generally obtains data from the other sources listed in this list, but in some cases uses values derived by EPA's Office of Air Quality Planning and Standards (OAQPS).

OPP. EPA's Office of Pesticide Programs' (OPP) Acute and Chronic Reference Doses Table lists OPP's evaluations of the non-carcinogenic potential of chemicals that are of interest to OPP. OPP also publishes the List of Chemicals Evaluated for Carcinogenic Potential, which examines carcinogens. Both of these lists are updated periodically. Individual Pesticide Reregistration Eligibility Documents (REDs) are also used.

ATSDR. The Agency for Toxic Substances and Disease Registry (ATSDR) is an agency of the U.S. Department of Health and Human Services (HHS), which deals with the effect on public health of hazardous substances in the environment. ATSDR develops Minimal Risk Levels (MRLs) for chemicals on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL). MRLs are an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. RSEI uses data from MRLs developed for chronic exposure only. MRLs are intended to serve as screening levels only, and are useful in identifying contaminants and potential health effects that may be of concern at hazardous waste sites. See https://www.atsdr.cdc.gov/mrls/index.asp for more information on MRLs and specific values.

CalEPA. The California Environmental Protection Agency (CalEPA), Office of Environmental Health Hazard and Assessment (OEHHA) is responsible for developing and distributing toxicological and medical information needed to protect public health. RSEI uses final toxicity values published by CalEPA in the Consolidated Table of OEHHA & California's Air Resources Board (ARB) Approved Risk Assessment Health Values. The table is continuously updated and can be found at https://ww3.arb.ca.gov/toxics/healthval/contable.pdf.

PPRTVs. EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs) include toxicity values developed by EPA's Office of Research and Development (ORD), Center for Public Health and Environmental Assessment (CPHEA), formerly known as the National Center for Environmental Assessment (NCEA), Superfund Health Risk Technical Support Center (STSC).

HEAST. EPA's Health Effects Assessment Tables (HEAST) are constructed for use in the CERCLA and RCRA programs but do not represent Agency-wide expert scientific judgments. These tables are publicly available from CERCLA's Superfund program. The tables include OSFs, IURs, and WOE categorizations for chemicals with cancer effects, and RfDs and RfCs for non-cancer effects.

Derived Values. For a prioritized group of chemicals for which sufficient data were not found in the above sources, a group of EPA expert health scientists reviewed other available data to derive appropriate toxicity weights. Although individual literature searches for toxicological and epidemiological data for each chemical were beyond the scope of the RSEI project, sources such as the Hazardous Substances Data Base (HSDB), as well as various EPA and ATSDR summary documents, provided succinct summaries of toxic effects and quantitative data, toxicological and epidemiological studies, and, in some cases, regulatory status data. When the available data on

chronic human toxicity were sufficient to derive values, a toxicity weighting summary was developed summarizing the information used to develop each of these values. The summaries are available in Technical Appendix A. The EPA scientists use a technical approach analogous to the Agency's method for deriving RfD and RfC values, cancer risk estimates, and WOE determinations. It must be emphasized, however, that these derived values are not the equivalent of the more rigorous and resource-intensive IRIS assessment process and are only useful for screening-level purposes.

Data from these sources are categorized in three-tiered, hierarchical fashion to give preference to EPA and consensus data sources, where possible. Toxicity data are gathered separately for individual endpoints; a chemical's RfD may be from IRIS, while its OSF may be from HEAST.

The three-tiered hierarchy used for toxicity weighting assignments is as follows:

Tier 1. The most recent data from EPA's IRIS and OPP are used for each chronic toxicity health endpoint. If the dates are comparable, preference is given to IRIS, since IRIS reflects Agency-wide expert scientific judgments. If EPA's NATA has made a policy decision to use an alternative data source, that is adopted unless otherwise indicated by modeling considerations.

Tier 2. In the absence of data from the above sources for an individual chronic toxicity health endpoint, toxicity data from the most recent entry in ATSDR and CalEPA are used.

Tier 3. In the absence of data from the above sources for an individual chronic toxicity health endpoint, the following data sources, in this order, are used: 1) PPRTVs; 2) HEAST; 3) Derived; and 4) IRIS values previously used in toxicity weighting, that were withdrawn pending revision.

For chemicals with carcinogenicity risk values, WOE designations are obtained using the same data source hierarchy. Therefore, preference is given to WOEs from EPA's IRIS or OPP. As a general rule, chemicals with cancer potency factors from IRIS or OPP will also have WOEs. CalEPA, however, references either EPA or the International Agency for Research on Cancer (IARC) for WOE designations. Therefore, in the absence of an EPA consensus WOE, WOEs are obtained from IARC. However, due to the differences in WOE definition, it is not always possible to translate IARC WOE into EPA WOE without examining the toxicity data. WOEs are matched in the following way:

- IARC Group 1 = EPA Group A (Carcinogenic to Humans)
- IARC Group 2A = EPA Group B (Probably Carcinogenic to Humans)
- IARC Group 2B = EPA Group B or EPA Group C (Possibly Carcinogenic to Humans)
- IARC Group 3 = EPA Group D (Not Classifiable as to Human Carcinogenicity)
- IARC Group 4 = EPA Group E (Evidence of Non-Carcinogenicity for Humans)

The IARC Group 2B designation is not easily translated to the EPA designation, because its definition spans EPA Groups B and C. This is a particularly important distinction because the use of a B2 or C WOE designation will affect the calculation of the toxicity weight. Therefore, for the chemicals with IARC Group 2B designations, summaries of the toxicity data used to generate the OSF or IUR are evaluated to derive the WOE designation. To date, this approach

has been used for chemicals with data from CalEPA; therefore, the CalEPA "Technical Support Document for Describing Available Cancer Potency Factors" was used for the background information.

Currently, using all of the available data sources described above, toxicity weights are available for over 400 of the more than 600 chemicals and chemical categories on the 2019 TRI Chemical List. Chemicals and chemical categories with toxicity weights account for 99% of the reported quantities for all releases and transfers to modeled media in 2019. The RSEI results are recomputed for all years in the TRI database on an annual basis in order to incorporate revisions to the reporting data.

Toxicity weights for individual chemicals and chemical categories are presented in Technical Appendix A.

4.5 How RSEI Toxicity Weightings Differ from EPCRA Section 313 Criteria

As previously noted, the RSEI model uses data and information reported to the TRI program. All TRI chemicals included in RSEI modeling are listed on the TRI chemical list because they have met one or more statutory criteria regarding acute or chronic human health toxicity, or environmental toxicity. The goal of the RSEI model is to use data reported to the Agency to investigate the relative risk-based impacts of certain waste management quantities (e.g., releases to the environment) of TRI chemicals on the general, non-worker population. To achieve this goal, the RSEI model differentiates the relative toxicity of listed chemicals and ranks them in a consistent and transparent manner. The ranking of each chemical reflects its toxicity only relative to other chemicals that are included in the model. Toxicity is not compared to some benchmark or absolute value as is required when adding or removing a chemical from the TRI chemical list. Furthermore, the RSEI model addresses only the single, most sensitive chronic human health toxicity endpoint.

It is important that users not confuse the use of the RSEI model as a screening-level tool with the very different and separate regulatory activity of listing/delisting chemicals on the TRI chemical list using statutory criteria. A description of the listing/delisting criteria and process is described below.

The Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) section 313(d)(2) sets out criteria for adding chemicals to the list of chemicals subject to reporting under EPCRA section 313(a). The statutory criteria used for listing and delisting chemicals addresses the "absolute" chronic toxicity of chemicals on the TRI (e.g., multiple effects or the severity of effects). For a chemical (or category of chemicals) to be added to the EPCRA section 313(c) list of toxic chemicals, the Administrator must judge whether there is sufficient evidence to establish any one of the following:

> **Acute Human Toxicity** §313(d)(2)(A) - The chemical is known to cause or can reasonably be anticipated to cause significant adverse acute human health effects at concentration levels that are reasonably likely to exist beyond facility site boundaries as a result of continuous, or frequently recurring, releases.

Chronic Human Toxicity §313(d)(2)(B) - The chemical is known to cause or can reasonably be anticipated to cause in humans–

(i) cancer or teratogenic effects, or

(ii) serious or irreversible–

(I) reproductive dysfunctions,

(II) neurological disorders,

(III) heritable genetic mutations, or

(IV) other chronic health effects.

Environmental Toxicity §313(d)(2)(C) - The chemical is known to cause or can reasonably be anticipated to cause, because of –

(i) its toxicity,

(ii) its toxicity and persistence in the environment, or

(iii) its toxicity and tendency to bioaccumulate in the environment, significant adverse effect on the environment of sufficient seriousness, in the judgment of the Administrator, to warrant reporting under this section.

To remove a chemical from the section 313(c) list, the Administrator must determine that there is not sufficient evidence to establish any of the criteria described above as required by EPCRA section 313(d)(3).

The EPA examines all of the studies available for a chemical to decide if the chemical is capable of causing any of the adverse health effects or environmental toxicity in the criteria. Agency guidelines describe when a study shows such effects as cancer (EPA, 1986a), developmental toxicity (teratogenic effects) (EPA, 1991b), or heritable genetic mutations (EPA, 1986b). The review makes a qualitative judgment regarding the potential of each chemical to meet at least one of the criteria and the chemical is added to the list if this judgment is positive. If a chemical is on the list and it is not possible to make a positive judgment regarding any of the criteria, then the chemical can be removed.

There is no correlation between the toxicity criteria and methodology used to make listing/delisting decisions under EPCRA section 313 and the methodology used to assign toxicity weights to chemicals for the RSEI model. Therefore, these toxicity weights cannot be used as a scoring system for evaluating listing/delisting decisions. RSEI also does not attempt to reflect the statutory criteria for these chemicals.

5. Exposure and Population Modeling

To estimate the magnitude of exposure potential from certain TRI waste management activities (e.g., releases to the environment), a separate exposure evaluation is conducted for each environmental exposure pathway. The following pathways are evaluated:

- **Air**: stack (point) and fugitive (non-point) air emission pathways;
- **Surface Water**: drinking water intake and fish ingestion pathways;
- **Publicly Owned Treatment Works (POTWs)**: fugitive air, groundwater (not currently modeled), drinking water intake and fish ingestion pathways;
- **Land**: groundwater pathway (not currently modeled), volatilization to air included in fugitive air emission pathway for on-site releases; and
- **Off-site transfers**: groundwater (not currently modeled), volatilization (not currently modeled) and stack air (from incineration) pathways.

The ideal derivation of an exposure dose would involve a *site-specific* exposure assessment for each waste management activity quantity and its environmental exposure pathway. Such an effort, however, is well beyond the scope of the RSEI project; further, reporting of extensive site-specific information relevant for exposure modeling is not subject to TRI reporting requirements. For example, the EPA Form R (Toxic Release Inventory Reporting Form) does not require reporting of data on groundwater flow, soil conditions, and other factors that affect groundwater contamination from land releases. Although some site-specific data are used in the RSEI model, it is not the intent of the RSEI project to gather extensive site-specific data or measurements that would be needed to perform site-specific calculations. The need to accurately reflect exposure scenarios and detailed characteristics in the RSEI model must be balanced by the need for simple, quick, and understandable results that are easily communicated to users that are based on current readily-available data.

Therefore, in the RSEI method, the exposure evaluations combine data on physicochemical properties, environmental fate and transport data, media-specific environmental release quantities, and where available, site (e.g., facility) characteristics, with models to predict an estimate of the ambient concentration of the chemical for each relevant exposure pathway. The ambient environmental media concentrations are then combined with human exposure assumptions to estimate a "surrogate dose". The term surrogate dose is used because limited site-specific data and the use of models that rely on default values for some input parameters preclude the calculation of an actual dose estimate. Instead, The purpose of this methodology is to generate as accurate a surrogate dose as possible without conducting an in-depth and resource-intensive risk assessment. The estimates of surrogate doses resulting from certain waste management activities of TRI chemicals are *relative to the surrogate doses resulting from other waste management activities included in the model.*

Estimates of the surrogate dose for each potentially exposed person are combined with estimates of the number of people potentially exposed. Potential exposure is determined by the geographic location of the population, as identified by the decennial U.S. censuses for 1990, 2000, and 2010. The size of the exposed population is calculated separately for each exposure pathway. The RSEI

model assumes continuous exposure, and does not account for the activity patterns of the people potentially exposed. However, population estimates do consider changing demographic patterns (total population, as well as subpopulations by age and sex).

The methods used to model each type of waste management activity are specific to that type of activity and depend on data available to evaluate that exposure pathway. In some cases, models are combined with some site-specific data to estimate exposure; in other cases, reasonable generic worst-case models and/or assumptions may be used in the absence of any site-specific data. The physicochemical property data used for the exposure evaluations are found in Technical Appendix B. It should be noted, however, that products of decay are not modeled. Exclusion of these decay products from the RSEI model may underestimate or overestimate the risk-related impacts of certain waste management activities, since the decay product(s) may be more or less toxic than the parent chemical.

Specific pathway calculations are discussed in the sections below. First, Section 5.1 discusses the geographic basis of the RSEI model, and describes the grid cell system underlying the model and how facilities and people are located on it. This discussion describes how annual grid cell-level general population data sets are created. From these general population data sets, the model generates estimates of populations exposed through particular exposure pathways. The next sections describe the modeling for each exposure pathway, including the estimation of surrogate doses and exposed population for that pathway.

5.1 Geographic Basis of the RSEI Model

Underlying the RSEI method is the ability to locate facilities and people geographically, and to attribute characteristics of the physical environment, such as meteorology, to areas surrounding the facilities once they are located. To locate the facilities and the attribute data to those facilities, the model describes the U.S. and its territories[31] as an 810 meter by 810 meter grid system. For each cell in the grid system, a location "address" in terms of (*x*,*y*) coordinates is assigned based on latitude and longitude (lat/long).

5.1.1 The RSEI Model Grid Cell System

RSEI uses a standard Albers Equal-Area projection[32] to create each of the grids that are used in the model. The grid cell system is split into six individual grids which cover the continental U.S., Alaska, Hawaii, and the territories. Each unique cell address is composed of (1) the grid number, and (2) the (*x*,*y*) address of the cell in that grid. Exhibit 5.1 below provides the grid number (used in the model to identify each grid), the grid characteristics that can be used to recreate the grid in a Geographic Information System (GIS) based system, and the bounding coordinates for each.

[31] The model also includes Puerto Rico, the U.S. Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands. 1990 U.S. census data were provided by GeoLytics, Inc., East Brunswick, NJ.

