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

RSEI Version 2.3.6

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Executive Summary

ES-1. Introduction

EPA's Risk-Screening Environmental Indicators (RSEI) is a screening-level model that assesses the potential impact of industrial chemical releases from pounds-based, hazard-based, and risk-related perspectives. RSEI uses risk concepts to quickly and easily screen large amounts of emissions data from EPA's Toxics Release Inventory (TRI), saving time and resources. RSEI is particularly useful for examining trends to measure change, ranking and prioritizing chemicals and industry sectors for strategic planning, conducting risk-related targeting, and supporting community-based projects.

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 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 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 risk of chemicals, facilities, regions, industries, or many other factors. The values are for comparative purposes and only meaningful when compared to other values produced by RSEI. It should be emphasized that the result is *not* a detailed or quantitative risk assessment, *but offers a screening-level, risk-related perspective for relative comparisons of chemical releases.*

The RSEI approach is very flexible and can be implemented in various 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 characteristics, physicochemical properties, release levels, and release location 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 and industrial sectors to human health impacts, and RSEI results serve as an analytical basis for setting priorities for further risk analysis, 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 releases and transfers of chemicals to estimate the risk-related impacts associated with each type of air and water release or transfer by every TRI facility. 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, 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 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 period of time. All of the results, including pounds and hazard, 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 chemical releases. The 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 pathways only (stack and fugitive air releases, direct water releases, and transfers off-site to wastewater treatment or incineration). Hazard results are available for all other kinds of releases and transfers for chemicals with toxicity data.² In cases where toxicity weights are not available, only pounds-based results can be viewed.

ES-2.1 Geographic Basis of the Model

The model relies on 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 territories³ as an 810m by 810m grid 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).

¹ The method is focused on general populations; individuals, particularly highly exposed individuals, are not the focus of the model.

² Chemicals with toxicity data account for 99% of the total pounds reported to TRI in 2016.

³ 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.

In order to estimate potential 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 data⁴ 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.

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. These releases are reported by facilities to the TRI, as

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.

mandated by the Emergency Planning and Community Right-to-Know Act. As of the 2016 reporting year, there are over 600 TRI chemicals and chemical categories listed. Users can view pounds of chemicals released per year (pounds-based results) for any combination of variables included in the model.

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 the toxicological potential to cause chronic human health effects increases. Toxicity-adjusted releases are called “hazard-based results” and provide an alternative perspective to pounds-based 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, and rank them in a consistent manner. Values called Oral Slope Factors and Inhalation Unit Risks⁵ provide information pertaining to toxicity for chemicals that may cause cancer. Reference Doses (RfDs) and Reference Concentrations (RfCs) provide toxicity information related to noncancer 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-Scale Air Toxics Assessment (NATA), which generally obtains data from the other sources listed in this list, but in some cases uses values derived by the Office of Air Quality Planning and Standards (OAQPS);
- EPA Office of Pesticide Programs’ Acute and Chronic Reference Doses Table, List of Chemicals Evaluated for Carcinogenic Potential, and Pesticide Reregistration Eligibility Documents (OPP);
- Final, published Minimum Risk Levels (MRLs) from the Agency for Toxic Substances and Disease Registry (ATSDR);
- Final published toxicity values from California Environmental Protection Agency’s Office of Environmental Health Hazard and Assessment (CalEPA);
- EPA’s Provisional Peer Reviewed Toxicity Values (PPRTVs), which include toxicity values that have been developed by EPA’s Office of Research and Development/National

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 µg/m³ 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 noncancer effects during a lifetime.

Center for Environmental Assessment/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 (Derived).

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

- Oral Slope Factor (OSF) in risk per mg/kg-day,
- Inhalation Unit Risks (IUR) in risk per mg/m³,
- Reference Doses (RfD) in mg/kg-day, and
- Reference Concentrations (RfC) in mg/m³

Each value is transformed into a toxicity weight, so that as the toxicity weight increases, the toxic effects 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
	Noncancer	3.5 / RfC	1 / RfD
*If the Weight of Evidence Category (WOE) 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 the RfC, RfD, IUR and OSF. The RSEI results may use different toxicity weights, depending on the data.

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

In addition, the RSEI score, cancer score and noncancer score all use the inhalation route toxicity weight (RfC or IUR as appropriate) for the portion of the POTW transfer that volatilizes during treatment and the oral route toxicity weight (RfD or OSF as appropriate) for the remainder that is released with the POTW effluent.⁷ The three hazard-based results do not account for partitioning,

⁷ Chemical-specific partition 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 as effluent.

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.

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

	Air Releases	Water Releases	POTW Transfers	Fill in Tox Data Gaps?
Score	Higher of IUR tox weight or RfC tox weight	Higher of OSF tox weight or RfD tox weight	For volatilization use higher of IUR tox weight or RfC tox weight. For effluent use higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no data in one exposure route, use data from other 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 volatilization use IUR tox weight. For effluent use higher of OSF.	No. If no route-specific cancer tox weight, then cancer score is zero.
NonCancer Score	RfC tox weight.	RfD tox weight.	For volatilization use RfC tox weight. For effluent use or RfD tox weight.	No. If no route-specific noncancer tox weight, then noncancer 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 data in one exposure route, use data from other 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.
NonCancer Hazard	RfC tox weight.	RfD tox weight.	RfD tox weight.	No. If no route-specific noncancer tox weight, then noncancer hazard is zero.

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 2016 TRI Chemical List. Toxicity weights are available for over 400 of these chemicals and chemical categories.⁸ Chemicals with toxicity weights account for 99% of the reported pounds for all releases to modeled media in 2016.

Adjustments for Exposure Potential and Population Size. Quantitatively, exposure potential is estimated using a “surrogate” dose. To estimate the surrogate dose, a separate exposure

⁸ TRI lists metal compounds and their elemental forms separately, e.g., “lead” and “lead compounds” are two categories in TRI. RSEI combines compounds and elemental forms into one category, as in “lead and lead compounds.”

evaluation is conducted for each pathway-specific chemical emission. 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 concentration in the 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 estimate of dose resulting from TRI releases, because limited facility-specific data and the use of models that rely on default values for many parameters prevent the calculation of an actual dose. Instead, the purpose of the methodology is to generate as accurate a surrogate dose as possible without conducting an in-depth risk assessment. The estimates of surrogate doses from releases of TRI chemicals are *relative to the surrogate doses resulting from other releases included in the model*. Please note that not all pathways are currently modeled.

ES-2.2 RSEI Results

Because of the multi-functional nature of the model, a variety of results can be created. 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	TRI Pounds released

Risk-related results (scores). The exposure route-specific 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 subpopulation-specific exposure factors. The score is a unitless measure that is *not* independently meaningful, but is a risk-related estimate that can be compared to other estimates calculated using the same methods. If toxicity data or data required for modeling is zero, or if the release pathway is not currently modeled, then the risk-related score is zero.

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

- **RSEI Score-** Product of surrogate dose, population, and the higher toxicity weight for each exposure route (see Exhibit ES.2 for details).

Hazard-based results. Hazard-based results (“Hazard”) are calculated by multiplying the pounds released by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure pathway). The inhalation toxicity weight is used for releases or transfers to fugitive air, stack air, and off-site incineration. The oral toxicity weight is used for releases to direct water 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.

- **Cancer Hazard-** Product of TRI Pounds and the IUR toxicity weight or the OSF toxicity weight (see Table ES.2 for details).
- **NonCancer Hazard-** Product of TRI Pounds and the RfC toxicity weight or the RfD toxicity weight (see Table ES.2 for details).
- **RSEI Hazard-** Product of TRI Pounds and the higher toxicity weight for each exposure route (see Table ES.2 for details).

Pounds-based results. These results (“TRI Pounds”) reflect only the number of pounds released or transferred that are reported to TRI, and are available for all releases and transfers.

Once 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 releases⁹.

This method is very flexible, allowing for countless variation in the creation of results. For example, results can be calculated for various subsets of variables (e.g., chemical, facility, release 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 calculated, 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 facilities or chemicals with the highest potential for hazard or risk, the score does not represent a quantitative estimate or provide an exact indication of the magnitude of individual hazard or risk associated with that facility or chemical.

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 facilities represented in TRI, the numerical value of RSEI results will be altered if no adjustments are

⁹ Separate results can also be calculated for the pathway components of a release, such as the drinking water exposure or fish ingestion components of a direct water release; however, in most user-facing applications the RSEI results are presented at the release level.

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 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 facilities in the TRI database 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 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 analysis, the model maintains a list of “core” chemicals which have been reported since 1987, and for which 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, in the first two years of reporting, facilities that manufactured or processed more than 50,000 pounds were required to report their releases. However, EPCRA lowered this threshold to 25,000 pounds in 1989. And for reporting year 2000, thresholds and other reporting requirements for 18 Persistent Bioaccumulative Chemicals (PBTs) have been changed. Effective for reporting year 1998, TRI has enlarged the set of 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 emissions reported on the TRI and the model’s estimate of the associated relative risk-based impacts.

When deletions from the chemical list of TRI chemicals occur, RSEI’s chemical database is modified to remove all results from previous reporting years. Also, the yearly TRI data for a given chemical list of chemicals and facilities are the subject of ongoing quality control review and correction by both EPA and reporting facilities. As a result, yearly comparisons could be flawed if such revisions in 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 revisions to the reporting data.

ES-2.4 RSEI Data Products

Users can access RSEI results in a variety of ways. RSEI results are included in EPA data tools such as Envirofacts¹⁰ or TRI.NET¹¹ (hazard-based results only). RSEI model results are currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet

¹⁰ RSEI results are located in the TRI section of Envirofacts (<https://www.epa.gov/enviro/tri-search>), under the heading “Risk-Screening.”

¹¹ TRI.NET is a downloadable application that allows you to select, sort and filter TRI data (<https://www.epa.gov/toxics-release-inventory-tri-program/trinet>). RSEI hazard-based results are found under “Hazard.” TRI.NET will be replaced by a new application, TRI Analyzer, which will also contain RSEI hazard results.

browser. The dashboard allows users to view and query all RSEI results for TRI reporting years 2006-2016 for modeled media. Pounds- and hazard-based results for non-modeled media are not available in this interface. A separate Qlik Sense dashboard is available for users who are interested in the full TRI time series (1988-2016), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download. Additional dashboards, including a full time series with TRI pounds and hazard results for all TRI waste management categories (including Section 8), are provided for EPA users.