[32] Versions 2.2.0 and earlier used a non-standard grid developed specifically for RSEI. The use of a standard projection makes it easier for users to import RSEI data into GIS applications.

Exhibit 5.1
RSEI Grid Characteristics

		Grid Reference Characteristics							
Grid Code	**Grid**	**Latitude of Origin**	**Central Meridian**	**Standard Parallel 1**	**Standard Parallel 2**	**Lower Left *x* Coord. (m)**	**Lower Left *y* Coord. (m)**	**Columns**	**Rows**
14	Conterminous U.S.	23°N	96°W	29.5°N	45.5°N	-2,365,605	251,505	5,724	3,618
24	Alaska	50°N	154°W	55°N	65°N	-1,046,115	564,975	3,291	2,505
34	Hawaii	20.5625°N	157.5625°W	19.4375°N	21.2375°N	-287,955	-185,895	739	480
44	Puerto Rico/ Virgin Islands	18°N	66.25°W	17.875°N	18.5°N	-185,895	-40,095	462	129
54	Guam/ Marianas	0°	155°E	12°N	15°N	-1,133,595	1,468,935	203	295
64	American Samoa	0°	170°W	12°S	15°S	-91,125	-1,578,285	203	36

		Bounding Coordinates for Lower-Left (LL), Upper-Right (UR), Lower-Right (LR), and Upper-Left (UL) Corners							
Grid Code	**Grid**	**LL Long**	**LL Lat**	**UR Long**	**UR Lat**	**LR Long**	**LR Lat**	**UL Long**	**UL Lat**
14	Conterminous U.S.	118.78°W	22.69°N	65.14°W	48.29°N	74.09°W	22.89°N	128.05°W	48.01°N
24	Alaska	170.07°W	53.95°N	111.99°W	68.54°N	129.76°W	52.41°N	176.63°W	71.23°N
34	Hawaii	160.29°W	18.86°N	154.54°W	22.37°N	154.6°W	18.86°N	160.36°W	22.38°N
44	Puerto Rico/ Virgin Islands	68°W	17.63°N	64.46°W	18.58°N	64.47°W	17.63°N	68.01°W	18.58°N
54	Guam/ Marianas	144.54°E	13.18°N	145.98°E	15.4°N	146.06°E	13.24°N	144.44°E	15.34°N
64	American Samoa	170.85°W	14.38°S	169.32°W	14.12°S	169.32°W	14.38°S	170.84°W	14.12°S

The (x,y) coordinates used in each grid are defined as:

x = number of cells from the center cell in the East-West direction

y = number of cells from the center cell in the North-South direction.

RSEI grid shapefiles containing the outlines of each grid cell for each grid, can be found on the RSEI ftp site at ftp://newftp.epa.gov/RSEI/Shapefiles/.

5.1.2 Locating Facilities on the Grid

Once the grid system for the U.S. is created, each facility must be located on the grid and assigned to a grid cell. Facilities are projected onto each grid using GIS software and the (*x*,*y*) coordinates of the cell where the facility is mapped are assigned to the facility. Once a grid cell's (*x*,*y*) coordinates are assigned, the facility is assumed to be at the cell's center, for ease of modeling. For a complete description of the method used to select lat/long coordinates for both reporting facilities and off-site facilities, see Technical Appendix D.

Reporting Facilities. Because the location of a facility is key to the subsequent exposure modeling (e.g., facility location will determine which population is assumed to be exposed to the facility's air releases), it is important that the lat/long coordinates are as accurate as possible. RSEI uses the best pick coordinates from EPA's Facility Registry System (FRS), which collects coordinates and related documentation on location from programs offices across EPA. The facility lat/long coordinates are projected onto the relevant grid, and the (*x*,*y*) coordinates of the grid cell to which the facility maps are assigned. The facility is then modeled as being located at the center of its assigned grid cell.

Off-site Facilities. RSEI also models some potential exposures that may result from waste management activities (e.g., releases to the environment) of TRI chemicals from "off-site" facilities, that is, facilities that receive waste transfers from TRI-reporting facilities. Note that these off-site facilities do not report transfers received from other facilities directly to TRI; instead their names, addresses, and the type and quantity of each waste management activity are reported by the facilities that transfer the TRI chemicals in waste streams to them.[33] Each report of a receiving off-site facility becomes a separate record in the TRI database, even though each off-site facility often receives transfers from more than one TRI-reporting facility. This produces multiple records of the same off-site facility; however, because the names and addresses are often reported slightly differently by reporting facilities, the records cannot easily be matched to each other. EPA has developed an approximate text string matching program to identify imperfect matches in order to refine the set of off-site facilities to what are considered to be unique off-site facilities. The program matches values without requiring their exact equality. This approach accommodates misspelled words and inconsistencies in how a facility might report its identifying information over time. For example, "DuPont," "Du Pont," and "E.I. DuPont" might all refer to the same facility. A possible match is identified based on similarity rather than exact equality in the name field, and then the address fields are examined to determine whether the records match.

For RSEI Version 2.1.3 (reporting year 2003), all off-site records went through the approximate text matching program, and were also geocoded (lat/long coordinates were assigned based on street address). For each set of facilities that were determined to be matches, the record whose geocoded lat/long was of the highest confidence level was selected. The name, address, and lat/long coordinates for this facility record are selected for the master database, and used in the

[33] Some facilities may be considered both on-site and off-site facilities, if they both receive chemical waste transfers from other facilities (as an off-site facility) and also meet TRI reporting criteria and report their waste management activity quantities on-site. RSEI only adjusts for double-counting of waste management quantities from facilities that both receive off-site transfers for the purpose of incineration and that also report on-site waste management quantities to TRI with a primary NAICS code of 562211 (Hazardous Waste Treatment and Disposal).

RSEI model to represent all of the records in that matched group. For Version 2.1.3, this resulted in a master off-site database of approximately 47,000 off-site facilities.

Beginning with Version 2.1.5 (reporting year 2005), off-site facilities are no longer geocoded. Instead, the entire set of all reporting years of off-site records (1988-2019) is matched back to the previous reporting year's master off-site database using an approximate text matching program. Again, this is necessary because there are no universal identifiers reported along with the off-site records in TRI that would allow for direct matching from year to year. Any records that are not matched back to the previous year's database (especially any new off-site facilities) are added to the master off-site database, resulting in a new master off-site database. Additional data from EPA's FRS are also used where possible to identify lat/longs for off-site facilities. Grid-cell locations for off-site facilities are determined in the same manner as for reporting facilities; the facility lat/long coordinates are projected onto the relevant grid, and the (x,y) coordinates of the grid cell to which the facility maps is assigned. The off-site facility is assumed to be in the center of its assigned grid cell.

5.1.3 Locating People on the Grid

In order to estimate potential exposure, the U.S. population must also be geographically located on the RSEI model grid. To match annual TRI waste management activity quantities and capture the effect of the changing distribution of the population, RSEI uses detailed annual population datasets at the grid cell level. The data are based on decennial U.S. census data, and includes information on population, age, and sex.

The following sections describe how the U.S. census data are used to generate annual population estimates, and how the unit of analysis for the U.S. census (the block) is translated into the unit of analysis for the model (the grid cell).

U.S. Census Data. The model uses decennial U.S. census data for 1990, 2000, and 2010 at the block level.[34] Census blocks are the smallest geographic area for which decennial census data are collected. Blocks are of varying size, formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. In 1990, there were approximately 7 million census blocks. Due to boundary changes and increased resolution for highly populated areas, there were approximately 9 million blocks in the 2000 census, and more than 11 million in 2010. Block-level data from the three decennial censuses[35] are used to create detailed age-sex population groups for each of the census blocks in the U.S. for 1990, 2000 and 2010. Because the U.S. Census Bureau presents data in slightly different format, some data processing was necessary to create the following age-sex population groups used in the model:

[34] Some U.S. census data and block shape files were provided by GeoLytics, Inc.

[35] For 1990, not all of the variables were available at the block level. For those variables that were only available at the block group level, block group ratios were calculated and applied to the data available at the block level. For 2000, all of the required variables were available at the block level.

- Males Aged 0 through 9 years
- Males Aged 10 through 17 years
- Males Aged 18 through 44 years
- Males Aged 45 through 64 years
- Males Aged 65 Years and Older
- Females Aged 0 through 9 years
- Females Aged 10 through 17 years
- Females Aged 18 through 44 years
- Females Aged 45 through 64 years
- Females Aged 65 Years and Older

For Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, and the Northern Mariana Islands, block-level shapefiles and block-level population data were only available for 2000.[36] For 1990, the grid cell-level populations from 2000 were scaled by age-sex specific census population estimates for 1990 to create 1990 population estimates. For 2010, block-level population was only available for Puerto Rico; for the other areas, similar age-sex specific census data from 2010 were used to scale the 2000 data to create 2010 population estimates. Grid cells for Puerto Rico and island areas are mapped in the same way as described below.

Mapping blocks to grid cells. Because the grid cell is the unit of analysis for the RSEI model, census data must be transposed from blocks to the model grid cells. The Census Bureau provides the geometry for each block in the Topologically Integrated Geographic Encoding and Referencing (TIGER) geographic database, which was used to create shape files for the 1990, 2000, and 2010 census years. A corresponding set of shape files for grid cells was created, with each grid cell defined by its four corner points, calculated from its (*x*,*y*) coordinates. The shape files were then compared, in essence overlaid, and each block was mapped to the cells in the grid that it overlaid, and the percentage of the block's total area falling within each cell was calculated.[37]

The process described above was performed separately for 1990, 2000, and 2010, as the block boundaries change between the censuses. This process resulted in three tables, each with four fields: the *X* coordinate and the *Y* coordinate which identify the grid cell, the block identifier assigned by the census, and the percent of that block assigned to the grid cell.

Calculating Populations. For each block assigned to a grid cell, the block populations were multiplied by the percentage of that block assigned to that grid cell. Those values were then summed over each grid cell. This process was performed separately for 1990, 2000, and 2010, resulting in three grid cell level datasets, each containing the ten age-sex population groups listed

[36] For 2010, block-level shapefiles were available, but block-level population data were not released in time for incorporation.

[37] Due to irregular, invalid block shapes, some of the block percentages did not sum to 100 percent. For these blocks, the boundary overlay process was not used; instead, the whole block was assigned to whatever grid cell contained the centroid of the block (an approximate center point defined in the census).

above.[38] For 1990, there were 11,083,291 populated grid cells; for 2000, there were 9,399,819; and for 2010 there were 9,258,679 populated grid cells.

To create annual datasets for 1991 through 1999, a straight-line interpolation at the grid cell-level is performed within the RSEI model between the 1990 and 2000 datasets; annual datasets for 2001 through 2009 are created using a straight-line interpolation between the 2000 and 2010 datasets. The 1990-2000 line is extrapolated backward to create annual datasets for 1988 and 1989 and the 2000-2010 line is extrapolated forward to 2019.

5.2 Pathway-specific Methods to Evaluate Chronic Human Exposure Potential

The following sections describe the algorithms used for modeling exposure for each of the following exposure pathways: (1) stack and fugitive air releases, (2) direct surface water discharges, (3) transfers to POTWs, (4) off-site transfers, and (5) on-site land releases. An overview of the exposure pathways and methods used to evaluate each pathway is presented in Exhibit 2.1.

The following discussions of exposure modeling frequently mention concentration and surrogate dose. This is not meant to imply that an actual dose can be accurately calculated within this RSEI model as discussed previously. The exposure algorithms used are intended to be simple ways to gauge risk-related impacts from certain waste management activities of TRI chemicals to different environmental media in a consistent, defensible way, by modeling and estimating resulting exposure. In some cases, the modeling is purposely simplified, given the lack of site-specific data and/or information.

When possible, exposures are estimated for relevant populations defined by age, sex, or other factors. Exposure for individual populations is modeled using exposure factors (i.e., inhalation rates, drinking water intakes, fish ingestion rates, and average body weight) and population data specific to these such populations. For example, ingestion rates specific to recreational and subsistence fishers are used to estimate exposures for these fishers and their families. Also, age- and sex-specific inhalation and drinking water ingestion rates are used. Assumptions for relevant exposure potential for populations are also described in the following sections.

5.3 Modeling Air Releases

Air releases can either be through stacks air emissions or as fugitive air emissions. Stack (or point) air emissions include releases to air through stacks, confined vents, ducts, pipes, or other confined air streams, and represent the majority of reported air releases. Fugitive (or non-point) air emissions include all other releases that are not stack air emissions, such as equipment leaks from valves, pump seals, flanges, compressors, sampling connections, open-ended lines, etc., evaporative losses from surface impoundments and spills, and releases for building ventilation systems. Stack and fugitive air emissions are modeled as two separate exposure pathways in the

[38] The data processing results in fractional people; populations were rounded to four decimal places for use in calculations, but are rounded to the nearest integer for display.

RSEI model, although the potentially exposed population and human exposure assumptions are the same for both. The following sections describe the method and data sources for each pathway.

5.3.1 Stack Air Emissions: Method

Stack air emissions are modeled using the American Meteorological Society/EPA Regulatory Model (AERMOD). AERMOD replaced the Industrial Source Complex (ISC) model as EPA's preferred regulatory model in 2005. AERMOD is a steady-state Gaussian plume model used to estimate pollutant concentrations downwind of a stack or area source. The pollutant concentration is a function of facility-specific parameters, meteorology, and chemical-specific, first-order air decay rates. The following sections describe the parameters of the AERMOD model used.[39]

5.3.1.1 AERMOD

The AERMOD model is specifically designed to support the EPA's regulatory modeling programs, as specified in the Guideline on Air Quality Models (Revised).[40] AERMOD is a steady-state plume model. In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. For sources in both the CBL and the SBL, AERMOD treats the enhancement of lateral dispersion resulting from plume meander. Unlike existing regulatory models, AERMOD accounts for the vertical inhomogeneity of the planetary boundary layer (PBL) in its dispersion calculations. This is accomplished by averaging the parameters of the actual PBL into effective parameters of an equivalent homogeneous PBL.

5.3.1.2 Model Dispersion Options

AERMOD is used with its regulatory default options[41], except for the following: chemical-specific decay is considered (the TOXICS with SCIM option is used), and flat terrain is assumed. The non-default option of modeling urban areas with increased surface heating is not used. Weather data from the National Weather Service (NWS) observation stations are used as the meteorological input (see Section 5.3.1.4 below).

[39] The following description is based on equations and text provided in the AERMOD manuals and documentation. The most recent AERMOD manuals are available from EPA's Support Center for Regulatory Atmospheric Modeling (SCRAM) website at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models.