Users of the 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 evaluation.

As noted above, users can evaluate releases using a number of variables, such as chemical, 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 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 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 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 activity of listing/delisting chemicals on the TRI using statutory criteria.

The goal of RSEI is to use data reported to the Agency to investigate the relative risk-based impacts of the releases and transfers of these chemicals on the general, non-worker population. The model differentiates the relative toxicity of listed chemicals and ranks them in a consistent 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. Furthermore, the model addresses only the single, most sensitive toxicity endpoint for chronic human health.

In contrast, the EPCRA statutory criteria used for listing and delisting chemicals consider 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 relative to a benchmark value.

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

ES-3. Important Caveats Regarding the RSEI Model

The RSEI model is a screening tool that provides a risk-related perspective in assessing the relative impacts of releases of toxic chemicals. Risk-related results are available for releases and transfers to air and water, and pounds- and hazard-based results can be calculated for all media. RSEI scores combine estimates of toxicity, exposure level, and the exposed population to provide risk-related comparisons, but do not provide a detailed or quantitative assessment of risk, and are not designed as a substitute for more comprehensive, site-specific risk assessments. There are a number of important considerations associated with each component of the model, as described in the following sections.

Release Component. The following caveat should be considered regarding the release component of the model:

- RSEI uses facility-reported TRI data, which are known to contain some reporting errors. Since facility management must certify reports to be accurate, the TRI program does not change any reported data until the reporting facility submits an official correction. Therefore, there are some releases in the TRI data that are thought to be erroneous but are still included because facilities have not submitted corrected reporting forms by the time of the annual public data release that RSEI uses. Some of these releases are associated with large risk-related impacts.

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

- Toxicity weights are not designed to (and may not) correlate with statutory criteria used for listing and delisting chemicals in TRI. RSEI risk-related model results account for estimated exposure and may not correlate with listing/de-listing decisions.
- The RSEI model only addresses chronic human toxicity (cancer and noncancer 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 Reference Doses and Reference Concentrations for noncancer effects incorporate uncertainty factors which are reflected in toxicity weights that are based upon these values.
- Toxicity weights for chemicals that are reported to TRI as groups are based on the toxicity for the most toxic member of the group. One exception to this is polycyclic aromatic compounds (PACs), the toxicity for which is assumed to be 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-Scale Air Toxics Assessment (NATA) evaluation for polycyclic organic matter.¹²
- 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 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. Industry-level estimates specific to 4- or 6-digit North American Industry Classification System (NAICS) codes from the 2011 National Emissions Inventory (NEI) are used to estimate the fraction of each type.¹³ As trivalent chromium has a very low toxicity, only the hexavalent 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.
- While the physical form of released metals or metal compounds can affect toxicity, a reasonable assumption is made regarding the likely form of most 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 acid aerosols are not expected to be typical so the toxicity weight for cancer based on the inhalation of particulates is used). Analysts need to consider these assumptions, and whether the gathering of additional data is warranted, when examining model results for metals and metal compounds.

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 model provides estimated air concentrations in each grid cell.
- The model uses some generic assumptions, e.g., default median stack heights, diameters, and exit gas velocities related to 4- or 6-digit NAICS codes, or a nationwide median,

¹² Additional information is available in the NATA documentation (<https://www.epa.gov/national-air-toxics-assessment/2011-nata-technical-support-document>). RSEI assumes that PAC emissions reported to TRI are most like NATA's "7-PAH" category.

¹³ A default of 34% hexavalent is used where NAICS-based data are unavailable. The NEI is available at <https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data>

where facility-specific median stack height, diameter, and exit gas velocity 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 model, only air and direct surface water exposures are fully modeled.
- The model does not account for population activity patterns.
- The model does not account for indirect exposure, 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 2016.
- 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 releases 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 2.3.6

- Includes TRI Reporting Years 1988-2016.
- Toxicity weights have been updated with the most recent toxicity data.
- The off-site database has been improved, with more precise locations for bigger off-site facilities, and better matching of facilities.

1. Introduction

EPA's Risk-Screening Environmental Indicators (RSEI) is a screening-level tool that assesses the potential impact of industrial releases from pounds-based, hazard-based, and risk-related perspectives. RSEI uses risk concepts to quickly and easily screen large amounts of TRI data, saving time and resources. RSEI is particularly useful for examining trends to measure change, ranking and prioritizing chemicals and industry sectors for strategic planning, conducting risk-related targeting, and supporting community-based projects.

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 all people are equally exposed. Formal risk assessments are more accurate, but are complicated and time consuming to prepare, requiring detailed data that is not always available, and the results are often limited in scope and geographic area. The RSEI approach augments estimates of pounds released with toxicity and exposure considerations, but does not address all of the potential factors normally 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 risk of chemicals, facilities, regions, industries, or many other factors. The values are for comparative purposes and only meaningful when compared to other values produced by RSEI. It should be emphasized that the result is *not* a detailed or quantitative risk assessment, *but offers a screening-level, risk-related perspective for relative comparisons of chemical releases.*

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 various ways. The use of the model is not limited to TRI chemicals; in principle, the adaptable method can model any chemical if toxicity characteristics, physicochemical properties, release levels, and release location are known or can be estimated.

1.1 Background

In 1989, EPA outlined the goals for establishing strategic planning processes at the Agency (EPA, 1990c). Underlying this approach 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 environmental health 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 contribution of particular chemicals, industries and geographic regions through the indicators would allow the Agency (and other users) 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 multimedia trends in environmental contaminant releases. The TRI is one of the Agency's most relevant source of continuous data for developing indicators of change in environmental impacts over time. The TRI is mandated by the Emergency Planning and Community Right-to-Know Act (EPCRA) Title III Section 313 and requires that U.S. manufacturing facilities file annual reports documenting multimedia environmental releases and off-site transfers for more than 600 chemicals and chemical categories which are of concern to the Agency.

In response to the need for environmental indicators, and to take advantage of the rich data source offered by the TRI, 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 toxicity, exposure and population considerations into the risk-related evaluation of releases. The RSEI model was developed in response to this initiative.

When evaluating impacts of chemicals, it is important to not only consider the number of pounds 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 chemical releases and transfers. To the extent possible, the RSEI model is based on existing EPA approaches, data, and models, to minimize duplication of effort and to maximize consistency with other Agency efforts to evaluate human health impacts.

The current version of the model tracks changes in chronic human health impacts. Ultimately, the model may be expanded to track acute human health and chronic and acute 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 and groups that may wish to use or adapt the model, or the RSEI methodology in general, to their own needs. In addition, it describes the advantages of the RSEI approach in terms of flexibility, power, and usefulness as an analytical and strategic policy-planning tool.

1.2 RSEI Data Products

Users can access RSEI results in a variety of ways. RSEI results are included in EPA data tools such as Envirofacts or TRI.NET (hazard-based results only). RSEI model results are also currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet browser. The dashboard allows users to view and query all RSEI results for TRI reporting years 2006-2016 for modeled media. Pounds- and hazard-based results for non-modeled media are not available in this interface. A separate Qlik Sense dashboard is available for users who are interested in the full TRI time series (1988-2016), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download. Additional dashboards, including a full time series with TRI pounds and hazard results for all TRI waste management categories (including Section 8), are provided for EPA users.

RSEI also produces geographically disaggregated data, called the Geographic Microdata. These are very large datasets that present results for air pathway at the level of the 810m² grid cell. Results include score, 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, 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 method and model, as well as a discussion of their overall strengths and limitations. Chapter 3 describes the TRI emissions data used in the model. Chapter 4 describes the methods used to adjust the emissions 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 - Listing of All 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

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](#). 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 TRI releases 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:¹⁴

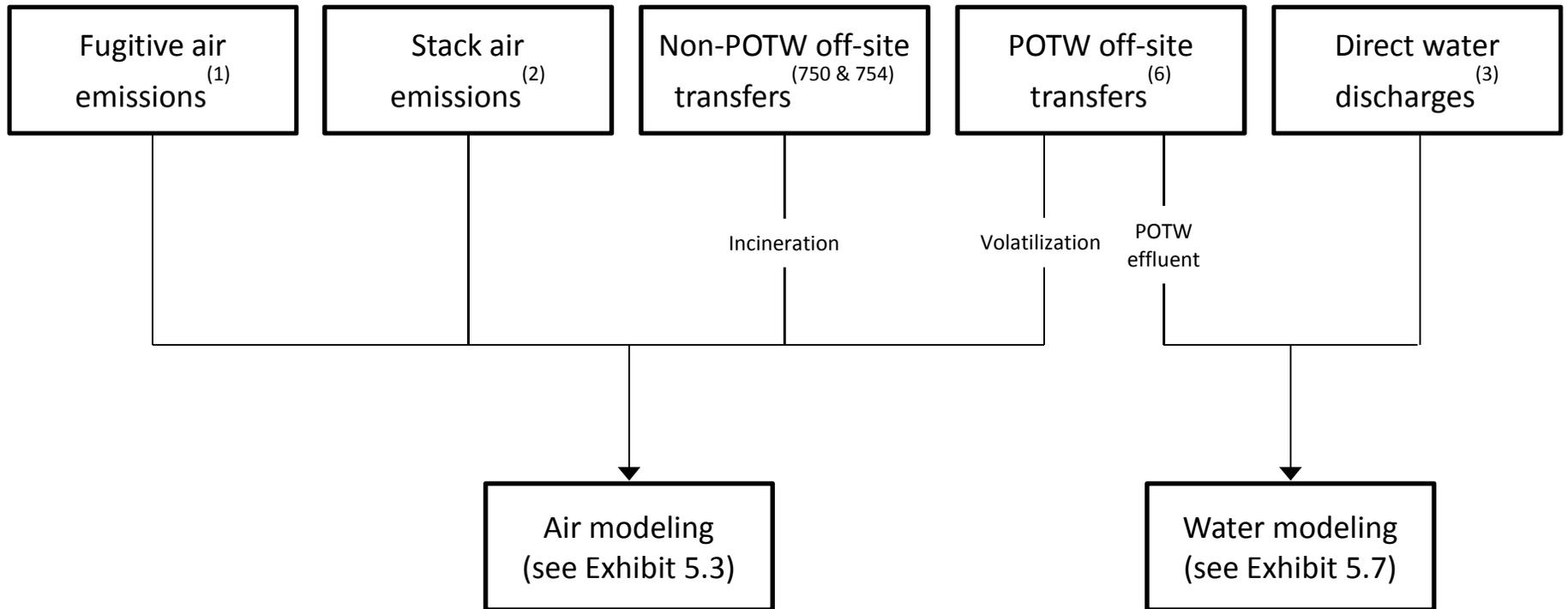
- The TRI, maintained by EPA, provides the data on the **quantity of chemicals** released to air, water, on-site disposal facilities, and transferred to off-site facilities for more than 600 toxic chemicals that are listed on the TRI. Reporting by facilities to the TRI began in 1987, and has continued each year since then (RSEI uses TRI reporting data beginning in 1988). RSEI Version 2.3.6 contains TRI data for reporting years 1988 through 2016 for modeled media only (stack air, fugitive air, direct water, transfers to POTWs and off-site transfers to incineration). Releases are reported in pounds per year.
- **Toxicity weights** are assigned to each chemical for which adequate data are available. These weights are assigned using quantitative toxicity values developed by EPA scientists and additional qualitative assessments, as described below.
- **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 estimated. The estimation of a surrogate dose allows comparisons across pathways. Then the population exposed to each release is estimated using decennial U.S. census data.

RSEI produces three main kinds of results: risk-related scores, hazard, and pounds. Scores require the most information to calculate (fate and transport information, toxicity, pounds released, population) and are not available for all kinds of releases and transfers reported to TRI. Hazard is calculated using only release volumes and toxicity, and is available for all kinds of releases and transfers. “Pounds” are release volumes as 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, 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 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 period of time. All of the results, including pounds and hazard, are proportional and work in the same way.

¹⁴ The method focuses on general populations: individuals, particularly highly exposed individuals, are not the focus of the model. Furthermore, worker exposures are not addressed.

**Exhibit 2.1
RSEI Modeling Approach**



⁽¹⁾ indicates media code 1: Fugitive Air Release

⁽²⁾ indicates media code 2: Stack Air Release

⁽⁷⁵⁰⁾ indicates media code 750: Offsite Incineration/Thermal Treatment Release

⁽⁷⁵⁴⁾ indicates media code 754: Offsite Incineration (no fuel value) Release

⁽⁶⁾ indicates media code 6: POTW Transfer

⁽³⁾ indicates media code 3: Direct Water Release

Exhibit 2.2
Description of RSEI Results

Risk-related results	Surrogate Dose x Toxicity Weight x Population
Hazard-based results	Pounds x Toxicity Weight
Pounds-based results	TRI Pounds Released

Risk-related results (scores). The pathway-specific 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 subpopulation-specific exposure factors. The score is a unitless measure that is *not* independently meaningful, but is a risk-related estimate that can be compared to other estimates calculated using the same methods. If the RSEI score cannot be calculated, because of a lack of toxicity data or data needed for modeling or because the release pathway is not currently modeled, then the risk-related score is zero.

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

Hazard-based results. Hazard-based results (“Hazard”) are calculated by multiplying the pounds released by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure pathway). The inhalation toxicity weight is used for releases or transfers to fugitive air, stack air, and off-site incineration. The oral toxicity weight is used for releases to direct water 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.

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

Pounds-based results. These results reflect only the number of pounds released or transferred that are reported to TRI, and are available for all releases and transfers. In some user-facing applications, there can be more than one pounds value reported- “TRI Pounds” counts all of the

pounds reported to TRI for all releases and transfers, while “RSEI Modeled Pounds” only counts the pounds reported for the kinds of 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, 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 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 period of time. All of the results, including pounds and hazard, 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 facilities or chemicals with the highest potential for hazard or risk, the score does not represent a quantitative estimate or provide an exact indication of the magnitude of individual hazard or risk associated with that facility or chemical.

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 TRI releases on chronic human health.
- The model quickly organizes and evaluates complex data. For example, the air exposure model is combined with U.S. census data to directly estimate the size of exposed populations and subpopulations 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-designed selections can be based upon a wide range of variables.
- This adaptable method can model any chemical if toxicity characteristics, appropriate physicochemical properties, release levels and release location 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 peer review.
- The model’s methodology and assumptions are transparent. Complete and detailed documentation of the RSEI model is available.

2.2.2 Limitations

The following are limitations of the model:

- RSEI results do not provide users with quantitative risk estimates (excess cases of cancer).
- RSEI results do not evaluate individual risk.
- The model does not account for all sources of TRI chemicals; it only accounts for those sources that are required to report to TRI. It also does not provide scores for all TRI chemicals, although chemicals without toxicity weights account for a very small percentage of total releases and of total risk-related impacts.
- TRI does not account for all toxic chemicals.
- 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.
- Acute health effects associated with short-term, periodic exposures to higher levels of these same chemicals are not addressed.
- Ecological effects are not addressed.

3. TRI Emissions Data

The RSEI model uses information on chemical releases and transfers collected by the TRI. The TRI 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 groups. TRI operates under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). EPCRA's primary purpose is to inform communities and citizens of chemical hazards in their areas. Sections 311 and 312 of EPCRA require businesses to report the locations and quantities of chemicals stored on-site in order to help communities prepare to respond to chemical spills and similar emergencies. EPCRA Section 313 requires EPA and the States to annually collect data on releases and transfers of certain toxic chemicals from industrial facilities, and to make the data available to the public in the TRI. In 1990, Congress passed the Pollution Prevention Act which required that additional data on waste management and source reduction activities be reported to TRI. The goal of the TRI Program is to provide communities with information about toxic chemical releases and waste management activities and to support informed decision making at all levels by industry, government, non-governmental organizations, and the public. EPA compiles the TRI data each year and makes it available through several data access tools, including several through Envirofacts.¹⁵

The TRI release and transfer data reported each year are the initial source of quantitative data on potential chronic human exposure used in RSEI. However, the EPA has an open revision policy that allows facilities reporting to the TRI to submit changes and corrections to their TRI data at any time. To avoid the effects of these fluctuations on RSEI results, the model extracts release and transfer data during the two week period each year when EPA "freezes" the data, that is, when no changes are allowed. To ensure that each RSEI model update is current on all revisions to the TRI database, data for all years are extracted once a year during the "data freeze" period, and added to the model, replacing the previous data. The same data freeze is used in preparing EPA's TRI National Analysis. It should be noted that the "frozen" data set is not necessarily the same as the TRI database publicly accessible through the Internet: EPA's TRI Explorer or Envirofacts are "live" databases that are regularly updated. Despite EPA's open revision policy, errors do still happen, and some errors remain in the system for more than one year. It is therefore important to perform additional inquiries and analyses to support and verify results from RSEI, which should only be used as a screening tool.

Even though the TRI National Analysis and RSEI both use the annual 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 releases from RCRA-regulated chemical treatment, storage, and disposal (TSD) facilities, while

¹⁵ This program description is taken from the TRI web site, <https://www.epa.gov/tri>. The web site provides additional information, including reporting requirements for facilities.

RSEI 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 off-site transfers to incineration to any facility reporting to TRI and in NAICS code 562211 (Hazardous Waste Treatment and Disposal).¹⁶

- 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.”

¹⁶ See section 5.6 for more information.

4. Methods for Calculating Toxicity Weights

The EPCRA Section 313 criteria list several human toxicity parameters that EPA must consider when evaluating a chemical for addition to TRI, 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. Some chemicals have toxicity data for only one effect, while others have evidence of effects within several of these toxicity categories. The definitions of types of toxicity as given in Section 313 are presented in Exhibit 4.1.

The RSEI model focuses on carcinogens and other types of chronic toxic effects that are typically associated with chronic exposures.¹⁷ The 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.
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).

¹⁷ 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.

4.1 Toxicity Weighting Scheme for Non-carcinogens and 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 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 these effects that it causes; the relative severity of the effects it causes; the potency of the chemical for one or more of these effects; and the uncertainty inherent in characterizing effects. The RSEI method focuses on the latter two factors (potency and uncertainty inherent in characterizing effects), 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 toxicity weights or in their underlying toxicity values. The approach is intended to differentiate the relative toxicity of these chemicals in a uniform manner.

When evaluating the potential toxicity of a chemical to humans, risk assessors use a variety of data, including epidemiological data, data from acute and chronic animal studies, and in vitro toxicity tests. Together, these data form a body of evidence regarding the potential for toxic chemicals to cause a particular health effect in humans. The risk assessor can judge qualitatively the strengths of this body of evidence when determining the probability of the occurrence of the effect in humans. Based on this 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 a specific health effect in general, or specifically in humans.

For **cancer** effects, the WOE system presented in this 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.¹⁸ The Cancer Guidelines define the six WOE categories shown in Exhibit 4.2. In the RSEI model, weight-of-evidence categories A, B1, and B2 (known and probable carcinogens) are combined. The combination of the A and B categories represents a modification of the Hazard Ranking System (HRS), which is

¹⁸ 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 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**

used by EPA’s Office of Superfund Remediation and Technology Innovation to rank hazardous waste sites for inclusion in the National Priorities List. 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 A and B categories stabilizes the model results against changes induced by chemicals switching between the A and B designations. Class C chemicals (possible carcinogens) are assigned 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 a factor is based on the advice of peer review and the HRS; an order of magnitude difference is an arbitrary uncertainty factor. Categories D and E are not considered in this weighting scheme (i.e., no toxicity weight is 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

For **noncancer** effects, weight-of-evidence is considered qualitatively in the hazard identification step of determining an RfD or an RfC. The WOE evaluation for noncancer effects is different from that for carcinogenic effects. The WOE judgment for noncancer effects focuses on the dose 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 is a judgment of the accuracy with which the dose relevant to humans has been estimated. The WOE evaluation is included qualitatively in the RfD, but does not affect its numerical calculation. Since weight-of-evidence has been considered in developing RfDs, RSEI does not consider WOE separately for noncancer effects.

4.1.2 Quantitative Data

Quantitative data on the relative potencies of chemicals are needed for toxicity weighting. These data generally result from analyses done during the third stage of risk assessment, the dose-response assessment. This stage involves describing the quantitative relationship between the

amount of exposure to a chemical and the extent of toxic injury or disease observed. 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 it 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 dose 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 $(\text{mg}/\text{kg}\text{-day})^{-1}$. The IUR is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of $1 \mu\text{g}/\text{m}^3$ in air (RSEI 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 a comparison of the relative cancer potency of chemicals.