[40] The Guideline on Air Quality Models can be found in 40 CFR Part 51, Appendix W or accessed online at: http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

[41] See https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models.

5.3.1.3 Source Parameters

In the RSEI model, the U.S.[42] is represented by a grid system composed of 810m by 810m square grid cells. Facilities are assigned to a particular grid cell in this grid according to their latitude and longitude coordinates (see Technical Appendix D for details on the coordinates used). To increase modeling efficiency, a facility is then assumed to be located at the center of the grid cell, regardless of where its latitude and longitude coordinates place it within the cell.

As a result of this assumption, the actual location of a facility may differ from its modeled location by up to 573 meters, which is the maximum distance between the center and the corner of the grid cell. To simplify the analysis, a facility's stack air (point source) emissions are modeled as a single stack located at the facility's geographic center.

RSEI uses facility-specific stack parameters derived from NEI[43] when available. These include stack height, exit-gas velocity, and stack diameter. Stack exit gas temperature is assumed constant for all stacks (432° K). For facilities with multiple stacks, the median value for the stack heights and diameters for that facility is used. For facilities without stack-specific values, industry-specific NAICS code-based median stack parameters are assigned. If no valid NAICS code is available for the facility, or no stack data are available for that industry-specific NAICS code, then overall median values are used. Stack parameters are further discussed in Section 5.3.6.1 and in Technical Appendix E.

Annual chemical stack air emissions as reported to the TRI program are converted to an equivalent constant emission rate (in grams per second) according to the following equation:[44]

$$Q = \frac{453.6\,q}{31{,}536{,}000} \qquad \text{(Eq. 5.3)}$$

where:

Q	=	chemical emission rate (g/sec)
q	=	TRI annual stack (point) air emissions (lbs/yr)
453.6	=	constant to convert pounds (lbs) to grams (g)
31,536,000	=	constant to convert years (yr) to seconds (sec) assuming 365 days per year

[42] Including Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, and the Northern Mariana Islands.

[43] NEI data are available here: https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data.

[44] Although RSEI can model any chemical air emission that is accompanied by the appropriate chemical, locational, and toxicity weight information, the model currently uses TRI reporting as the source of chemical release information.

5.3.1.4 Meteorological Input Data

For a given chemical source, meteorology around the source affects the dispersion characteristics. Meteorological factors such as wind speed and direction, air temperature, stability, turbulence, and the height of the mixing layer all have a direct effect on the dispersion and dilution of air pollution and the resulting magnitude and location of ground level concentrations of emitted chemicals.

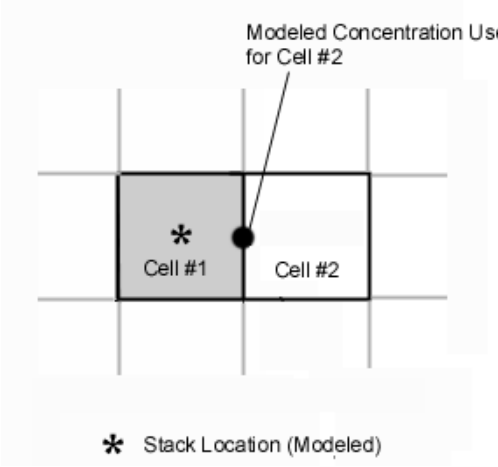
AERMOD is designed to run with a minimum of observed meteorological parameters, and requires only a single surface measurement of wind, wind direction, and ambient temperature. Like ISC, AERMOD also needs observed cloud cover. However, if cloud cover is not available (e.g., from an on-site monitoring program), two vertical measurements of temperature (typically at 2 and 10 meters) and a measurement of solar radiation can be substituted. A full morning upper air sounding is required in order to calculate the convective mixing height throughout the day. Surface characteristics (surface roughness, Bowen ratio, and albedo) are also needed in order to construct similarity profiles of the relevant PBL parameters.

5.3.1.5 Calculating Chemical Concentrations

The RSEI model calculates chemical air concentrations at hypothetical "receptors" located within a circle with a radius of 49 km surrounding each facility. Any grid cells with centers within the 49 km circle are included. The model calculates ground-level concentrations for receptors at 5 kilometer increments for distances from 5 to 49 km away from the modeled facility. The concentration assigned to a grid cell containing a receptor is determined at the point in that grid cell which is nearest to the facility (see Exhibit 5.2). For grid cells between the receptor points where calculations are made, concentrations are interpolated using a spatial weighting technique similar to inverse distance-weighted averaging.

Exhibit 5.2

Assigned concentration at point nearest to facility.



To estimate the concentration for the 810m by 810m center grid cell containing the facility, the RSEI model calculates the interpolated concentration based on calculated concentrations at 441 receptor points within a kilometer of the grid cell center. Analyses performed during the development of RSEI Version 2.0 (which used the ISC model[45]) indicated that using the concentration in a surrounding grid cell as an estimate for the center grid cell may either significantly over or under-represent chemical concentrations there (See Part B of *Analyses Performed for the Risk-Screening Environmental Indicators*).

The RSEI model estimates concentrations up to 49 km from the facility. To determine the optimal distance, EPA modeled air concentrations for the 20 most toxic carcinogens and the 20 most toxic non-carcinogens included in the RSEI model at various stack heights. These analyses indicated that extending modeled distances to 50 km[46] was necessary to capture potential concentrations of concern under certain atmospheric conditions. This distance is expected to capture the majority of the potential environmental impacts from the TRI reporting facilities, including electric utilities, which usually have taller stack heights than other facilities. Details of these analyses can be found in Part B of *Analyses Performed for the Risk-Screening Environmental Indicators.*[47]

5.3.2 Fugitive Air Emissions: Method

As for stack air emissions, long-term chemical concentrations downwind of the facility due to TRI-reported fugitive (non-point) air emissions are also modeled using algorithms from AERMOD.

5.3.2.1 Model Dispersion Options

Model dispersion options used in modeling fugitive air emissions are the same as those used for stack air releases, as described in Section 5.3.1.2.

5.3.2.2 Source Options

Fugitive emissions are modeled as an area source which is 10 meters by 10 meters in size, located at the center of the grid cell containing the facility. The model assumes a release height at ground level.

[45] Version 3 of the long-term ISC model (ISCLT3) was used to calculate chemical concentrations in air until Version 2.2.0, the first version in which AERMOD was used.

[46] In the final RSEI modeling, 49 km was used instead of 50km due to modeling constraints.

[47] These analyses were performed using an earlier version of RSEI that incorporated EPA's Industrial Source Complex (ISC) model. RSEI now uses AERMOD, which has replaced ISC as the Agency's recommended air modeling program.

Fugitive emissions are converted from pounds per year to grams per square meter per second (g/m^2s) according to the following equation:

$$Q_a = \frac{453.6\, q_a}{31{,}536{,}000 * 10^2} \quad \text{(Eq. 5.4)}$$

where:

Q_a	=	chemical area emission rate (g/m^2s)
q_a	=	TRI annual fugitive air emissions (lbs/yr)
453.6	=	constant to convert pounds (lbs) to grams (g)
31,536,000	=	constant to convert years (yr) to seconds (sec)
10^2	=	conversion factor necessary to convert annual emissions (g/s) to area emission rate (g/m^2s), assuming an area 10 m x 10 m.

5.3.2.3 Calculating Chemical Concentration

Chemical concentrations for fugitive air emissions are calculated using AERMOD, as described previously for stack air emissions.

5.3.3 Calculating Surrogate Dose for Air Releases

The calculated air concentrations described earlier are combined with assumptions regarding inhalation rate and human body weight to arrive at a surrogate dose for a given grid cell:

$$DOSE_{air} = \frac{C_{air} * I_{air}}{BW} * \frac{1}{1000} \quad \text{(Eq. 5.5)}$$

where:

$DOSE_{air}$	=	surrogate dose of chemical contaminant from air (mg/kg-day)
C_{air}	=	air concentration in grid cell ($\mu g/m^3$)
I_{air}	=	inhalation rate (m^3/day)
BW	=	human body weight (kg)
1000	=	constant to convert (μg) to (mg)

5.3.4 Estimating Population Size for Air Releases

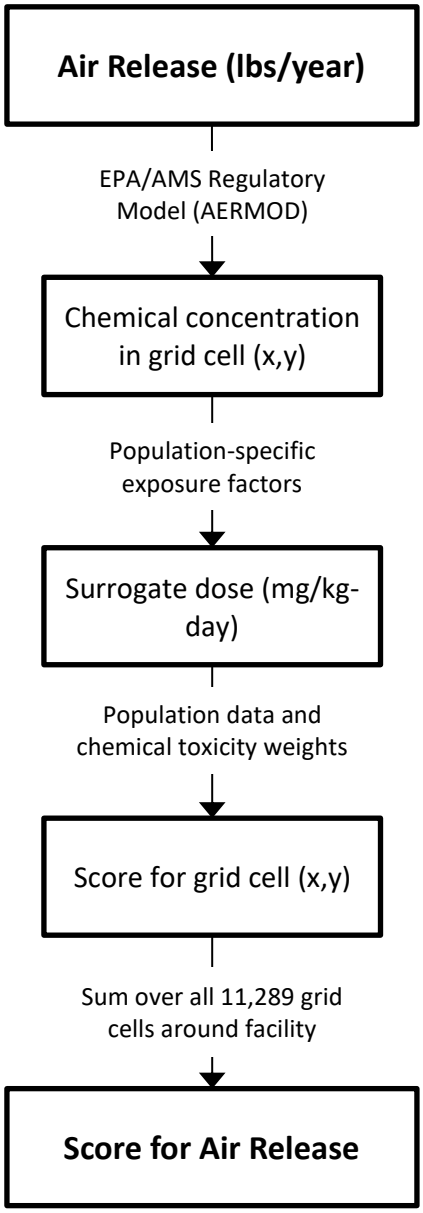
The population potentially exposed to air releases is assumed to be equal to the population assigned to the grid cells in the 810m by 810m modeled area, as described previously in Section 5.1.3. Exposed population is only considered for grid cells with non-zero chemical concentrations.

5.3.5 Calculating the RSEI Score for Air Releases

Exhibit 5.3 provides a graphical overview of the steps for determining the air modeling component of the RSEI model. First, the chemical concentration in each grid cell is calculated using TRI emissions data and the AERMOD algorithms. Then, population-specific exposure factors are used to calculate a surrogate dose for each grid cell. Finally, the surrogate dose is

multiplied by the number of people potentially exposed in each population in the grid cell and by the chemical toxicity weight to obtain the score for the grid cell. Then the scores for all relevant grid cells are summed. The result is the RSEI score for an air release. To calculate the RSEI score for all air releases, the same steps are followed for each air release, and the results are summed.

Exhibit 5.3
Calculating the RSEI Score for Air Releases



5.3.6 Stack and Fugitive Air Releases: Data

The air exposure pathway use facility-specific parameter values (stack height, stack diameter, and exit gas velocity), meteorology, chemical-specific first-order air decay rates, and exposure assumptions (inhalation rate and body weight). The values used for this pathway are summarized in Exhibit 5.4.

Exhibit 5.4
Air Modeling Parameters

Parameter	Value	Source/Comment
Chemical emission rate	Site-specific (lbs/yr)	TRI
Stack height	In order of preference: • Median value across stacks at facility as reported to NEI or EPRI (for electric utilities) • Median value across stacks in the facility's 4-digit NAICS code or in EPRI dataset (for electric utilities) • Median value across all stacks	NEI (2014, 2011, 2008, and 2005), EPRI (for Electric Utilities)
Stack diameters	In order of preference: • Median value across stacks at facility as reported to NEI or EPRI (for electric utilities) • Median value across stacks in the facility's 4-digit NAICS code or in EPRI dataset (for electric utilities) • Median value across all stacks	NEI (2014, 2011, 2008, and 2005), EPRI (for Electric Utilities)
Exit gas velocity	In order of preference: • Median value across stacks at facility as reported to NEI or EPRI (for electric utilities) • Median value across stacks in the facility's 4-digit NAICS code or in EPRI dataset (for electric utilities) • Median value across all stacks	NEI (2014, 2011, 2008, and 2005), EPRI (for Electric Utilities)
Exit gas temperature	432° K	Based on EPA (2004b)
Meteorological data	Site-specific	Processed using AERMET as contained in the HEM-3 data library (EPA, 2007)
Decay rate	Chemical-specific values account for removal by physical and chemical processes (s^{-1})	SRC (1994-1999)
Area source size	10 m^2	Based on EPA (1992b)
Area source height	Ground level	

5.3.6.1 Stack Height, Stack Diameter, and Exit Gas Velocity

Stack parameter data (height, diameter, and exit-gas velocity) were obtained from the four most recent NEI databases (data years 2014, 2011, 2008, and 2005)[48]. For each TRI reporting facility, the closest NEI year that is greater than or equal to the last year of stack releases reported to TRI is used for the stack parameter data. For instance, if a facility last reported to the TRI in reporting year 2012, data from the 2014 NEI is used; if a facility last reported to the TRI in reporting year 2010, then data from the 2011 NEI is used. For any facility with stack parameter data in NEI, the median parameter of all stacks that emit TRI chemicals at the facility is used. For the TRI facilities that have no stack parameter data in NEI, the median parameter values for all of the facilities in that facility's NAICS code is used instead. The NAICS code-based stack parameters are estimated from data in NEI for facilities in the appropriate 4-digit NAICS code. If no 4-digit NAICS code is available, the median of all stack parameters with TRI-reportable NAICS codes is used.

The Electric Power Research Institute (EPRI) provided EPA with site-specific data for electric utilities (electric utilities were required to report to TRI beginning with reporting year 1998), transmitted in two databases. These data included stack height, stack diameter, and exit-gas velocity. Of the 948 TRI facilities reporting in any year and classified in NAICS code 2211-Electric Power Generation in reporting year 2019, 43 percent match a corresponding facility listed in one of the EPRI databases; approximately 57 percent of TRI electric utility facilities do not. For the 57 percent that did not match specific facilities, facility-specific data from NEI were used. If no facility-specific data were found in NEI, then the median parameters taken across all of the coal or oil combusting stacks in the EPRI databases were used (the overall EPRI median was used for 9 percent of facilities in NAICS 2211).

Analyses have been conducted that show air concentrations predicted by the RSEI model using a combination of generic and site-specific data closely match concentrations estimated by using more complete site-specific data.[49] See Technical Appendix E for details on the derivation of stack data.