RSEI's oral cancer toxicity weight (OTW_c) represents how toxic a substance is relative to a substance that produces a 1 in 1 million risk¹⁹ (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 substance is more toxic than the arbitrary slope factor), the OTW_c is greater than 1.

$$OTW_c = \frac{OSF \text{ kg-day} / \text{mg}}{10^{-6} \text{ kg-day} / \text{mg}} \quad (\text{Eq. 4.1})$$

For **noncancer 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) or Inhalation 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 [or continuous inhalation exposure the RfC] to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious [noncancer] effects during a lifetime” (EPA, 1988a; EPA, 1990b). The units of RfD are mg/kg-day, while the units of the RfC are mg/m³. A chemical's RfD or RfC is typically based on a No Observable Adverse Effect Level (NOAEL) or Lowest Observable 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 database for the chemical. By definition, exposures below the RfD/RfC are unlikely to produce an adverse effect; above this value, an exposed individual may

¹⁹ 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).

be at risk for the effect. Empirical evidence generally shows that as the dosage of a toxicant increases, the severity and/or incidence of effect increases (EPA, 1988a), but for a given dose above the RfD/RfC, the specific probability or severity of an effect is not known. For purposes of the RSEI model, it is assumed that noncancer risk varies as the ratio of the estimated dose to the RfD/RfC.

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

$$OTW_{nc} = \frac{1 \text{ mg / kg-day}}{RfD \text{ mg / kg-day}} \quad (\text{Eq. 4.2})$$

4.1.3 Algorithm for Calculating Toxicity Weight

The RSEI method uses several different algorithms to assign toxicity weights. RSEI toxicity weights are designed to be proportional to a substance's toxicity. The more toxic a substance is, the higher the toxicity weight.

Toxicity values for the inhalation pathway are typically expressed in units of exposure, that is, mg of chemical per m³ of air. The toxicity weighting methodology, therefore, uses standard adult human exposure factors for inhalation rate (20 m³/day) and body weight (70 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 (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, noncancer 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 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 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
	NonCancer	3.5 / RfC	1 / RfD
*If the Weight of Evidence Category (WOE) 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 results may use different toxicity weights, depending on the data.

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

In addition, the RSEI score, cancer score and noncancer score all use the inhalation route toxicity weight (RfC or IUR as appropriate) for the portion of the POTW transfer that volatilizes during treatment and the oral route toxicity weight (RfD or OSF as appropriate) for the remainder that is released with the POTW effluent.²⁰ 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.

Exhibit 4.4
Selection of Toxicity Weights for Each RSEI Result

	Air Releases	Water Releases	POTW Transfers	Fill in Tox Data Gaps?
Score	Higher of IUR tox weight or RfC tox weight.	Higher of OSF tox weight or RfD tox weight.	For volatilization use higher of IUR tox weight or RfC tox weight. For effluent use higher of OSF tox weight or RfD tox weight.	Yes. If a chemical has no data in one exposure route, use data from other pathway. For instance, if a chemical has no IUR or RfC tox weight, use higher of RfD or OSF tox weight for air releases.

²⁰ Chemical-specific partition 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 as effluent.

	Air Releases	Water Releases	POTW Transfers	Fill in Tox Data Gaps?
Cancer Score	IUR tox weight.	OSF tox weight.	For volatilization use IUR tox weight. For effluent use higher of OSF.	No. If no route-specific cancer tox weight, then cancer score is zero.
NonCancer Score	RfC tox weight.	RfD tox weight.	For volatilization use RfC tox weight. For effluent use or RfD tox weight.	No. If no route-specific noncancer tox weight, then noncancer 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 data in one exposure route, use data from other 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.
NonCancer Hazard	RfC tox weight.	RfD tox weight.	RfD tox weight.	No. If no route-specific noncancer tox weight, then noncancer hazard is zero.

RSEI Score and RSEI Hazard select the higher cancer/noncancer toxicity weight for each exposure route (oral/inhalation), and if one route is missing both toxicity weights, the other route’s 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 effects via one route; in these instances, a toxicity weight is assigned only to the route that results in chronic human health 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 chemicals can cause several types of toxic effects, the model assigns a toxicity weight to a chemical based on the single most sensitive adverse effect for the given exposure route (oral or inhalation). If a chemical exhibits both carcinogenic and noncarcinogenic effects, the higher of the associated cancer and noncancer weights is assigned as the final weight for the chemical for the given route for the RSEI score and RSEI hazard. For the other results, cancer and noncancer effects are not mixed.

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

still hazardous chemicals. For these reasons, the options for applying additional weights based on number and relative severity of endpoints were not adopted.

4.3 Chemical Groups

TRI collects information for some chemicals as combined groups, such as glycol ethers, polycyclic aromatic compounds, and metal compounds. For metal compounds, RSEI combines the elemental form of the metal with its compounds category. This is done to reflect the uncertainty of the chemical identity of the substance released. For example, TRI has separate reporting for ‘nickel’ and ‘nickel compounds’. Both reflect the pounds of the parent metal nickel that is released and, in some cases, the two can be combined as a single report for nickel compounds. RSEI combines the pounds into one entry listed as ‘nickel and nickel compounds’. Metals and metal compounds are assumed to have the same toxicity weight, although the chronic toxicity of some metal compounds may be higher. Generally, metals and metal compounds are assumed to be released in the valence (or oxidation state) associated with the highest chronic toxicity.

For all chemical groups, data for the most toxic member of the group is used to represent the toxicity of the entire group. There are four exceptions. The first exception is chromium and chromium compounds, for which it is assumed that facilities may release some combination of hexavalent chromium and trivalent chromium. NAICS-code specific estimates from the 2011 NEI are used to estimate the fraction of each type.²¹ As trivalent chromium has a very low toxicity, only the hexavalent fraction is modeled, using a toxicity weight specifically for that valence state.

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 it is assumed that the overall toxicity for the category is 18% of the toxicity for benzo(a)pyrene, the most toxic member of the group. This figure is based on the polycyclic organic matter (POM) methodology used by EPA’s National Air Toxics Assessment (NATA) model, which is based on emissions factors for representative processes used in industries that emit large amounts of POM. RSEI assumes that the TRI PACs category is most like the 7-PAH category used in NATA.²²

The fourth exception is for dioxins and dioxin-related compounds. EPA first required reporting of releases and transfers for this category in 2000. Facilities were required to report total dioxin releases/transfers (in grams) released/transferred to each medium, as well as the amount of each of the 17 congeners that comprise the category released/transferred to all media combined. EPA changed the reporting requirements in 2008, when reporters were required to provide the congener breakdown for each medium. Toxicity information is only available for one congener,

²¹ The NEI is available at <https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data>.

²² The documentation on modeling polycyclic organic matter (POM) from EPA’s NATA model can be found at <https://www.epa.gov/national-air-toxics-assessment/2005-national-air-toxics-assessment#pom>.

TCDD, but EPA has determined a toxicity equivalence factor (TEF) for each congener, based on its toxicity relative to TCDD²³. RSEI combines TRI's congener breakdown with EPA's TEFs to calculate a weighted average TEF for each release. When multiplied by the toxicity weight for TCDD, this provides a toxicity weight for each dioxin release/transfer. For releases/transfers where the congener breakdown is blank or invalid, RSEI adopts the mean TEF for all of the dioxin releases to that medium in the reporting facility's 4-digit NAICS code. If a 4-digit NAICS code for the reporting facility is not available, the overall mean for the specific medium is used. Because the congener breakdown at the level of the release/transfer is only available from 2008 on, hazard and full modeling results are only available for that period; however users can examine pounds-only results for dioxins from 2000 on.

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

4.4 Sources of Data

Information regarding the human health effects data on the 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). IRIS is available on the internet (at <https://www.epa.gov/iris>), and includes information on EPA evaluations of chemical toxicity for both cancer and noncancer 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 noncancer effects. Data contained in IRIS have been peer-reviewed and represent Agency-wide expert 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.

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

OPP. EPA's Office of Pesticide Programs (OPP) Acute Chronic and Reference Doses Table lists OPP's evaluations of the noncarcinogenic 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, which deals with the effect on public health of

²³ 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 TEFs, see <https://www.epa.gov/risk/documents-recommended-toxicity-equivalency-factors-human-health-risk-assessments-dioxin-and>.

hazardous substances in the environment. ATSDR develops Minimum Risk Levels (MRLs) for chemicals on the CERCLA National Priorities List. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer 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://www.arb.ca.gov/toxics/healthval/healthval.htm>.

PPRTVs. EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) include toxicity values developed by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC).

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

Derived Values. For a prioritized group of chemicals for which sufficient data was 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 this 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 values, RfC values, cancer risk estimates, and weight-of-evidence (WOE) determinations. However, it must be emphasized that these derived values are not the equivalent of the more rigorous and resource-intensive IRIS 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. Data are gathered separately for individual endpoints; a chemical's RfD may be from IRIS, while its OSF may be from HEAST.

The hierarchy used in toxicity weighting is as follows:

Tier 1. The most recent data from IRIS and OPP is used for each chronic health endpoint. If the dates are comparable, preference is given to IRIS, since IRIS reflects Agency-wide judgments. If 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 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 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, weight-of-evidence (WOE) values are obtained using the same data source hierarchy. Therefore, preference is given to WOE's from IRIS or OPP. As a general rule, chemicals with cancer potency factors from IRIS or OPP will also have WOE's. 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, WOE's are obtained from IARC. However, due to the differences in WOE definition, it is not always possible to translate IARC WOE's into EPA WOE's without examining the toxicity data. WOE's are matched in the following way:

- IARC Group 1 = EPA Group A (Human Carcinogen)
- IARC Group 2A = EPA Group B (Probable Human Carcinogen)
- IARC Group 2B = EPA Group B or EPA Group C (Possible Carcinogen)
- IARC Group 3 = EPA Group D (Not Classifiable as to Human Carcinogenicity)
- IARC Group 4 = EPA Group E (Evidence of Non-Carcinogenicity)

The IARC 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 designation will affect the calculation of the toxicity weight. Therefore, for the chemicals with IARC 2B designations, summaries of the toxicity data used to generate the OSF or IUR are evaluated to derive WOE's. 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 2016 TRI Chemical List. Chemicals with toxicity weights account for over 99% of the reported pounds for all modeled releases in 2016. 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 groups are presented in Technical Appendix A.