5.3.6.2 Meteorology[50]

The meteorological data used in the RSEI model are taken from EPA's Human Exposure Model, Version 3 (HEM-3), a model for use in site-specific air toxics risk assessment. RSEI uses weather data included in EPA's HEM-3 data library, which has been prepared using AERMOD's meteorological processor, AERMET. AERMET requires hourly surface weather observations

[48] Currently, the RSEI model can only assign one set of stack parameters to each facility. If a facility has reported stack releases throughout the period of NEI data (2005-2014), the most recent stack parameters (2014 NEI if available) are used.

[49] These analyses were performed using an earlier version of RSEI that incorporated EPA's Industrial Source Complex (ISC) model. RSEI now uses AERMOD, which has replaced ISC as the Agency's recommended air model.

[50] This description is taken from the HEM-3 User's Manual (EPA, 2007), available at https://www.epa.gov/fera/human-exposure-model-hem-3-users-guides.

and the full twice-daily upper air soundings (i.e., meteorological variables reported at all levels). The surface and upper air stations are paired to produce the data files require for input into AERMOD: one file consists of surface scalar parameters, and the other file consists of vertical profiles of meteorological data.

To simplify processing and to minimize the amount of quality assurance needed, HEM-3's processing was restricted to meteorological data collected prior to the installation of the Automated Surface Observation System (ASOS). The ASOS has previously been found to omit the ceiling height for a large percentage of the observations at a number of meteorological stations. Installation and operation of ASOS equipment began in 1992; therefore, data for 1991 were used. Data were retrieved from products available from the National Climatic Data Center (NCDC). The surface data for 1991 were retrieved from the Hourly United States Weather Observation (HUSWO) CD. Upper air soundings were obtained from the Radiosonde Data of North America CDs produced by NCDC and the Forecast Systems Laboratory (FSL).

Certain surface characteristics must be specified when processing meteorological data using AERMET, including the surface roughness length, the Bowen ratio (an indicator of surface moisture), and the albedo (an indicator of surface reflectivity). These surface characteristics are used by AERMET to calculate the level of shear-induced mechanical turbulence generated by flow over the surface and for the energy balance calculations used in the determination of the Monin-Obukhov stability parameter and the convective velocity scale. For the HEM-3 meteorological data, the following surface characteristics were used:

- Surface roughness length = 0.25 m. At the airport meteorological site, the surface roughness includes runways, terminal buildings and other airport structures. In addition, off-airport structures often are within 3 kilometers of the measurement site. This combination of land covers suggests a value of 0.2 – 0.3 meters is appropriate.
- Bowen ratio = 1.0. Representing an equal partition of the heat fluxes.
- Albedo = 0.15. Representing conditions for all seasons, including winter without continuous snow cover.
- The file STNS.TXT located on the HUSWO CD was used for the anemometer heights required by AERMET. These heights are to the nearest meter and were deemed appropriate for use in this application.

5.3.6.3 First-Order Chemical Air Decay Rates

Chemicals may be removed from the atmosphere by either physical processes or chemical transformation. The model uses chemical-specific air decay rates from SRC's Atmospheric Oxidation Program (AOPWIN), an atmospheric oxidation computer program (SRC, 1994-1998). AOPWIN estimates the second-order rate constant for the atmospheric, gas-phase reaction between photochemically produced hydroxyl radicals and organic chemicals.[51] The daughter products of photodegradation are not modeled further, i.e., it is assumed that all chemicals are photodegraded into non-toxic compounds. AOPWIN data also contains certain empirically derived air decay rates. For the RSEI model, a concentration of hydroxyl radicals of 1.5×10^6

[51] For a few chemicals, other sources were used. See Technical Appendix B for the source used for each chemical.

molecules/cm^3 is used to convert the second-order rate constant provided in AOPWIN to a first-order rate constant. Furthermore, the rate is divided by a factor of two to reflect an assumed average day length of 12 hours:

$$K_{air} = \frac{AOPWIN}{2} * 1.5 \times 10^6 * 3600 \quad \text{(Eq. 5.6)}$$

where:

K_{air}	=	air decay rate (hr^{-1})
$AOPWIN$	=	second-order rate constant from AOPWIN
1.5×10^6	=	hydroxyl radical concentration (molecules/cm^3)
3600	=	constant to convert molecules/seconds to molecules/hour
2	=	constant to reflect assumed day length of 12 hours

5.3.6.4 Human Exposure Data and Assumptions

For the air exposure pathway, sex- and age-specific inhalation rates and body weights are used in the RSEI model. The primary source for all exposure factors used in the model is EPA's Exposure Factors Handbook (EPA, 2011, hereafter denoted as EFH)[52], which provides a summary of the available statistical data on various factors used in assessing human exposure. These factors include: drinking water consumption, soil ingestion, inhalation rates, dermal factors including skin area and soil adherence factors, consumption of fruits and vegetables, fish, meats, dairy products, homegrown foods, breast milk intake, human activity factors, consumer product use, and residential characteristics. In the EFH, EPA recommends mean values for the general population and also for various segments of the population who may have characteristics different from the general population. RSEI uses inhalation rates and body weights derived from the recommended factors, except where noted.

EFH (EPA, 1997b, Table 5-23, p. 5-24) was used to estimate inhalation rates for the eight RSEI age-sex groups (ages 0-17, 18-44, 45-64, 65+).[53] The inhalation rates recommended by the EFH were not categorized into the same age groups used in RSEI. For children, the RSEI age groups were broader than the EFH age groups. Therefore, the exposure factor was calculated using a weighted average of the inhalation rates for all EFH age groups that overlap the RSEI age group as follows:

[52] The Exposure Factors Handbook can be found at http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

[53] The RSEI model provides the ability to view risk scores for the 0-9 year old age group, however, there is not a separate exposure factor for this age group. Instead, the exposure factor for the 0-17 year old age group is used.

$$EF = \frac{\sum_i (IR_i * n_i)}{N} \quad \text{(Eq. 5.7)}$$

where:

EF	=	RSEI exposure factor,
IR_i	=	intake rate for EFH age group i,
n_i	=	number of years that EFH age group i overlaps with the RSEI age group
N	=	number of years in RSEI age group.

For adults, the EFH provides only one range of recommended inhalation rate for males and females. The RSEI adult inhalation factors are based on weighted averages calculated from this data, using Equation 5.7. The RSEI inhalation factors are then divided by age- and sex-specific body weights, averaged to match the RSEI age groups using data provided in the EFH (EPA, 2011, Table 6-1). Exhibit 5.5 provides the range of data used, and Exhibit 5.6 presents the final exposure factors used in the RSEI model. More detail on the derivation of the exposure factors can be found in Technical Appendix C.

Exhibit 5.5
Range of Data Used to Estimate Exposure Factors

Parameter	Value	Source/Comment
Inhalation rate	3.6-16.3 m^3/day (Varies by age)	EPA (2011)
Body weight	4.6 -90.5 kg (Varies by age and sex)	EPA (2011)

Exhibit 5.6
Inhalation Exposure Factors (m^3/kg-day)

Model Age Group	Male	Female
0-17	0.315	0.332
18-44	0.185	0.217
45-64	0.173	0.201
>65	0.159	0.187

5.4 Modeling Surface Water Releases

People may be exposed to chemicals released into surface water in one of two ways: by drinking tap water from a public water system whose water intake was located in the path of a chemical release; or by eating contaminated fish caught in a water body in the path of a chemical release. The following sections first describe the methods used to calculate the initial chemical concentrations for both exposure pathways, and then the different methods used to calculate surrogate dose and population for the drinking water pathway and the fish ingestion pathway. The data section presents the data used for both exposure pathways and the human exposure defaults and assumptions used.

5.4.1 Surface Water Releases: Methods

5.4.1.1 Locating the Facility Discharge Flowline

The first step in assessing surface water discharges is to locate the discharging facility on the RSEI model grid using their lat/long, and the flowline(a linear, unbranched section of a water body) into which the chemicals are discharged. To find the discharge flowline, RSEI uses EPA records of Clean Water Act (CWA) discharge permits for facilities, which in some cases specify the discharge flowline by the locational coordinates of the discharging outfall. National Pollutant Discharge Elimination System (NPDES) permit records, including permit conditions, permit limits, monitoring data (e.g., Discharge Monitoring Reports (DMRs)), locational, and descriptive information are maintained in EPA's Integrated Compliance Information System (ICIS-NPDES), which is incorporated in EPA's Enforcement and Compliance History Online (ECHO) system.

Facilities without outfall location coordinates are assumed to discharge to the nearest flowline, as long as that flowline is within four kilometers of the facility and meets minimum criteria for flow and flowline type, as described below in Section 5.4.3.1. If no outfall coordinates are available, and no acceptable flowline is found within four kilometers, the discharge is not modeled. Flowline data are not available for Alaska, Guam, American Samoa, and the Northern Mariana Islands; therefore, no surface water releases are modeled for these areas.

5.4.1.2 Calculating Chemical Concentrations

Chemical concentrations in the receiving flowline at a distance *x* from the discharging facility at time *t* are estimated by using a simple first-order decay equation. The facility is assumed to release its annual discharge quantity at a constant rate throughout the year. Annual average chemical concentrations are then estimated until one of three conditions occurs: (1) the release has traveled 300 km downstream; (2) the release has been traveling downstream for a week; or (3) the chemical concentration reaches 1×10^{-9} mg/L. Within the initial flowline, the mass quantity of the discharge is assumed to be instantaneously mixed with the flow at the upstream end of that flowline. The calculated chemical concentration at the downstream end of the flowline is then converted back to a mass quantity (after any decay) and the process is repeated in the next adjoining flowline. Flowlines are defined by intersections with other hydrological features and these "nodes" initiate the next flowline. The chemical-specific decay coefficient is predominantly based on abiotic hydrolysis or microbial biodegradation, but may also include photooxidation. The general form of the first-order decay equation is as follows:

$$C_x = C_0 e^{-k_{water} t} \quad \text{(Eq. 5.8)}$$

where:

C_x	=	concentration at distance x meters from the facility release point (mg/L)
C_0	=	initial concentration (mg/L), which equals chemical release (mg/day) divided by mean flow
k_{water}	=	decay coefficient (sec^{-1})
t	=	time at which C_x occurs (sec), which equals x/u, where u is the water velocity (m/sec)

For surface water releases, the RSEI model estimates chronic human health exposures for two exposure pathways: drinking contaminated water and eating non-commercial contaminated fish. The methods used to estimate each of these exposure pathways are described below.

5.4.1.3 Modeling the Drinking Water Pathway

Surrogate doses from drinking water are calculated using the chemical concentrations in flowlines where drinking water intakes are located. Drinking water intake locations were obtained from the Public Supply Database (PSDB), a database of drinking water system information developed and maintained by the U.S. Geological Survey (USGS), based on information in the EPA's Safe Drinking Water Information System (SDWIS). Each drinking water intake is assumed to be drawing water from the flowline nearest to its plotted location. For this exposure pathway, the chemical concentration in drinking water is assumed to be equal to its flowline concentration (calculated at the upstream end of the flowline; conservatively using the highest concentration), up to the level of the Maximum Contaminant Level (MCL),[54] where applicable. Seventy-nine TRI chemicals had existing MCLs in effect during one or more reporting years for which TRI data are available;[55] this number includes metal compound chemical categories, which are treated similar to their elemental metal forms. If the flowline concentration exceeds the MCL, the drinking water is assumed to be treated to the level of the MCL for the year of that release. For each flowline with a drinking water intake, the chemical concentration is combined with standard exposure parameters (see Section 5.4.3.6) to yield a surrogate dose:

[54] Copper and lead have action levels instead of MCLs; however, RSEI models them in the same manner as MCLs. This also applies to copper compounds and lead compounds, as metal compounds are modeled like their elemental forms.

[55] As MCLs are sometimes revised and new ones are added in the years of TRI reporting, RSEI applies MCL limits for only the years that the MCLs were in effect. For several chemicals for which MCLs were first instituted in 1976 and then revised in 1991, the original MCL values were not readily available, so the revised values were also used for the years before the revision. These chemicals are barium, cadmium, chromium, lead, lindane, mercury, methoxychlor, nitrate, selenium, and toxaphene.

$$DOSE_{dw} = \frac{C_{water,flowline} * I_{water}}{BW} \quad \text{(Eq. 5.9)}$$

where:

$DOSE_{dw}$	=	surrogate dose of chemical in drinking water (mg/kg-day)
$C_{water,\ flowline}$	=	average annual chemical concentration in the flowline of interest, calculated at the upstream end of the flowline (mg/L)
I_{water}	=	drinking water ingestion rate (L/day)
BW	=	human body weight (kg)

5.4.1.4 Estimating Population Size for the Drinking Water Exposure Pathway

To estimate the size of the population exposed to surface water releases of TRI chemical through drinking water, the RSEI model uses estimates of the population served by each drinking water intake from USGS's PSDB, which incorporates population estimates from the EPA's SDWIS[56]. However, this data set only lists the intake location and the number of people served by the water system. In many cases, there are multiple water intakes per water system. In the absence of other data, it is assumed that the total population of the public water system is exposed to the full concentration of the released chemical estimated at the flowline where a public water intake is located (calculated at the upstream end of the flowline).

The drinking water intake information from SDWIS contains only the number of people served by each drinking water system; it does not provide demographic or locational information for those served (the time frame in which this information was collected also varies widely). To derive demographic information (that is, age and sex breakdowns) for the population served, RSEI uses the percentages of people in each of the ten age-sex categories for the total population located in grid cells within an 80-km radius of each flowline containing a drinking water intake (this information is calculated for the fish ingestion pathway - see Section 5.4.1.6). Then, these percentages are applied to the SDWIS intake population (population served), creating the population groups that are used for calculating RSEI model results.

5.4.1.5 Modeling the Fish Ingestion Exposure Pathway

A second potential exposure pathway is through consumption of fish contaminated by chemicals discharged from facilities. These fish may be consumed by recreational and subsistence fishers and their families.[57] As in the drinking water exposure pathway, chemical concentrations are calculated until one of three conditions occurs: (1) the release has traveled 300 km downstream; (2) the release has been traveling downstream for a week; or (3) the chemical concentration reaches 1 x 10^{-9} mg/L. The chemical concentration in fish is estimated using the following equation:

[56] RSEI uses SDWIS data that is contained in the USGS Public Supply Database (PSDB), see Section 5.4.3.2. More information about SDWIS can be found at https://www.epa.gov/enviro/sdwis-search.