4.5 How RSEI Toxicity Weightings Differ from EPCRA Section 313 Criteria

As noted above, the model uses TRI chemical reporting data. All TRI chemicals included in the model are listed on the TRI because they meet one or more statutory criteria regarding acute or chronic human toxicity, or environmental toxicity. The goal of the RSEI model is to use these data reported to the Agency to investigate the relative risk-based impacts of the releases and transfers of these chemicals on the general, non-worker population. To achieve this goal, the model differentiates the relative toxicity of listed chemicals and ranks them in a consistent 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 a benchmark or absolute value as is required when adding or removing a chemical from the TRI. Furthermore, the model addresses only the single, most sensitive chronic human health toxicity endpoint.

It is important that the public not confuse the use of the RSEI 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 activity of listing/delisting chemicals on the TRI 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 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 TRI releases, a separate exposure evaluation is conducted for each chemical release pathway. The following pathways are evaluated:

- **Air:** stack and fugitive 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 a dose would involve a *site-specific* exposure assessment for each release and exposure pathway. However, such an effort is well beyond the scope of this project; further, reporting of extensive site-specific information relevant for exposure modeling is not part of a TRI data submission. For example, the EPA Form R (Toxic Release Inventory Reporting Form) does not require submission 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 model, it is not the intent of this project to gather extensive site-specific data or measurements that would be needed to perform site-specific calculations. The need to accurately reflect exposure characteristics in the RSEI model must be balanced by the need for simple and understandable results that are easily communicated to the public and that are based on currently available data.

Therefore, in this method, the exposure evaluations combine data on pathway and media-specific emission volumes, physicochemical properties and, where available, site characteristics, with models to determine an estimate of the ambient concentration of contaminant in the medium into which the chemical is released. The ambient media concentrations are then combined with human exposure assumptions to estimate a “surrogate dose”. The term surrogate dose is used because limited facility-specific data and the use of models that rely on default values for many parameters preclude the calculation of an actual dose estimate. Instead, the purpose of the method is to generate as accurate a surrogate dose as possible without conducting an in-depth risk assessment. The estimates of surrogate doses from releases of TRI chemicals are *comparable only to the surrogate doses resulting from other releases 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 pathway. The 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 release are specific to that type of release and depend on data available to evaluate that pathway. In some cases, models are combined with some site-specific data to estimate exposure; in other cases, generic reasonable worst-case models may be used in the absence of any site-specific data. The physicochemical property data used for the exposure evaluation 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 model may underestimate or overestimate the risk impact of releases, since the decay product may be more or less toxic than the parent compound.

Specific pathway calculations are discussed in the sections below. First, Section 5.1 discusses the geographic basis of the 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 pathways. The next sections describe the modeling for each 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 geographically, and to attribute characteristics of the physical environment, such as meteorology, to areas surrounding the facilities once they are located. To accomplish the location of facilities and the attribution of data to those facilities, the model describes the U.S. and its territories as an 810m by 810m grid system. For each cell in the grid system, a location “address” in terms of grid and (x,y) coordinates is assigned based on latitude and longitude (lat/long).

5.1.1 The Model Grid Cell System

RSEI uses a standard Albers Equal-Area projection²⁴ to create each of the grids that is used in the model. The grid 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 GIS-based system, and the bounding coordinates for each.

²⁴ 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.

They can be calculated as follows:

$$x = INT(Easting / 810 + Adjust_x) \quad (\text{Eq. 5.1})$$

$$y = INT(Northing / 810 + Adjust_y) \quad (\text{Eq. 5.2})$$

where:

<i>Easting</i>	=	projected Albers distance East of the central meridian for the grid (m)
<i>Northing</i>	=	projected Albers distance North of the latitude of origin for the grid (m)
<i>Adjust_x</i>	=	0.5 if Easting >0, -0.5 if Easting <0
<i>Adjust_y</i>	=	0.5 if Northing >0, -0.5 if Northing <0

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 its 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 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 is assigned. The facility is then modeled as being located at the center of its assigned cell.

Off-site Facilities. RSEI also models some potential exposures that may result from environmental releases of chemicals from "off-site" facilities, that is, facilities that receive transfers from TRI-reporting facilities. Note that off-site facilities do not report transfers received from other facilities directly to TRI; instead their names and addresses are reported by the facilities that transfer chemicals to them.²⁵ Each report of a receiving off-site facility becomes a separate record in the TRI, 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;

²⁵ Some facilities may be considered both on-site and off-site facilities, if they both receive chemical transfers from other facilities (as an off-site facility) and emit reportable chemical releases (as an on-site facility). RSEI only adjusts for double-counting from facilities that both receive off-site transfers to incineration and report to TRI with a primary NAICS code of 562211 (Hazardous Waste Treatment and Disposal).

however, because the names and addresses are not standardized, the records are usually slightly different, and so cannot easily be matched to each other. EPA has developed an approximate text string matching program to identify imperfect matches in order to collapse 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 (RY 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 group 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 for this facility record is selected for the master database, and used in the 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 (RY 2005), off-site facilities are no longer geocoded. Instead, the entire set of all years of off-site records (1988-2016) is matched back to the previous years’ master off-site database using an approximate text matching program. Again, this is necessary because there are no IDs assigned to 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 years’ database (including any new off-site facilities) are added in to the master database, resulting in a new set of approximately 40,000 records. Additional data from EPA’s Facility Registry System (FRS) are also used where possible to identify lat/longs for off-site facilities. Grid-cell addresses 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 model grid. To match annual TRI emissions 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.²⁶ Census blocks are the smallest geographic area for which decennial census data are

²⁶ Some U.S. census data and block shape files were provided by GeoLytics, Inc.

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 censuses²⁷ 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:

- 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 2000.²⁸ 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 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.²⁹

²⁷ 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.

²⁸ For 2010, block-level shapefiles were available, but block-level population data were not released in time for incorporation.

²⁹ Due to irregular, invalid block shapes, some of the block percentages did not sum to 100 percent. For these blocks,

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 percent 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 above.³⁰ 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 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 2000-10 line is extrapolated forward to 2016.

5.2 Pathway-specific Methods to Evaluate Chronic Human Exposure Potential

The following sections describe the algorithms for modeling exposure for each of the following exposure pathways: (1) stack and fugitive air releases, (2) direct surface water releases, (3) transfers to POTWs, (4) off-site transfers, and (5) on-site land releases. An overview of the 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 dose can be accurately calculated within this model. The exposure algorithms are intended to be simple ways to gauge relative risks from releases to different media in a consistent, defensible way, by modeling and estimating exposure. In some cases, the modeling is purposely simplified, given the lack of site-specific data.

When possible, exposures are estimated for relevant subpopulations defined by age, sex, or other factors. Exposure for individual subpopulations is modeled using exposure factors (i.e., inhalation rates, drinking water intakes, fish ingestion rates, and body weight) and population data specific to such subpopulations. 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. The relevant exposure assumptions for these subpopulations are also described in the following sections.

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).

³⁰ 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 in the model.

5.3 Modeling Air Releases

Air releases can either be released through stacks or as fugitive releases. Stack (or point) air releases include releases to air through stacks, confined vents, ducts, pipes, or other confined air streams, and represent the majority of air releases. Fugitive releases to air include all other on-site air releases, including leaks, evaporation from surface impoundments, and releases for building ventilation systems. These are modeled as two separate pathways in the 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. In 2016, nine percent of TRI emissions and transfers were directly released to air.

5.3.1 Stack Air Emissions: Method

Stack air releases 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.³¹

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).³² 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.

³¹ 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 SCRAM website at <https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models>.

³² The Guideline on Air Quality Models can be found in 40CFR Part 51, Appendix W or accessed online at: http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

5.3.1.2 Model Dispersion Options

AERMOD is used with its regulatory default options³³, 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 National Weather Service (NWS) observation stations is used as the meteorological input (see Section 5.3.1.4 below).

5.3.1.3 Source Parameters

In the RSEI model, the U.S.³⁴ 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, the maximum distance between the center and the corner of the cell. To simplify the analysis, a facility's point source emissions are modeled as a single stack located at the facility's geographic center.

RSEI uses facility-specific stack parameters from NEI³⁵ 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, a North American Industry Classification System (NAICS) code-based median stack parameter is assigned to the facility. If no valid NAICS code is available for the facility, or no stack data are available for that NAICS code, then overall median values are used. Stack parameters are discussed further in Section 5.3.6.1 and in Technical Appendix E.

Annual stack air releases as reported to TRI are converted to an equivalent constant emission rate in grams per second according to the following equation:³⁶

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

where:

Q	=	pollutant emission rate (g/sec)
q	=	TRI annual stack or point air emissions (lbs/yr)

³³ See <https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models>.

³⁴ Including Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, and the Northern Mariana Islands.

³⁵ NEI data are available here: <https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-data>.

³⁶ Although RSEI can model any chemical air emission that is accompanied by the appropriate locational, chemical, and toxicity weight information, the model currently uses TRI reporting as the source of chemical release information.

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

5.3.1.4 Meteorological Input Data

For a given pollutant 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 pollutants.

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 Pollutant Concentration

RSEI calculates air concentrations at hypothetical “receptors” located within a circle with a radius of 49 km surrounding each facility. Any 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 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.

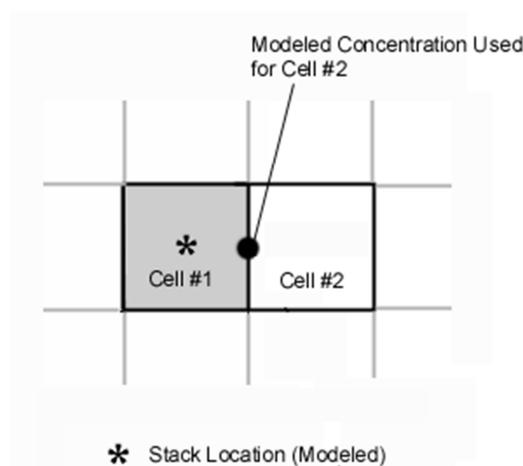


Exhibit 5.2

Assigned concentration at point nearest to facility.

To estimate the concentration for the 810m by 810m center cell containing the facility, the model calculates the interpolated concentration based on calculated concentrations at 441 receptor points within a kilometer of the cell center. Analyses performed during the development of RSEI Version 2.0 (which used the ISC model³⁷) indicated that using the concentration in a surrounding cell as an estimate for the center cell may either significantly over or under-represent chemical concentrations there (See Part B of *Analyses Performed for the Risk-Screening Environmental Indicators*).