[57] Although store-bought fish may also contain chemicals originating from facilities, modeling this exposure pathway is not currently possible.

$$C_{fish,reach} = C_{water,flowline} * BCF \quad \text{(Eq. 5.10)}$$

where:

$C_{fish, reach}$	=	chemical concentration in fish in the specified flowline (mg/kg)
$C_{water, flowline}$	=	average annual chemical concentration in the flowline of interest (mg/L)
BCF	=	bioconcentration factor for chemical (L/kg)

The chemical concentration in fish in a flowline is combined with exposure assumptions to determine the surrogate dose from this exposure pathway:

$$DOSE_{f,c} = \frac{C_{fish,reach} * I_{fish,pop}}{BW} \quad \text{(Eq. 5.11)}$$

where:

$DOSE_{f,c}$	=	surrogate dose of chemical *c* from facility *f* (mg/kg-day)
$C_{fish, reach}$	=	average annual chemical concentration in fish tissue (mg/kg)
$I_{fish, pop}$	=	fish ingestion rate for recreational or subsistence fishers (kg/day)
BW	=	human body weight (kg)

5.4.1.6 Estimating Population for the Fish Ingestion Exposure Pathway

The RSEI model uses several steps to estimate the population within each grid cell that consumes non-commercial fish. First, a county-level dataset containing the number of fishing or hunting/fishing combination licenses was created from state fish and wildlife licensing data for 1996 (if 1996 data were not available, 1997 data were used). The number of fishing licenses in a county is then divided by the 1990 total population in the county.[58] The resulting ratio is multiplied by the population in each grid cell in 2000 to obtain the number of individuals with fishing licenses within that grid cell. To account for family members who also eat fish caught by one member, the RSEI model multiplies the number of fishers by 2.62, the size of the average U.S. household in 1995 (U.S. Census Bureau, 1996). The total population in a grid cell consuming non-commercial fish is described by the following equation:

[58] If no licensing information for a county was available, all of the grid cells in that county are assigned the ratio of total state licenses to total state population. If no information was available for the state in which the grid cell is located, the ratio for the state closest to that grid cell is assigned.

$$FishPop_{cell} = TotalPop_{cell} * \frac{Licenses}{Pop} * FamSize \quad \text{(Eq. 5.12)}$$

where:

$FishPop_{cell}$	=	total fish-eating population in a grid cell in 2000
$TotalPop_{cell}$	=	total resident population in a cell (see Section 5.1.3)
Licenses	=	number of fishing licenses in the county or state
Pop	=	total population in the county or state in 1990
FamSize	=	average family size

Next, the population that consumes fish is then apportioned based on whether fish are eaten recreationally or for subsistence. Recreational fishers may fish during only certain times of the year for recreational purposes or to supplement their diet. In contrast, subsistence fishers may fish throughout the year and a major part of their diets may consist of the fish they catch. Data are lacking on the numbers of recreational compared to subsistence fishers; RSEI follows guidance from EPA's Office of Water (Harrigan, 2000). The RSEI model assumes that of the population that eats non-commercial fish, 95 percent eat fish on a recreational basis, and the remaining 5 percent subsist on fish. This apportionment is described by the following relationships:

$$RecPop_{cell} = FishPop_{cell} * 0.95 \quad \text{(Eq. 5.13)}$$

$$SubsistPop_{cell} = FishPop_{cell} * 0.05 \quad \text{(Eq. 5.14)}$$

where:

$RecPop_{cell}$	=	recreational fishers (and families) in a grid cell
$SubsistPop_{cell}$	=	subsistence fishers (and families) in a grid cell

The fishing population in each grid cell is then assigned to specific flowlines where they are presumed to catch fish. This is done in two steps. First, overlapping circles of 80-km radii associated with each of the two to seven points that describe individual flowlines are used to define those grid cells that will be modeled for fishing population in the 48 contiguous states (i.e., all fishing areas within 80 km of all stream flowlines). The distance of 80 kilometers (50 miles) from the flowline is chosen based on a finding reported in the *1991 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* that 65 percent of anglers travel less than 50 miles to fish (U.S. Department of the Interior, 1993). This distance approximates the size of many counties and corresponds with the use of county-level fishing license data.

Second, all flowlines within an 80-km radius of the center of each grid cell from the first selection are identified. The fish-eating population in the grid cell is apportioned to each surrounding flowline based on the ratio of the length of that flowline to the total flowline kilometers within 80 km of the grid cell. For example, Flowlines A and B may be located within 80 km of a given grid cell. If Flowline A is 15 km in length and Flowline B is 5 km in length

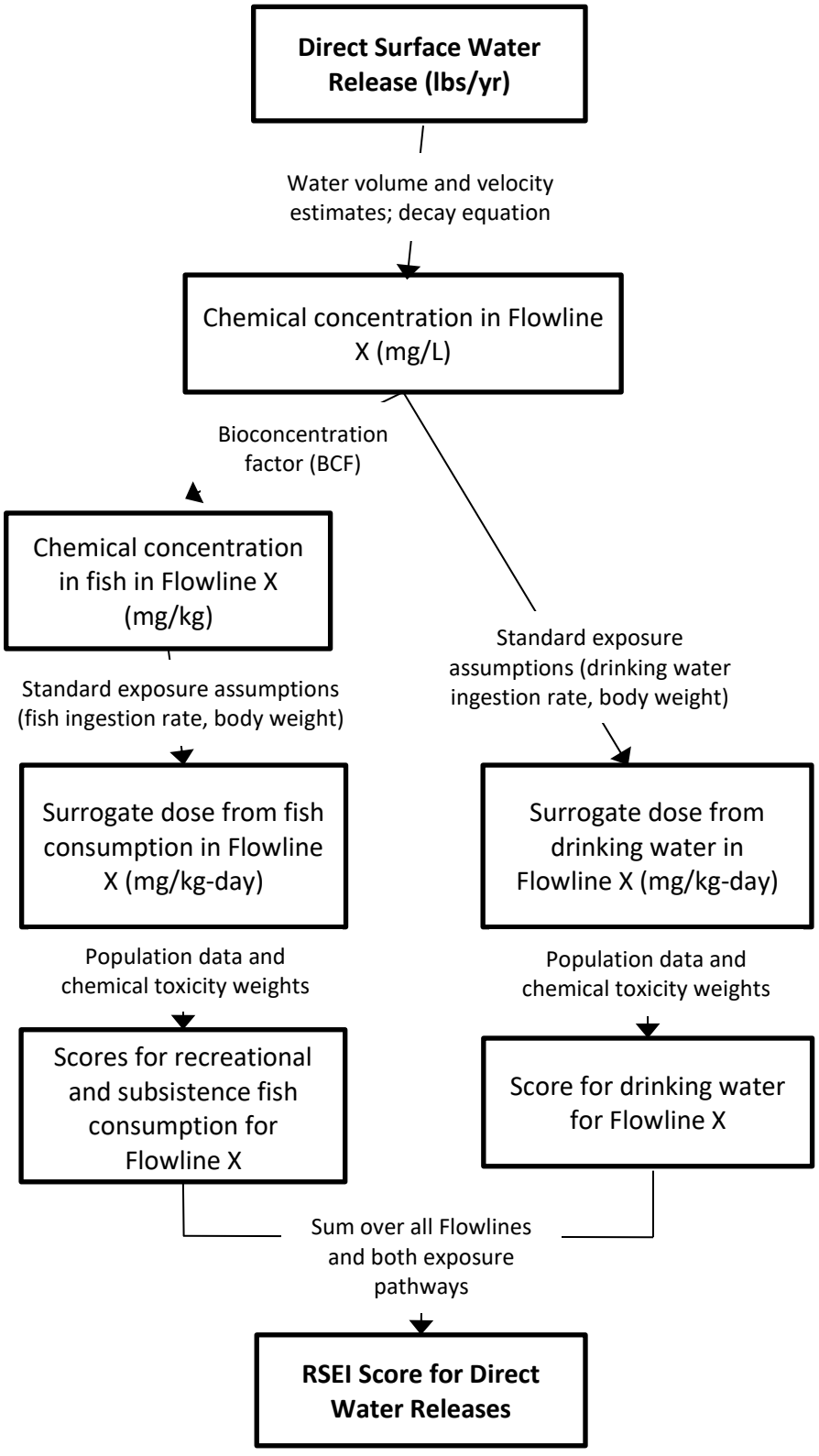
(and the entire length of each flowline is completely within 80 km of the grid cell), then a total of 20 km of flowlines are located within the specified distance. Because Flowline A represents three-fourths (15/20) and Flowline B represents one-fourth (5/20) of total km, the RSEI model therefore assumes that three-fourths of the fishing population in the cell catches fish from Flowline A and one-fourth catches fish from Flowline B. Note that the model uses only the portion of the flowline's length that is within 80 km of the grid cell.

Because of the size of the database created, the fishing population data attributed to individual flowlines is summed and stored at the flowline level. The percentage of people in each of the ten age-sex categories for the aggregated total fishing population (reflecting the ratio of the various age and gender populations in the neighboring grid cells) is also maintained for each flowline. The RSEI model then matches the chemical concentration in fish in the appropriate flowline to the correctly-apportioned population. This is done for all flowlines that have modeled chemical concentrations.

5.4.2 Calculating the RSEI Score for Surface Water Releases

RSEI scores for drinking water and fish ingestion are calculated by generating a surrogate dose for each unique combination of chemical release, flowline, and exposure pathway, then multiplying this surrogate dose by the chemical toxicity weight and the estimated population. The RSEI score for a surface water release from a facility is calculated by adding the drinking water score and the fish consumption score (recreational and subsistence fishing) for each flowline and then summing over all flowlines affected by the release (up to 300 km downstream from the facility). Exhibit 5.7 shows the approach for calculating the RSEI score for surface water releases.

Exhibit 5.7
Calculating the RSEI Score for Surface Water Releases



5.4.3 Surface Water Releases: Data

A variety of data are required to estimate exposure to chemical discharges to surface waters. The parameters required for surface water modeling and the data sources used are listed in Exhibit 5.8 and described further below.

Exhibit 5.8
Surface Water Modeling Parameters

Parameter	Value (Units)	Source/Comment
Flowline location	Lat/long in decimal degrees	NHDPlus Version 2 (U.S. EPA/USGS, 2012)
Drinking water intake location and population served	Lat/long in decimal degrees and number of persons	Public Supply Database (2012), based on SDWIS
Water flow	mean flow (million L/day)	NHDPlus Version 2 (U.S. EPA/USGS, 2012)
Decay rate of chemical in water	chemical-specific (sec^{-1})	SRC (1994-99)
Pollutant chemical concentration in stream	(mg/L)	calculated
Bioconcentration factor	chemical-specific (L/kg)	SRC (1994-99); Lyman et al. (1990); EPA (1999b)
Fish tissue concentration	(mg/kg)	calculated
Family size	2.62 (people/household)	U.S. Census Bureau (1996)

5.4.3.1 Flowlines

Each facility is matched to an EPA-assigned discharge flowline, or if no assigned discharge flowline is available, the facility is assumed to discharge into the nearest flowline within four kilometers of the facility. Certain minimum criteria regarding flow and flowline type are applied to the set of potential discharge flowlines, as explained below. If no acceptable flowline is found within four kilometers, then the water discharge is not modeled. The flowlines used in the RSEI model are linear sections of streams, lakes, reservoirs, and estuaries that are linked to form a skeletal structure representing the branching patterns of surface water drainage systems. Non-transport flowlines (i.e., those that do not have an upstream or downstream connection) are excluded from the RSEI model.

RSEI has adopted the National Hydrography Dataset (NHD) system for indexing flowlines, which is much more detailed than the Reach File 1 (RF1) system, which was used in RSEI Version 2.2.0 and before. The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or flowlines that comprise the nation's surface water drainage

system. The NHD provides a national framework for assigning flowline addresses to water-related entities such as industrial dischargers, drinking water supplies, fish habitat areas, and wild and scenic rivers. Flowline addresses establish the locations of these entities relative to one another within the NHD surface water drainage network in a manner similar to street addresses. Once linked to the NHD by their flowline addresses, the upstream/downstream relationships of these water-related entities and any associated information about them can be analyzed using software tools ranging from spreadsheets to Geographic Information Systems (GIS). EPA's Watershed Assessment, Tracking & Environmental Results System (WATERS) uses the flowline codes in NHD to link multiple databases containing water quality and programmatic information. EPA, in partnership with the U.S. Geological Survey, has created a version of the NHD called NHDPlus[59], which contains information on stream velocity and flow volume, which are necessary for modeling chemical concentrations in streams in the RSEI model.

Certain criteria were applied to the NHDPlus dataset to select the flowlines to be used in the RSEI model. Specifically, because RSEI calculates the movement of a chemical release downstream using flow and velocity data, qualifying flowlines must have at least one downstream or upstream connecting flowline[60], and have a non-negative flow and velocity. The RSEI model will not calculate chemical concentrations for certain types of flowlines, such as coastlines, treatment reservoirs, and bays; the downstream path of any chemical is assumed to stop if one of these types of flowlines is encountered. Additionally, some types of flowlines are excluded from the set of fishable flowlines, such as pipelines, aqueducts, and certain types of reservoirs. NHDPlus does not separate canals (presumably fishable) and ditches (presumably not fishable), so the RSEI model excludes flowlines in the canal/ditch category if the annual mean flow is less than 5 cubic feet per second (ft^3/s). This is an arbitrary minimum, and is intended primarily to exclude ditches at the point of the facility discharge. For flowlines designated as not fishable in NHDPlus, the chemical is still assumed to travel downstream to the next flowline, which may or may not be fishable.

Because NHDPlus contains a large number of flowlines with very small annual mean flows, the RSEI model also excludes the very smallest flowlines from assignment as discharge flowlines. To determine an appropriate minimum, a national set of EPA-assigned discharge flowlines from the ICIS-NPDES database was matched to the NHDPlus annual mean flow data. For each NHDPlus region, the non-zero annual mean flows were ranked, and the fifth percentile flow for each region was selected as the minimum annual mean flow. Assigned regional minimum values ranged from 0.0036 ft^3/s to 1.9 ft^3/s. For instance, if a facility in a region whose minimum value was selected as 0.0036 ft^3/s had a nearest flowline with annual mean flow of 0.0025 ft^3/s, this would not be selected as the discharge flowline. Instead the next closest flowline with a flow equal or greater than 0.0036 ft^3/s would be selected as the discharge flowline.

[59] https://www.epa.gov/waterdata/nhdplus-national-hydrography-dataset-plus. The NHDPlus Version 2 data are hosted by Horizon Systems Corporation, which hosts and maintains the NHDPlus data. Documentation and data are available at http://www.horizon-systems.com/nhdplus/index.php.

[60] In the NHDPlus dataset, topologically connected flowlines with known flow are indicated by a "FlowDir" value of "With Digitized." Only flowlines with this value for this field were included in RSEI modeling, which includes 2.6 million out of 2.9 million flowlines in NHD.

5.4.3.2 Drinking Water Intakes and Populations

Drinking water intake locations were obtained from the PSDB, a database of drinking water system information developed and maintained by the USGS, based on information in EPA's SDWIS. SDWIS is a publicly accessible database that contains the information EPA uses to monitor public water systems. The database contains information on over 156,000 water systems, which serve over 96 percent of the U.S. population.[61] SDWIS is operated and maintained by EPA's Office of Water (OW). USGS's PSDB was designed to support USGS analyses of the water resources used by public drinking water systems. The PSDB includes SDWIS data, and supplements it with additional information about the water bodies from which systems draw their water. In addition, multiple quality-assurance checks have been performed on the data, including the lat/longs.

The version of the PSDB used contains SDWIS population data from 2007, which was updated during 2011. Approximately 11,400 drinking water intakes were included in the database. Several types of intakes were excluded from the set used for RSEI modeling: 1) if the drinking water system for the intake closed prior to 2002; 2) if the source water for the intake was something that could not reasonably be expected to be connected a network of streams (such as an aqueduct or an infiltration gallery); or 3) if the intake was emergency, interim (peak) or other (rather than permanent or seasonal). Excluding these cases left 6,215 drinking water intakes that are modeled in RSEI.

5.4.3.3 Water Flow and Velocity

The RSEI model uses NHDPlus Version 2 estimates of water flow and velocity based on the unit runoff method,[62] which was developed for the National Water Pollution Control Assessment Model (NWPCAM). The unit runoff method calculates average runoff per square kilometer in a watershed (8-digit hydrologic unit code (HUC)) based on gages in the HydroClimatic Data Network (HCDN). These gages are usually not affected by human activities, such as major reservoirs, intakes, and irrigation withdrawals; thus, the mean annual flow estimates are most representative of "natural" flow conditions. Based on elevation and drainage patterns, each square kilometer in a watershed is assigned to a catchment area, from which the runoff flows to a specific flowline. The runoff from each catchment area is summed and attributed to its assigned flowline. That flow is assigned to the next downstream flowline, to which the downstream flowline's catchment runoff is added, and so on down the stream path. Unit runoff estimates are calibrated for areas west of the Mississippi to account for water withdrawals and transfers.

NHDPlus velocities are estimated for mean annual flow conditions (using the unit runoff method) based on the work of Jobson (1996). This method uses regression analyses on hydraulic variables for over 980 time-of-travel studies, which represent about 90 different rivers in the U.S. representing a range of sizes, slopes, and channel geometries. Four principal flowline variables

[61] https://www.epa.gov/waterdata/drinking-water-tools.

[62] NHDPlus also contains estimates developed using the Vogel method, but this is method is considered to have a narrow band of applicability.

are used in the Jobson methods: drainage area, flowline slope, mean annual discharge, and discharge at the time of the measurement.[63]

5.4.3.4 Water Decay Rates

Water decay rates are required to model downstream chemical concentrations. The primary sources for water decay values were Syracuse Research Corporation's (SRC's) ChemFate database, a component of SRC's Environmental Fate Data Base (SRC, 2002a), which contains experimental data, and SRC's Aqueous Hydrolysis Rate Program, HYDROWIN (part of the Estimation Programs Interface (EPI) Suite of estimation programs (SRC, 1994-1999)), both of which were developed for the EPA. The ChemFate database contains environmental fate and physical/chemical property information for commercially important chemical compounds, including TRI-listed chemicals. HYDROWIN estimates hydrolysis rate constants for esters, carbamates, epoxides, halomethanes, and selected alkyl halides. Values of water decay rates can be found in Technical Appendix B.

5.4.3.5 Bioconcentration Factors

Bioconcentration factor (BCF) is the term used to describe the equilibrium concentration of chemicals in aquatic organisms living in contaminated water. The BCF is defined as the ratio of the chemical concentration in the organism (mg/kg) to that in the surrounding water (mg/L). The term "bioconcentration" refers to the uptake and retention of a chemical by an aquatic organism *from the surrounding water only*.[64] Experimental BCF values were obtained from SRC's ChemFate database. Other BCFs were estimated from either log(K_{ow}) values using regression equations from Lyman et al. (1990), or from the SRC estimation program BCFWIN. See Technical Appendix B for values and references for the BCFs of chemicals used in the RSEI model.

5.4.3.6 Human Exposure Assumptions

Drinking Water. For the drinking water exposure pathway, the RSEI model uses estimates for the amount of tap water ingested to estimate exposure. As in the stack and fugitive air release pathways, data are acquired from the February 2019 update to Chapter 3 of EPA's Exposure Factors Handbook (EFH) (EPA, 2019). The EFH recommends mean tap water intake values for males and females combined from EPA's analysis of National Health and Nutrition Examination Survey (NHANES) data from 2005-2010.

Drinking water intake rates per body weight were calculated for each of the RSEI modeled groups (male and female: ages 0-17, 18-44, 45-64, 65+)[65] using the weighted average approach

[63] For more information, see the NHDPlus User's Guide (US EPA/USGS 2012) at https://www.epa.gov/waterdata/learn-more

[64] The BCF can underestimate the accumulation of chemicals that are highly persistent and hydrophobic as compared to the bioaccumulation factor (BAF), which measures the uptake and retention of a chemical by an aquatic organism *from all surrounding media (e.g., water, food, sediment).* The bioaccumulation factor (BAF) is defined as the ratio of the chemical concentration in the organism (mg/kg) to that in the surrounding water (mg/L), in situations where both the organism and its food are exposed. Due to data limitations at the present time, only BCFs are used in the RSEI model.

[65] The RSEI model provides the ability to view risk scores for the 0-9 year old age group, however, there is not a

presented in Equation 5.7. The final drinking water exposure factors are presented in Exhibit 5.9. More detail on the derivation of exposure factors can be found in Technical Appendix C.

Exhibit 5.9
Drinking Water Exposure Factors

Model Age Group	Exposure Factors (Male)	Exposure Factors (Female)
	(L/kg-day)	
0-17	0.0101	0.0101
18-44	0.0099	0.0099
45-64	0.0117	0.0117
>65	0.0108	0.0108

Fish Ingestion. The RSEI model uses annual estimates of the amount of fish ingested by recreational and subsistence fishers and their families. However, there are no national data on fish ingestion rates specific to recreational and subsistence fishers. In the absence of such data, the RSEI model uses fish ingestion rates from the 1994-1996 U.S. Department of Agriculture (USDA) Continuing Survey of Food Intake by Individuals (CSFII). This survey was conducted by the USDA in 50 states and the District of Columbia over a three-year period. A total of 15,303 individuals provided two non-consecutive days of data on dietary intake. Appropriate statistical techniques were used to extrapolate to the national population. In a 2002 publication, EPA assigned specific fish species to habitats (freshwater, estuarine, and marine) based on the majority of time the species spend in those habitats (EPA, 2000). Based on these assignments, EPA estimated a distribution of uncooked finfish and shellfish ingestion rates specific to freshwater and estuarine fish.[66] As recommended by EPA's Office of Water (Tudor et al., 2000), for environmental assessments, the 90th percentile is used to represent ingestion rates for recreational fishers, and the 99th percentile is used for subsistence fishers. The ingestion rates are reported by age group (<15 years, 15-44 years, 45+ years) and sex (EPA, 2002). These values are roughly similar to ingestion rates obtained from regional studies of recreational fishers and subsistence fishers, respectively. Fish ingestion values were estimated for the RSEI model age groups using Equation 5.7. These values are then divided by age- and sex-specific body weights, averaged to match the RSEI model age groups using data provided in the EFH (EPA, 2011, Tables 8-4 and 8-5). Exhibit 5.10 presents the fish ingestion rates used in the RSEI model. More detail on the derivation of exposure factors can be found in Technical Appendix C.

separate exposure factor for this age group. Instead, the exposure factor for the 0-17 year old age group is used

[66] Consumption of marine fish is not included in the ingestion rates, because marine areas are not modeled in RSEI.

Exhibit 5.10
Fish Ingestion Exposure Factors

	Recreational (g/kg-day)[1]		Subsistence (g/kg-day)[1]	
Model Age Group	**Male**	**Female**	**Male**	**Female**
0-17	0.0678	0.0288	2.37	1.85
18-44	0.182	0.0862	1.76	1.50
45-64	0.362	0.229	1.85	1.41
>65	0.398	0.255	2.04	1.57

[1] Fish ingestion exposure factors are converted to kg/kg-day for the surrogate dose calculation in the RSEI model.

5.5 Modeling Transfers to POTWs

TRI reporting has included chemical data and information on off-site transfers to Publicly Owned Treatment Works (POTW) facilities since the first year of TRI reporting (reporting year 1987). As part of the TRI reporting requirements, subject facilities are required to report total annual quantities of TRI-listed chemicals in wastes that they send off-site to each POTW for further waste management.[67] The most common transfers of this type are conveyances of the toxic chemical in facility wastewater through underground sewage pipes; however, materials may also be trucked or transferred via some other direct methods to a POTW.

The Pollution Prevention Act (PPA) of 1990 introduced additional TRI reporting requirements for subject facilities on source reduction and waste management activities, effective for TRI beginning with reporting year 1991. With these new reporting requirements, subject facilities were not only now required to report the quantities of TRI-listed chemicals transferred off-site to POTWs during a given reporting year, but were also required to use their best readily-available information to provide estimates on the ultimate disposition of the chemicals following their transfer to POTWs.[68] If information (data) on a recipient POTW's removal efficiencies and waste management activities involving TRI chemicals are readily available, reporting facilities should use such data. In cases where reporting facilities do not have information on the removal efficiencies and environmental fates of TRI chemicals once at POTWs, EPA provides chemical-specific default POTW distribution percentages for TRI reporting purposes.[69]

These chemical-specific default POTW distribution percentages provided by EPA are based on experimental and estimated data collected by the Agency and used in the RSEI model (see Technical Appendix B for more details). Table III does not contain POTW distribution percentages for all TRI-listed chemicals and chemical categories. For chemicals and chemical

[67] POTWs are not subject to TRI reporting requirements, but are regulated under other EPA regulations and programs such as those under the Clean Water Act.

[68] See https://ofmpub.epa.gov/apex/guideme_ext/f?p=guideme:qa:16874845131167:::qa:19-633 for more details.

[69] See Table III in https://ofmpub.epa.gov/apex/guideme_ext/guideme_ext/guideme/file/ry_2019_rfi.pdf#page=148

categories not included in this table, the default assumption is that 100% of the chemical or chemical category transferred to a POTW is treated for destruction, with the exception of metals and metal compounds, for which the default assumption is that 100% of the chemical or chemical category is released to the environment (e.g., disposed of).

EPA's understanding is that these default distribution percentages and assumptions are realistic expectations for typical POTWs handling TRI chemicals and that the Agency will incorporate improved default POTW distribution percentages when it learns of more accurate data. In pursuit of this goal and to more closely align with how transfer quantities to other off-site facilities (i.e., non-POTW facilities) are reported, the TRI program has incorporated new POTW waste management activity transfer codes, effective for reporting year 2019. EPA is currently evaluating screening-level exposure methodologies which might be used and incorporated into the RSEI model to better assess risk-related impacts pertaining to these new reportable POTW waste management activity transfer codes.

Overall, the quantity of a TRI-listed chemical removed by a POTW is divided into the percentages removed by (1) sorbing to sludge, (2) volatilizing into the air or (3) being biodegraded by microorganisms. The remaining portion (i.e., the portion not removed by the POTW) is the percentage of the influent TRI chemical that passes through the POTW untreated and is ultimately discharged into surface waters, which could potentially result in human exposure through drinking water or fish ingestion.

The following sections describe the method and data used to model transfers to POTWs.

5.5.1 Transfers to POTWs: Method

Each TRI-reported chemical transfer to a POTW is modeled in RSEI as entering the POTW as liquid influent. Dependent upon on the chemical's physicochemical properties, the RSEI model uses estimates of POTW removal efficiencies and within-POTW partitioning percentages to describe the environmental fate of TRI chemicals that are sent off-site to POTWs.

Modeling exposures from TRI-reported chemical transfers to POTWs requires: (1) location of the POTWs to which the TRI-listed chemicals are transferred, (2) location of the flowlines to which the POTWs discharges, (3) consideration of overall removal efficiencies of POTWs and resulting effluent discharges from POTWs (e.g., chemical-specific removal rates), and (4) waste management handling and activities at POTWs (environmental partitioning within the POTW and ultimate disposition of the chemical).

5.5.1.1 Locating the POTW

In order to model discharges from POTWs, these facilities must first be located on the RSEI model grid. Like other off-site facilities, POTW names and addresses are reported to the TRI by the facility transferring its chemical waste. Latitude and longitude coordinates of the receiving POTWs are not reported to the TRI program. In order to derive lat/long coordinates, the reported street addresses were geocoded for RSEI Version 2.1.3 (lat/long coordinates were assigned based on street address).[70] POTWs (as well as incinerators) were matched to EPA's Facility Registry

[70] Geocoding services were provided by Thomas Computing Services, a commercial firm.

System (FRS), based on name, address, and Resource Conservation and Recovery Act (RCRA) identification number, where possible. Duplicate entries for the same POTW (in the common instance where two or more TRI-reporting facilities have transferred to the same POTW) were collapsed to a single entry using an approximate string matching program (see Technical Appendix D for more details). Once latitude and longitude coordinates are assigned (from geocoding, the FRS data, or based on zip code centroids), the data are used to map the POTW to the RSEI grid cell with the same coordinates. Substantial data processing was necessary to prepare the set of off-site facilities (including POTWs) for use in the RSEI model; see Technical Appendix D for more details on the steps that were taken.

5.5.1.2 Locating the POTW Discharge Flowline

As with TRI-reporting facilities, the POTW's discharge flowline must be identified. The main data used to accomplish this are EPA records of Clean Water Act (CWA) discharge permits for POTWs, which in some cases specify the discharge flowline by the locational coordinates of the discharging outfall. National Pollutant Discharge Elimination System (NPDES) permit records, including permit conditions, permit limits, monitoring data (e.g., Discharge Monitoring Reports (DMRs)), locational, and descriptive information are maintained in EPA's Integrated Compliance Information System (ICIS-NPDES), which is incorporated in EPA's Enforcement and Compliance History Online (ECHO) system.