The 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 the model at various stack heights. These analyses indicated that extending modeled distances to 50 km³⁸ was necessary to capture potential concentrations of concern under certain atmospheric conditions. This distance is expected to capture the majority of the potential impacts from the TRI facilities, including electric utilities, which usually have taller stacks than other facilities. Details of these analyses can be found in Part B of *Analyses Performed for the Risk-Screening Environmental Indicators*.³⁹

5.3.2 Fugitive Air Releases: Method

As for stack air releases, long-term pollutant concentrations downwind of the facility due to TRI-reported fugitive air releases are modeled using algorithms from AERMOD.

³⁷ 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.

³⁸ In the final RSEI modeling, 49 km was used instead of 50km due to modeling constraints.

³⁹ 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.

5.3.2.1 Model Dispersion Options

Model dispersion options used in modeling fugitive air releases 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 cell containing the facility. The model assumes a release height at ground level.

Fugitive emissions are converted from pounds per year to grams per square meter per second ($\text{g}/\text{m}^2\text{s}$) 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	=	pollutant area emission rate ($\text{g}/\text{m}^2\text{s}$)
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 ($\text{g}/\text{m}^2\text{s}$), assuming an area 10 m x 10 m.

5.3.2.3 Calculating Pollutant Concentration

Pollutant concentrations fugitive air releases are calculated using AERMOD, as described above for stack air releases.

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 cell:

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

where:

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

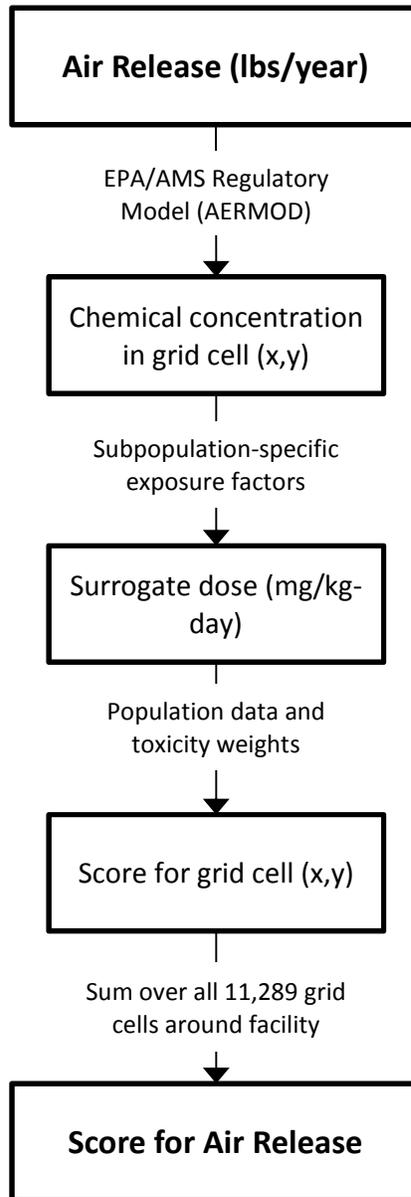
5.3.4 Estimating Population Size for Air Releases

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 above in Section 5.1.3. Exposed population is only considered for grid cells with nonzero pollutant 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 model. First, the pollutant concentration in each cell is calculated using TRI emissions data and the AERMOD algorithms. Then, subpopulation-specific exposure factors are used to calculate a surrogate dose for each cell. Finally, the surrogate dose is multiplied by the number of people in each subpopulation in the cell and by the chemical toxicity weight to obtain the score for the grid cell. Then the results for all grid cells are summed. The result is the RSEI score for an air release. To calculate the 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 pathways use facility-specific 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 these pathways are summarized in Exhibit 5.4.

Exhibit 5.4
Air Modeling Parameters

Parameter	Value	Source/Comment
Pollution emission rate	Site-specific (lbs/yr)	TRI
Stack height	In order of preference: <ul style="list-style-type: none"> • 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 2011, EPRI (for Electric Utilities)
Stack diameters	In order of preference: <ul style="list-style-type: none"> • 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 2011, EPRI (for Electric Utilities)
Exit gas velocity	In order of preference: <ul style="list-style-type: none"> • 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 2011, 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	Pollutant-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)

**Exhibit 5.4
Air Modeling Parameters**

Parameter	Value	Source/Comment
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 2011 NEI. For each TRI facility that had stack parameter data in NEI, the median parameter of all stacks at the facility is used. For the TRI facilities that had 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 approximately 935 TRI facilities reporting in any year and classified in NAICS code 2211- Electric Power Generation in RY 2016, almost 45 percent match a corresponding facility listed in one of the EPRI databases; approximately 55 percent of TRI electric utility facilities do not. For the 55 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 median was used for 14 percent of facilities in NAICS 2211).

Analyses have been conducted that show air concentrations predicted by the model using a combination of generic and site-specific data closely match concentrations estimated by using more complete site-specific data.⁴⁰ See Technical Appendix E for details on the derivation of stack data.

5.3.6.2 Meteorology⁴¹

The meteorological data used in RSEI 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 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

⁴⁰ 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.

⁴¹ 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>.

AERMOD: one file consists of surface scalar parameters, and the other file consists of vertical profiles of meteorological data.

To simplify processing and 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 Air Decay Rates

Pollutants may be removed from the atmosphere by either physical processes or chemical transformation. The model uses pollutant-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.⁴² The daughter products of photodegradation are not modeled further, i.e., it is assumed that all chemicals are photodegraded into nontoxic compounds. AOPWIN data also contains certain empirically derived air decay rates. For the model, a concentration of hydroxyl radicals of 1.5×10^6 molecules/cm³ 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:

⁴² For a few chemicals, other sources were used. See Technical Appendix B for the source used for each chemical.

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

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 pathways, sex- and age-specific inhalation rates and body weights are used in the model. The primary source for all exposure factors used in the model is EPA's Exposure Factors Handbook (EPA, 2011, hereafter denoted as EFH)⁴³, 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 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+).⁴⁴ The inhalation rates recommended by 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:

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

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.

⁴³ The Exposure Factors Handbook can be found at <http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252>.

⁴⁴ 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.

For adults, 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 5.15. 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 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 model. More detail on the derivation of 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 (m³/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 stream path of a chemical release; or by eating contaminated fish caught in a water body in the stream path of a chemical release. The following sections first describe the methods used to calculate the initial stream concentration for both 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 pathways and the human exposure assumptions used. In 2016, almost three percent of TRI emissions and transfers were directly released to surface water.

5.4.1 Surface Water Releases: Methods

5.4.1.1 Locating the Facility Discharge Flowline

The first step in assessing surface water emissions is to locate the discharging facility on the model grid using the lat/long. Facilities are then matched to a receiving stream flowline (a linear, unbranched section of a water body).

The main data source used is EPA's records of discharge permits for facilities, which in some cases specify the discharge flowline by the coordinates of the outfall. Permit records, including permits, monitoring data, and locational and descriptive information pertaining to more than 67,000 regulated are maintained in EPA's Integrated Compliance Information System-National Pollutant Discharge Elimination System (ICIS-NPDES).

Facilities without outfall 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 Pollutant Concentrations

Chemical concentrations in the receiving stream 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 at a constant rate throughout the year. Annual average 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 concentration reaches 1×10^{-9} mg/L. Within the initial flowline, the mass of the release is assumed to be instantaneously mixed with the flow at the upstream end of that flowline. The calculated concentration at the downstream end of the flowline is then converted back to a mass (after any decay) and the process is repeated in the 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 pathways: drinking contaminated water and eating non-commercial contaminated fish. Methods used to estimate each of these exposures 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, a database of drinking water system information developed and maintained by the U.S. Geological Survey (USGS), based on information in the Safe Drinking Water Information System (SDWIS). Each 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 the stream concentration (calculated at the upstream end of the flowline; conservatively using the highest concentration), up to the level of the Maximum Contaminant Level (MCL),⁴⁵ where applicable. (Seventy-nine TRI chemicals had existing MCLs in effect during one or more years for which TRI data are available;⁴⁶ this number includes chemical categories that are treated as their elemental forms). If the stream 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:

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

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)

⁴⁵ 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.

⁴⁶ As MCLs are sometimes revised and new ones have been added since TRI began 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.

5.4.1.4 Estimating Population Size for the Drinking Water Pathway

To estimate the size of the population exposed to TRI releases through drinking water, the model uses estimates of the population served by each drinking water intake from USGS's Public Supply Database, which incorporates population estimates from the Safe Drinking Water Information System (SDWIS)⁴⁷. 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 water system is exposed to the full concentration of the released chemical estimated at the flowline where a 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 percentage 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 5.4.1.4). Then, these percentages are applied to the SDWIS intake population (population served), creating the subpopulation groups that are used for calculating results.

5.4.1.5 Modeling the Fish Ingestion Pathway

A second potential exposure pathway is through consumption of fish contaminated by chemicals discharged from TRI reporting facilities. These fish may be consumed by recreational and subsistence fishers and their families.⁴⁸ As in the drinking water 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 concentration reaches 1×10^{-9} mg/L. The chemical concentration in fish is estimated using the following equation:

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

where:

$C_{fish, flowline}$	=	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 pathway:

⁴⁷ 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 <http://www3.epa.gov/enviro/facts/sdwis/search.html>.

⁴⁸ Although store-bought fish may also contain pollutants originating from TRI facilities, modeling this exposure pathway is not currently possible.

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

where:

$DOSE_{f,c}$	=	surrogate dose of chemical c from facility f (mg/kg-day)
$C_{fish,flowline}$	=	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 Pathway

The 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.⁴⁹ 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 cell. To account for family members who also eat fish caught by one member, the 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:

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

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 fish they catch. Data are lacking on numbers of recreational compared to subsistence fishers; RSEI follows guidance from EPA's Office of Water (Harrigan, 2000). The 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:

⁴⁹ 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, ratio for the state closest to that grid cell is assigned.

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

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

where:

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

The fishing population in each 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 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 cell. For example, Flowlines A and B may be located within 80 km of a given 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 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 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 cell.