POTWs were matched to the FRS system based on name and address to obtain the FRS IDs for each POTW. The FRS IDs were then used to access ICIS-NPDES and the assigned discharge flowlines for each POTW. Approximately 3,000 records were matched to a discharge flowline using this method.

POTWs not matched to an ICIS-NPDES discharge flowline were assumed to discharge to the nearest flowline within four kilometers that meets the minimum flow requirements described previously in Section 5.4.3.1.

5.5.1.3 Overall POTW Removal Rate

POTWs cannot completely remove all of the chemicals that are transferred to them from TRI-reporting facilities, and as a result, some chemicals in POTW influent streams will be discharged untreated as effluent to surface waters. To calculate the fraction of transferred chemical removed by the POTW, typical chemical-specific POTW removal rates are applied to the quantities transferred to the POTW from the TRI-reporting facility. See Technical Appendix B for a listing of POTW removal rates and references for each chemical. The remaining fraction is assumed to exit the POTW untreated in water effluent. The water effluent quantities discharged from the POTW are modeled in RSEI for the drinking water and fish ingestion exposure pathways using the same methods for surface water releases described previously.

5.5.1.4 Partitioning within the POTW

The quantities of chemicals removed by POTWs are divided into percentages removed by (1) sorbing to sludge, (2) volatilizing into the air or (3) being biodegraded by microorganisms. The quantities of chemicals removed by each of these three processes is modeled in RSEI using typical chemical-specific within-POTW partitioning rates (see Technical Appendix B for the listing of within-POTW partitioning rates and references for each chemical).

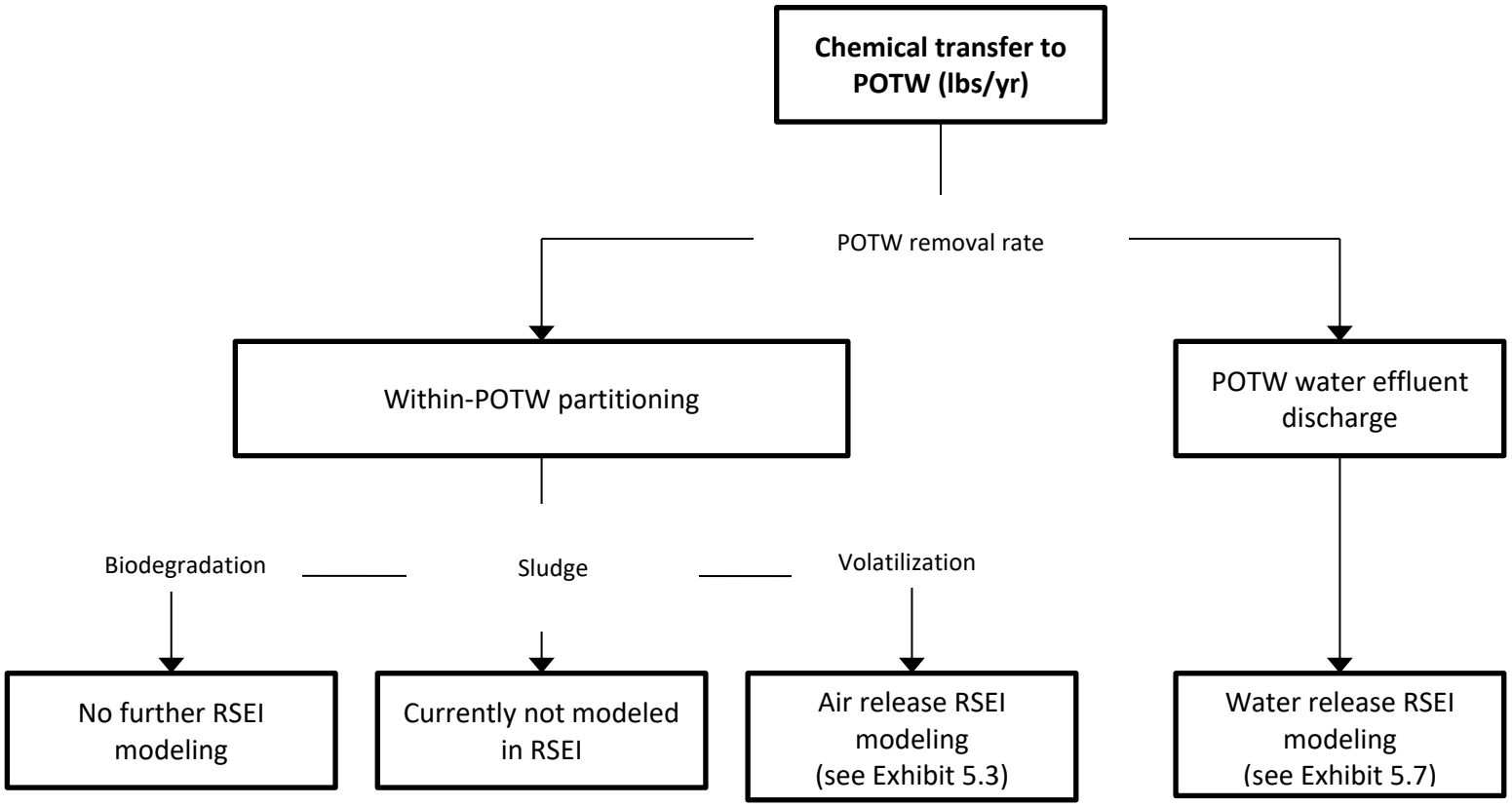
Once the environmental fate of chemicals entering POTWs is established, exposures associated with the quantities of chemicals partitioned to each environmental compartment are estimated. Chemical quantities discharged to surface waters in the POTW effluent are modeled in RSEI using the surface water release evaluation methods described previously in Section 5.4. Chemical quantities that biodegrade at the POTW are assumed to degrade into innocuous chemicals that do not pose any further potential risk. Chemical quantities that volatilize off to air at the POTW are treated like area-source (non-point) air emissions, as described earlier in Section 5.3.2 in the fugitive air release evaluation method.

For exposures to chemical quantities that are removed via partitioning to sludge, the exposure pathway estimates are dependent upon the sludge waste management activity employed and utilized by the POTW. The specific method of sludge waste management utilized by POTWs cannot be directly determined from the information reported by subject facilities to the TRI program.[71] Therefore, the RSEI model algorithm currently assumes all POTW chemical sludge is landfilled at the POTW, a common method of sludge disposal. POTWs may in reality, however, use other sludge waste management activities, such as sludge incineration, land treatment/application farming, disposal to surface impoundments, and other land disposal methods. These various waste management activities may result in different exposure levels and may effect different exposed populations.

A summary of the RSEI approach to modeling chemical transfers to POTWs is found in Exhibit 5.11.

[71] Newly implemented POTW waste management activity transfer codes (effective for TRI reporting year 2018), however, may help to elucidate these quantities in the future.

Exhibit 5.11
RSEI Modeling Approach for Chemical Transfers to POTWs



5.5.1.5 Estimating Exposed Population Size from Transfers to POTW Model

The population exposed to fugitive air releases by within-POTW volatilization of the transferred chemical is assumed to be the population within 49 km around the POTW (see Section 5.3.2 for more detail). The population exposed to POTW water effluent discharges surrounding the POTW is further described in the section on exposed populations from surface water releases (see Sections 5.4.1.2 and 5.4.1.4.) Populations exposed by releases to land from within-POTW sorption to sludge (e.g., landfills) are not currently estimated and modeled in RSEI.

5.5.2 Transfers to POTWs: Data

Exhibit 5.12 presents the data sources used in the RSEI modeling of chemical transfers to POTWs in estimating environmental releases and exposures from POTWs. In addition to the parameter data presented here, data from the air release exposure pathway (see Exhibit 5.3), and water release exposure pathway (see Exhibit 5.7) are also used. Environmental fate and exposure factors specific to these pathways are described in their previous relevant sections.

Exhibit 5.12
Data Used to Estimate Environmental Releases from POTWs

Parameter	Value	Source/Comment
POTW removal efficiencies	chemical-specific	RREL or STPWIN (SRC, 1994-99)
Within-POTW partitioning	chemical-specific	RREL or STPWIN (SRC, 1994-99)

5.5.2.1 POTW Removal Efficiencies and Within-POTW Partitioning

Data specific to this type of off-site transfer include chemical-specific POTW removal efficiencies and within-POTW partitioning values. These parameters help to describe the environmental fate of chemicals once transferred to POTWs. As further described in Technical Appendix B, the total POTW removal efficiency is the total percentage of the chemical removed by the POTW (i.e., influent concentration minus effluent concentration divided by influent concentration). The within-POTW partitioning values describe the fate of that portion of the chemical removed by the POTW, that is, whether the chemical may sorb to sludge, volatilize into the air, or be biodegraded by microorganisms. The within-POTW partitioning values are expressed as percentages of the total POTW removal efficiency; that is, they sum to 100 percent.

POTW removal efficiencies were obtained primarily from the Treatability Database maintained by EPA's Office of Research and Development (ORD), National Risk Managment Research Laboratory (NRMRL), Risk Reduction Engineering Laboratory (RREL). For any given chemical, the RREL Treatability Database provided a list of POTW removal efficiencies published in the scientific literature. Each value is characterized by the technology used, the type

of influent, and the scale of the experiment. For all values associated with activated sediment and full scale experiments, a geometric mean was derived and used as the POTW removal efficiency. Within-POTW partitioning values were obtained for most organic chemicals from EPA's Exposure Assessment Branch (EAB), now presently grouped in the Risk Assessment Division (RAD) within the Office of Pollution Prevention and Toxics (OPPT). Inorganic chemicals, except for ammonia, were assumed to partition 100% to sludge. For chemicals without data from these sources, SRC's Sewage Treatment Plant Fugacity Model (STPWIN) was used to estimate total POTW removal efficiencies and within-POTW partitioning values.

5.6 Modeling Other Off-site Transfers

Facilities subject to TRI reporting must also report the total annual quantities of TRI-listed chemicals in wastes sent to all other off-site facilities (non-POTW facilities) for further waste management activities. These types of off-site waste management activities include disposal, treatment, energy recovery, and recycling operations. As part of the TRI reporting requirements, TRI reporting facilities are required to report the names and addresses of the receiving facilities, the quantities transferred, and the type of waste management activity used by the receiving off-site facility.

Currently, only transfers of TRI-listed chemicals in wastes to off-site facilities for the purpose of incineration are modeled by RSEI, and are further described below.

5.6.1 Off-site Transfers to Incineration: Method

To assess the exposure potential associated with off-site transfers to incineration, it is important to have information about the off-site facility location and some of its operational characteristics. Locations of other off-site facilities (i.e., non-POTW facilities) are determined in the same way as the locations of POTWs. The reported street addresses were geocoded for Version 2.1.3 (lat/long coordinates were assigned based on street address).[72] Incinerators (as well as POTWs) were also matched to EPA's FRS, based on name, address, and RCRA identification number, where possible. Duplicate entries for the same off-site facility (in the common instance where two or more reporting facilities have transferred to the same off-site facility) were collapsed to a single entry using an approximate string matching program (see Technical Appendix D for more details). Once latitude and longitude coordinates for a facility are assigned (from geocoding, the FRS data, or based on zip code centroids), the data are used to map the facility to the RSEI grid cell with the same coordinates. See Technical Appendix D for detailed information on locating off-site facilities.

TRI reporting requirements require the reporting facility to indicate the waste management activity used at the off-site facility. If this information is not reported (despite the requirement), the off-site transfer is not evaluated in the RSEI algorithm, but is flagged as a missing value and assigned a zero quantity.

Beginning with reporting year 1998, facilities in the commercial hazardous waste treatment sector were subject to reporting requirements to the TRI program. This introduces the potential

[72] Geocoding services were provided by Thomas Computing Services, a commercial firm.

for "double counting" the quantities of some off-site transfers and on-site releases, as many of the facilities in this industry sector also receive waste transfers from other TRI-reporting facilities. Beginning with Version 2.3.5, adjustments were made in the RSEI model to reported chemical waste transfer quantities to off-site facilities for incineration to help account for this potential double counting. TRI-reporting facilities in NAICS code 562211 (Hazardous Waste Treatment and Disposal), which is the most likely NAICS code in the commercial hazardous waste treatment sector to include commercial hazardous waste incinerators, are matched against the list of off-site facilities (reported by the transferring facilities). For any matched facilities that receive a transfer for off-site incineration, it is assumed that the receiving facility is reporting any on-site environmental releases (e.g., air releases) from this incineration operation to the TRI program. To correct for this potential double counting, the reported off-site transfer for incineration by the originating facility and the corresponding pounds and modeled-based results related to this off-site transfer are dropped from the RSEI model. Since the expansion of TRI-covered industry sectors to include the commercial hazardous waste treatment sector was first in effective for reporting year 1998, only transfers quantities from 1998 and onward are adjusted.

For off-site chemical waste transfer quantities to incineration that are not dropped by the double counting adjustments, incinerator destruction and removal efficiencies (DREs) are applied to the off-site transfer quantity amount. Once the DREs have been applied, the resulting air releases are modeled using the AERMOD-based air modeling algorithms described previously in Section 5.3.

5.6.2 Estimating Population for Off-Site Transfers to Incineration

Similar to on-site air releases, the population exposed to air releases from off-site transfers to incineration is the population within 49 km around the off-site incinerator. See Section 5.3.4 for more details.

5.6.3 Off-site Transfers to Incineration: Data

5.6.3.1 Incinerator Destruction and Removal Efficiencies

For organics, the destruction and removal efficiency (DRE) is assumed to be 99 percent (see Technical Appendix B). The exceptions to the 99 percent removal assumption are Polychlorinated Biphenyls (PCBs) and dioxin and dioxin-like compounds, which are assumed to have a DRE of 99.9999 percent, as required by Toxic Substances Control Act (TSCA) regulation. For inorganics, DRE values are taken from multiple hearth sludge incinerator studies (EPA, 1992a).

5.7 Modeling Land Releases

Chemical releases to land include disposal[73] to landfills, surface impoundments, land treatment (application farming), underground injection wells, and other land disposal methods. For these types of land releases, two major exposure pathways are of interest; volatilization of chemicals to air and leaching of chemicals into groundwater. Any volatilization of chemicals from on-site land disposal is reported to the TRI program on reporting forms by subject facilities under the fugitive air emissions quantities, and is modeled by RSEI as part of the facility's fugitive air releases (see Section 5.3). Volatilization from off-site transfers to land disposal are not currently modeled in RSEI. The potential for groundwater contamination from chemical releases to land depends on the regulatory status of the land disposal unit in which the chemical is disposed to. For example, chemical waste could be deposited in an on-site Resource Conservation and Recovery Act (RCRA) Subtitle C-regulated hazardous waste unit, or in an on-site RCRA Subtitle D-regulated non-hazardous solid waste management unit. RCRA Subtitle C regulatory standards for hazardous waste units are designed to include technical controls to prevent release of contaminants into groundwater. If chemicals are placed in such regulated units, EPA assumes that releases to groundwater are negligible, so the RSEI model assigns a zero value to the risk-related scores for such releases. If chemicals are placed in non-hazardous land disposal units such as those regulated by RCRA Subtitle D (e.g., non-RCRA Subtitle C landfills, non-RCRA Subtitle C surface impoundments, etc.), there may be a potential for chemical groundwater exposure.

The current version of the RSEI model, however, does not provide risk-related modeling results for these types of reported land releases. EPA is currently evaluating screening-level exposure methodologies which might be used and incorporated into the RSEI model to assess risk-related impacts pertaining to groundwater exposure from on- and off-site land releases and volatilization from off-site land releases. For the time being, however, the RSEI model does provide the capability for users to examine the quantities of releases (pounds) to land that are reported to the TRI program, as well as viewing these releases from a hazard-based perspective.

[73] Disposal means any underground injection, placement in landfills, surface impoundments, land treatment, or other intentional land disposal as defined under EPCRA (40 CFR 372.3)

6. Calculating RSEI Results

This section summarizes the computation of the principal types of RSEI results. Because of the multi-functional nature of the RSEI model, a wide variety of results can be created. The three main kinds of results are described below.

Exhibit 6.1
Description of RSEI Results

Risk-related results (scores)	Surrogate Dose **x** Toxicity Weight **x** Population
Hazard-based results	Pounds **x** Toxicity Weight
Pounds-based results	TRI Pounds Released/Transferred

Risk-related results. The exposure route-specific chemical toxicity weight, surrogate dose, and population components are multiplied to obtain a risk-related score. The surrogate dose is determined through pathway-specific modeling of the fate and transport of the chemical through the environment, combined with population-specific exposure factors. The final score generated is a unitless measure that is *not* independently meaningful, but is a risk-related estimate that can be compared to other risk-related estimates calculated using the same methodology. If toxicity data or other data required for modeling are zero, or if the exposure pathway is not currently modeled, then the risk-related score generated is zero. RSEI risk-related scores are only calculated for certain types of TRI chemical releases and transfers (modeled media).

- **RSEI Score**- Product of surrogate dose, population, and the higher toxicity weight for each exposure route (see Exhibit ES.2 for details).
- **Cancer Score**- Product of surrogate dose, population, and the IUR or OSF toxicity weight (see Exhibit ES.2 for details).
- **Non-Cancer Score**- Product of surrogate dose, population, and the RfC or RfD toxicity weight (see Exhibit ES.2 for details).

Higher component toxicity weights are associated with higher relative risk-related values (and lower toxicity weights are associated with lower relative risks-related values). For chemicals with cancer effects, multiplying the toxicity weights associated with cancer toxicity and exposure to the chemical seems intuitive, since this is similar to the calculation of cancer risk with a slope factor or unit risk value and dose or exposure level. For chemicals with non-cancer effects, the multiplicative nature of the toxicity weights and exposure level may not seem intuitive, because in risk assessments, risk is usually characterized as the estimated exposure divided by the RfD/RfC. However, because of the manner in which the RSEI model toxicity weights have been constructed, the product of toxicity weight and surrogate dose varies in the same direction and degree as the ratio of exposure to RfD/RfC. This is because the toxicity weight is inversely related to the magnitude of the RfD/RfC. Thus, for a given dose or exposure level, a chemical with a more stringent (i.e., lower) RfD/RfC will receive a higher toxicity value than a chemical with a less stringent (i.e., higher) RfD/RfC, as shown in the following example:

	RfD (mg/kg-day)	Toxicity Weight	Surrogate dose (mg/kg-day)	Exposure (i.e., surrogate dose) /RfD Ratio	Toxicity Weight * Surrogate Dose
Scenario 1	0.1	5	1	1/0.1 = 10	5*1 = 5
Scenario 2	0.01	50	1	1/0.01 = 100	50*1 =50

Since no adverse effects are expected to occur below the RfD/RfC, one could argue that releases that result in surrogate doses below the RfD/RfC should be excluded. However, this approach was not pursued for the following reasons: first, the estimation of surrogate dose is only a screening-level approximation for the purposes of comparing one release quantity to another in a relative way, and should never be considered an actual calculation of exposure. To exclude release quantities resulting in surrogate doses below the RfD/RfC would incorrectly imply that the method could predict precisely when doses would occur below the RfD/RfC. Second, exposure to the same chemical from multiple facilities, or multiple chemicals from one or more facilities affecting the same health endpoint could act additively to pose potential risk, even if each release quantity individually did not exceed the RfD/RfC. Finally, if the surrogate dose is low, this will be reflected by a correspondingly low score relative to other release quantities for that chemical.

Hazard-based results. Hazard-based results ("Hazard") are calculated by multiplying the TRI chemical quantities released or transferred (in pounds) by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure-specific pathway). The inhalation toxicity weight is used for releases of fugitive air and stack air, and transfers to off-site incineration. The oral toxicity weight is used for surface water releases and transfers to POTWs. For these results, no exposure modeling or population estimates are involved. If there is no toxicity weight available for the chemical, then the hazard score is zero. Hazard can be calculated for modeled media (modeled hazard) or for any TRI waste management quantity.

- **RSEI Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Exhibit 4.4 for details).
- **RSEI Modeled Hazard**- Product of TRI Pounds and the higher toxicity weight for each exposure route (see Exhibit 4.4 for details). Same as RSEI hazard, but calculated for modeled media only.
- **Cancer Hazard**- Product of TRI Pounds and the IUR toxicity weight or the OSF toxicity weight (see Exhibit 4.4 for details).
- **Non-Cancer Hazard**- Product of TRI Pounds and the RfC toxicity weight or the RfD toxicity weight (see Exhibit 4.4 for details).

Pounds-based results. These results ("TRI Pounds") reflect only the number of pounds reported to TRI for each waste management activity, and are available for all TRI-reported quantities.

6.1 Combining RSEI Scores

Once all of the results are calculated, they can be combined in many different ways. All of the results are additive, so a result for a specific set of variables is calculated by summing the scores for all of the relevant waste management activity quantities.[74]

This method is very flexible, allowing for countless variation in the resulting outputs. For example, results can be generated for various subsets of variables (e.g., chemical, facility, exposure pathway) and compared to each other to assess the relative contribution of each subset to the total potential impact. Or, results for the same subset of variables for different years can be produced, to assess the general trend in pounds-based, hazard-based, or risk-related impacts over time.

It must be reiterated that while changes in results over the years would imply that there have been changes in hazard- or risk-related environmental impacts, the actual magnitude of any specific change or the reason may not be obvious. Although the value itself may be useful in identifying chemicals, facilities, or geographic locations with the highest potential for hazard or risk, the score itself does not represent a quantitative estimate or provide an exact indication of the magnitude of associated individual hazard or risk.

6.2 Accounting for Changes in TRI Reporting

When a change occurs in the number of or reporting requirements for chemicals and/or facilities regulated by the TRI program, the numerical value of RSEI results will be altered if no adjustments are made to the method of calculation to account for the changes respective to trend analyses. However, such changes would not necessarily represent a large change in actual environmental impact, but rather would reflect a broader understanding of the impacts that may have always existed. To maintain comparability in the weights over time, the results must be adjusted in some manner when such changes in TRI reporting occur.

A change in the number of chemicals and/or facilities subject to TRI reporting can occur through several mechanisms. The addition to or deletion of chemicals from the TRI chemical list will occur as EPA responds to petitions or initiates its own regulatory action through the chemical listing or delisting process. The largest revision to the list occurred in November 1994, when the Agency added 245 chemicals and chemical categories to the existing TRI chemical list, effective for the reporting year 1995. When deletions from the TRI chemical list occur, RSEI's chemical database is modified to remove all results from previous reporting years. Also, the yearly TRI data in the TRI database are subject to ongoing quality control review and correction by both EPA and by TRI-reporting facilities. As a result, yearly comparisons could be flawed if such revisions to reported data were not included in each previous year's results. Therefore, RSEI results are recomputed for all years on an annual basis in order to incorporate chemical deletions and modifications to the reported data.

[74] Separate results can also be calculated for each exposure pathway component of an environmental release, such as the drinking water exposure or fish ingestion components of a surface water release; however, in most user-facing applications the RSEI model results are presented at the overall environmental release level.

The deletion of chemicals for the TRI chemical list would presumably have a minor effect since such chemicals would be deleted due to their low hazard. Delisted chemicals are removed from the RSEI model. To account for changes in the representation of chemicals in the TRI database, RSEI uses flag fields to denote chemicals that have been listed on the TRI since a given year with no changes in reporting requirements. To allow for meaningful trend analyses, the RSEI model maintains a list of "core chemicals" which have been reported on since 1987, and for which their reporting requirements have not changed.

Facility-level changes can also affect year-to-year scores generated using the RSEI model. Compliance with TRI reporting has changed over time, which has led to more facilities reporting. Increases in the number of reporting facilities may also occur as a result of changes in reporting requirements. For instance, chemical activity threshold requirements for facilities were decreased over the first few years of TRI reporting, in addition to lowered thresholds for Persistent Bioaccumulative Toxic chemicals (PBTs). The TRI program has also expanded the set of industrial facilities required to report to include electric utilities, mining facilities, commercial hazardous waste facilities, solvent recovery facilities, and wholesale chemical and petroleum terminal facilities. All of these modifications can act to alter the total quantities reported to the TRI program and in turn result in alterations to the model's estimate of the associated relative risk-based impacts.

7. Current Implementation of the RSEI Method

RSEI model results are currently distributed in several different formats, for different users and stakeholders. Additional data products may be created in the future. Users are advised to check the RSEI website at https://www.epa.gov/rsei for updates and new products and features.

7.1 EasyRSEI Dashboard

RSEI model results are currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet browser[75] or through the RSEI website. The EasyRSEI dashboard allows users to view and query all RSEI model results for TRI reporting years 2007-2019 for modeled media. Pounds- and hazard-based results for non-modeled media, including waste management activities reported in Section 8 of the TRI Form R, are also available. A separate Qlik Sense dashboard is available for users who are interested in the full TRI time series (1988-2019), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download.[76]

Users of the EasyRSEI dashboard can quickly and easily view trends and rankings and filter by dimensions such as state, chemical, industry, year, etc., with no downloading required. Preformatted reports are also available for printing. Results can be used for screening-level ranking and prioritization for strategic planning purposes, risk-related targeting, and trends analyses. Considerable resources can be saved by conducting preliminary analyses with RSEI to identify risk-related situations of high potential concern, which warrant further investigation and evaluation.

As noted above, users can evaluate RSEI information using a number of variables, such as chemical, environmental medium, geographic area, or industry. For instance, the following types of questions can be investigated:

- How do industry sectors compare to one another from a risk-related perspective?
- What is the relative contribution of chemicals within a given industry sector?
- What exposure pathways for a particular chemical pose the greatest potential risk-related impacts?

Users can view pounds-based, hazard-based, and other results, to investigate the relative influence of toxicity and population components on the risk-related results, which also incorporate exposure modeling.

Information regarding the RSEI project is available on the RSEI web site at https://www.epa.gov/rsei. Complete documentation and contact information are all posted on the site. Periodic updates and troubleshooting information are also available for users.

[75] EasyRSEI is available at https://edap.epa.gov/public/extensions/EasyRSEI/EasyRSEI.html. The All Years version is available at https://edap.epa.gov/public/extensions/EasyRSEI_AllYears/EasyRSEI_AllYears.html.

[76] RSEI Queries and other data products are available at https://www.epa.gov/rsei/ways-get-rsei-results.

7.2 RSEI Geographic Microdata

RSEI users should note that, as implemented in EasyRSEI, the RSEI model employs a facility-based approach. All RSEI-modeled impacts are attributed to the facility originally releasing or transferring the TRI-listed chemical. For instance, an air release resulting from an off-site incinerator is modeled as exposing the population around that off-site facility, but the results (pounds, hazard, score, etc.) are attributed to the reporting facility that transferred the chemical to the off-site incinerator. Similarly, while impacts may extend beyond geographic boundaries such as zip code, county, or state, the RSEI results are attributed to the geographic entity in which the facility is located. EPA employs the RSEI methodology to create other databases which are geographically based. These Geographic Microdata datasets are very large and have to be manipulated outside of the user-friendly interface provided by the EasyRSEI dashboard.

Various Microdata datasets are available for download, as well as a brief documentation to help users understand the data and use them correctly. More information is available on the Ways to Get RSEI Results page on the EPA's RSEI website.

7.3 Other RSEI Data Products

RSEI model results can also be accessed in EPA data products like Envirofacts and the TRI National Analysis. There is also a map with current-year results on the RSEI website. Additional outlets for RSEI data are listed on the Ways to Get RSEI Results page on EPA's RSEI website.

7.4 Conclusion

As an indication of improvements in environmental quality over time, the RSEI model provides EPA and the public with a valuable tool to measure general trends based upon the relative risk-related impacts of TRI chemicals. Although RSEI model results do not capture all waste management activity quantities (e.g., all environmental releases of toxic chemicals), the model results generally relate changes in environmental releases to relative changes in chronic human health impacts from a large number of toxic chemicals of concern to the Agency. Importantly, RSEI provides an ability to analyze the relative contribution of chemicals, facilities, and industry sectors to adverse human health impacts, and RSEI results serve as an analytical basis for setting priorities for pollution prevention, regulatory initiatives, enforcement targeting, and chemical testing requirements.

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RSEI supporting documentation released by EPA

These documents can be found on the RSEI website at https://www.epa.gov/rsei/rsei-documentation-and-help.

RSEI Technical Appendices:

- Technical Appendix A - Toxicity Weights for TRI Chemicals and Chemical Categories
- Technical Appendix B - Physicochemical Properties for TRI Chemicals and Chemical Categories
- Technical Appendix C - Derivation of Model Exposure Parameters
- Technical Appendix D - Locational Data for TRI Reporting Facilities and Off-site Facilities
- Technical Appendix E - Derivation of Stack Parameter Data
- Technical Appendix F - Summary of Differences between RSEI Data and the TRI National Analysis

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