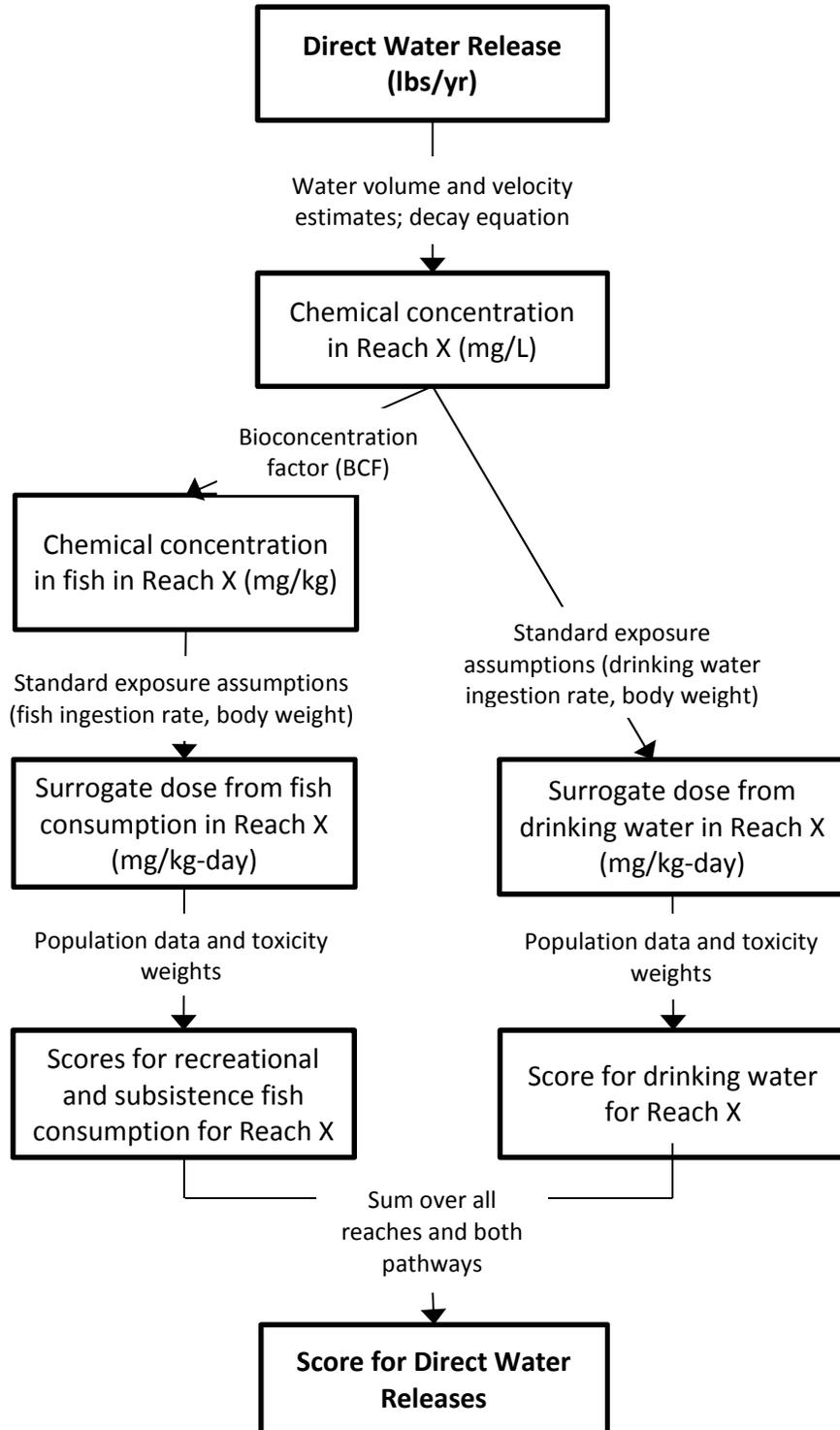
Because of the size of the database created, the fishing population data attributed to individual flowlines is summed and stored at the flowline level. The percentage of people in each of the ten age-sex categories for the aggregated total fishing population (reflecting the ratio of the various age and gender subpopulations in the neighboring grid cells) is also maintained for each flowline. The model then matches the chemical concentration in fish in the appropriate flowline ($C_{fish,flowline}$) 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

RSEI scores for drinking water and fish ingestion are calculated by generating for each unique combination of chemical release, flowline, and exposure pathway a surrogate dose, then multiplying this dose by the toxicity weight of the chemical released and the estimated population. The RSEI score for a surface water release from a TRI 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



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 are described below and listed in Exhibit 5.8.

**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 location and population served	Lat/long in decimal degrees 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)
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	calculated (mg/kg)	
Family size	2.62	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 discharge is not modeled. The flowlines used in the 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 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 (WATERS) system uses the flowline codes in NHD to link multiple databases containing water quality and programmatic information. EPA has created a version of the NHD called NHDPlus⁵⁰, 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 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 flowline⁵¹, and have a non-negative flow and velocity. RSEI will not calculate 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 flowline 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 RSEI excludes flowlines in the canal/ditch category if the annual mean flow is less than 5 ft³/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, RSEI 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 ft³/s to 1.9 ft³/s. For instance, if a facility in a region whose minimum value was selected as 0.0036 ft³/s had a nearest flowline with annual mean flow of 0.0025 ft³/s, this would not be selected as the discharge flowline. Instead the next closest flowline with a flow greater than 0.0036 ft³/s would be selected as the discharge flowline.

5.4.3.2 Drinking Water Intakes and Populations

Drinking water intake locations were obtained from the Public Supply Database, a database of drinking water system information developed and maintained by the U.S. Geological Survey

⁵⁰ 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>.

⁵¹ 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, which includes 2.6 million out of 2.9 million flowlines in NHD.

(USGS), based on information in EPA's Safe Drinking Water Information System (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.⁵² SDWIS is operated and maintained by EPA's Office of Water. USGS's Public Supply Database was designed to support USGS analyses of the water resources used by public drinking water systems. The Public Supply Database 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 Public Supply database 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: 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 intakes that are modeled in RSEI.

5.4.3.3 Water Flow and Velocity

RSEI uses NHDPlus Version 2 estimates of water flow and velocity based on the unit runoff method,⁵³ which was developed for the National Water Pollution Control Assessment Model (NWPCAM). The unit run-off method calculates average runoff per square kilometer in a watershed (8-digit 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 are used in the Jobson methods: drainage area, flowline slope, mean annual discharge, and discharge at the time of the measurement.⁵⁴

⁵² <https://www.epa.gov/waterdata/drinking-water-tools>.

⁵³ NHDPlus also contains estimates developed using the Vogel method, but this is method is considered to have a narrow band of applicability.

⁵⁴ For more information, see the NHDPlus User's Guide (US EPA/USGS 2012).

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 EPI suite of estimation programs (SRC, 1994-1999)), both of which were developed for the Environmental Protection Agency. The ChemFate database contains environmental fate and physical/chemical property information for commercially important chemical compounds, including TRI 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*.⁵⁵ 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 bioconcentration factors used in the model.

5.4.3.6 Human Exposure Assumptions

Drinking Water. For the drinking water pathway, the model uses estimates for the amount of tap water ingested to estimate exposure. As in the stack and fugitive air pathways, data are acquired from EPA's Exposure Factors Handbook (EFH) (EPA, 2011). EFH recommends mean tap water intake values for males and females combined from two related studies, Kahn and Stralka (2008) and Kahn (2008) for children less than three years of age, and EPA's analysis of NHANES data from 2003-2006 for individuals three years of age and older (as cited in EPA, 2011, Table 3-1). The body weights used in these studies to calculate the exposure factors were different from those recommended in the 2011 EFH, so the values were adjusted to reflect the currently recommended sex- and age-specific body weights.

Drinking water intake rates per body weight were calculated for each of the modeled groups (male/female: ages 0-17, 18-44, 45-64, 65+)⁵⁶ using the weighted average approach presented in

⁵⁵ The BCF can underestimate the accumulation of chemicals that are highly persistent and hydrophobic relative 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.

⁵⁶ 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

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)
	<i>(L/kg-day)</i>	
0-17	0.0111	0.0117
18-44	0.0117	0.0137
45-64	0.0117	0.0135
≥65	0.0128	0.0151

Fish Ingestion. RSEI 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, RSEI uses fish ingestion rates from the 1994-1996 USDA Continuing Survey of Food Intake by Individuals (CSFII). This survey was conducted by the U.S. Department of Agriculture 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.⁵⁷ 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 age groups using Equation 5.7. These values are then divided by age- and sex-specific body weights, averaged to match the RSEI age groups using data provided in EFH (EPA, 2011, Tables 8-4 and 8-5). Exhibit 5.10 presents the fish ingestion rates used in the model. More detail on the derivation of exposure factors can be found in Technical Appendix C.

⁵⁷ 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

Model Age Group	Recreational (g/kg-day)*		Subsistence (g/kg-day) ¹	
	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 model.

5.5 Modeling Transfers to POTWs

Transfers to Publicly-Owned Treatment Works (POTWs) are mostly of facility wastewater through underground sewage pipes to a POTW. Each chemical transfer to a POTW is modeled as entering as liquid influent. Depending on the chemical’s physical properties, some portion of the chemical release in the influent may be discharged into surface water from the POTW, potentially resulting in human exposure through drinking water or fish ingestion. The rest of the chemical release may be removed by the POTW through one or more of the following processes: 1) biodegradation, which is not modeled; 2) volatilization, which is modeled like other area air releases (see Section 5.2.3); or 3) landfilling of sludge, which is not modeled. The following sections describe the method and data used to model transfers to POTWs. In 2016, almost four percent of TRI emissions and transfers were transferred off-site to POTWs.

5.5.1 Transfers to POTWs: Method

Modeling exposure from TRI-reported transfers to POTWs requires: (1) location of the POTW to which the chemicals are discharged, (2) location of the flowline to which the POTW discharges, (3) consideration of overall removal efficiencies of POTWs and resulting effluent discharges from POTWs (the chemical-specific removal rate), and (4) consideration of residuals management at POTWs (partitioning within the POTW).

5.5.1.1 Locating the POTW

In order to model releases from POTWs, these facilities must first be located on the model grid. Like other off-site facilities, POTW names and addresses are reported to TRI by the facility transferring its waste. Latitude and longitude are not reported. In order to derive lat/long coordinates, the reported street addresses were geocoded for Version 2.1.3 (coordinates were assigned based on street address).⁵⁸ POTWs (and incinerators) were also matched to EPA’s Facility Registry System (FRS), based on name, address, and RCRA identification number, where possible. Duplicate entries for the same POTW (in the common instance where two or more reporting facilities have transferred to the same POTW) were collapsed to a single entry

⁵⁸ Geocoding services were provided by Thomas Computing Services, a commercial firm.

using an approximate string matching program (see Technical Appendix D for details). Once latitude and longitude 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 grid cell with the same coordinates. Substantial data processing was necessary to prepare the set of off-site facilities for use in the model; see Technical Appendix D for 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 source used is EPA's records of discharge permits for POTWs, which in most cases specify the discharge flowline by name or flowline number. Permit records, including permits, monitoring data, and locational and descriptive information pertaining to more than 67,000 regulated facilities are maintained in EPA's Integrated Compliance Information System-National Pollutant Discharge Elimination System (ICIS-NPDES).

POTWs were matched to the FRS system based on name and address to obtain the FRS ID for each POTW. THE FRS ID was then used to access ICIS-NPDES and the assigned discharge flowline 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 above 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 the plant from the TRI facility. Some of the chemical loading in the influent will be discharged as effluent to surface waters. To calculate the fraction of transferred chemical removed by the POTW, the typical chemical-specific removal rate is applied to the volume transferred to the POTW from the TRI facility. See Technical Appendix B for a listing of removal rates and references for each chemical. The remainder is assumed to exit the POTW in water effluent. This effluent is modeled for drinking water and fish ingestion using the same methods for surface water releases described above.

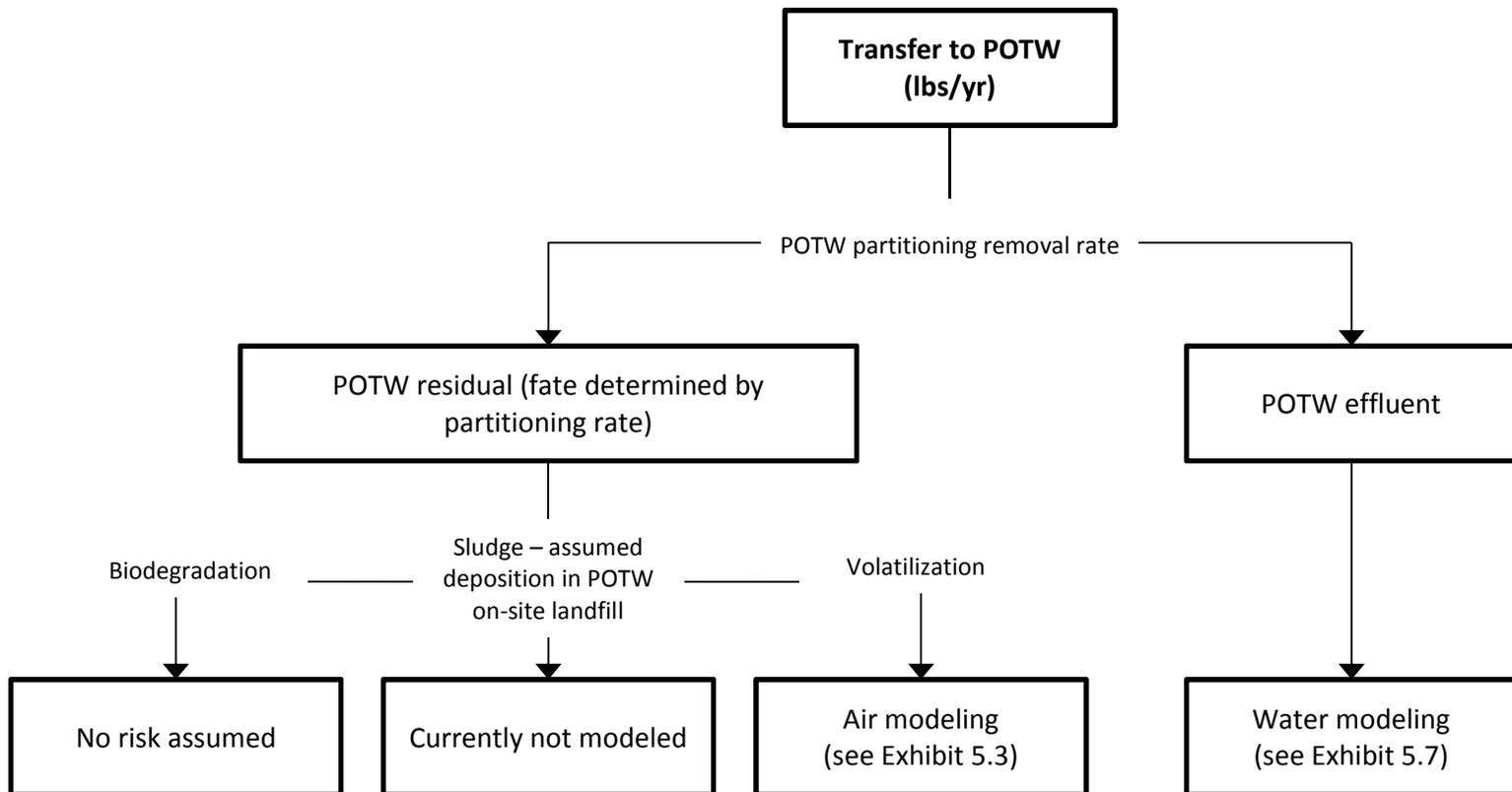
5.5.1.4 Partitioning within the POTW

Chemical loadings may be removed by the POTW treatment processes through biodegradation, volatilization, and adsorption to sludge. The amount of the chemical that is removed by each of these processes is modeled using average partitioning rates (see Technical Appendix B for the listing of partitioning rates and references for each chemical).

Once the fates of chemicals entering the POTW are estimated, exposures associated with chemical loadings to each compartment are estimated. Chemicals discharged in the POTW effluent are modeled using the surface water evaluation methods described above. Chemicals that biodegrade are assumed to degrade to chemicals that do not pose risk. POTW volatilization releases are treated like area-source air releases, as described earlier.

For chemicals that partition to sludge, the model used to estimate exposure should ideally depend on the sludge disposal method employed by the POTW. However, sludge disposal practices at a POTW receiving a TRI transfer cannot be determined from the TRI database. Therefore, the model algorithm currently assumes all POTW sludge is landfilled at the POTW, a common method of sludge disposal. POTWs may in reality use other methods of sludge disposal, such as incineration of sludge. If sludge were incinerated by a POTW, for example, this would result in different exposure levels (and a different, larger exposed population). RSEI does not currently model land releases. A summary of the approach to modeling POTW emissions is found in Exhibit 5.11.

Exhibit 5.11
POTW Modeling Approach



5.5.1.5 Estimating Population Size for POTW Transfers

The population exposed to air releases is assumed to be the population within 49 km around the POTW. The method used to estimate the population surrounding the POTW that is exposed to surface water effluent discharges up to 300 km downstream from these facilities is described in the section on exposed populations for surface water releases (see Sections 5.4.1.2 and 5.4.1.4.)

5.5.2 Transfers to POTWs: Data

Exhibit 5.12 presents data used to estimate exposure from releases to POTWs. In addition to the parameter data presented here, data from the air release pathway (see Exhibit 5.3), and water release pathway (see Exhibit 5.7) are also used. Environmental fate and transport data and exposure factors specific to these pathways are described in the relevant sections above.

**Exhibit 5.12
Data Used to Estimate Exposure from Releases to POTWs**

Parameter	Value	Source/Comment
Removal efficiencies	chemical-specific	RREL or STPWIN (SRC, 1994-99)
Partitioning within the POTW	chemical-specific	RREL or STPWIN (SRC, 1994-99)

5.5.2.1 POTW Removal Rate Efficiency and Within-POTW Partitioning

Data specific to this pathway include POTW removal efficiencies and within-POTW partitioning rates. These parameters describe the fate of chemicals during treatment at POTWs. The “POTW Partition Removal” is the total POTW removal efficiency, or the total percentage of the chemical removed by the POTW (influent minus effluent). The within-POTW partition values describe the fate of that portion of the chemical removed, that is, whether the chemical may sorb to sludge (POTW Partition Sludge), volatilize into the air (POTW Partition Volatil) or be biodegraded by microorganisms (POTW Partition Biodeg). 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 from the Treatability Database maintained by EPA’s Risk Reduction Engineering Laboratory (RREL). For any given chemical, the RREL Treatability Database provides a list of 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 from two sources. For most organic chemicals, values were supplied by the EPA’s Exposure Assessment Branch within 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 removal efficiency and within-POTW partitioning values.

5.6 Modeling Other Off-site Transfers

TRI-reported chemicals can be transferred to off-site locations other than POTWs for storage or disposal. TRI reporters are required to supply the name and address of the receiving facility, and the treatment method used. Currently, only transfers that are incinerated at the off-site facility are modeled by RSEI. In 2016, almost four percent of TRI emissions and transfers were transferred off-site for incineration.

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 characteristics. Locations of other off-site facilities are determined in the same way as the locations of POTWs. The reported street addresses were geocoded for Version 2.1.3 (coordinates were assigned based on street address).⁵⁹ Incinerators (and POTWs) were also matched to EPA's Facility Registry System (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 details). Once latitude and longitude 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 grid cell with the same coordinates. See Technical Appendix D for detailed information on locating off-site facilities.

The TRI forms require the reporting facility to indicate the treatment/disposal method used at the off-site facility. If this information is not reported (despite the requirement), the transfer is not evaluated in the algorithm, but is flagged as a missing value and assigned a zero.

Beginning with reporting year 1998, facilities in the commercial hazardous waste treatment sector were required to report to TRI. This introduces the potential to double-count the impact from some transfers and releases, as many of the facilities in this sector also receive transfers from other reporting facilities. Beginning with Version 2.3.5, adjustments are made to transfers to off-site 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 facility that receives a transfer to off-site incineration, it is assumed that the facility is reporting any releases from the incineration process to TRI, and the pounds and modeled results related to the transfer are dropped from RSEI. Since the requirement to report was first in effect for reporting year 1998, only transfers from 1998 on are adjusted. For reporting year 2016, this drops slightly more than half of the pounds that are transferred to off-site incineration. Users should note that the trend in off-site incineration will show a drop in

⁵⁹ Geocoding services were provided by Thomas Computing Services, a commercial firm.

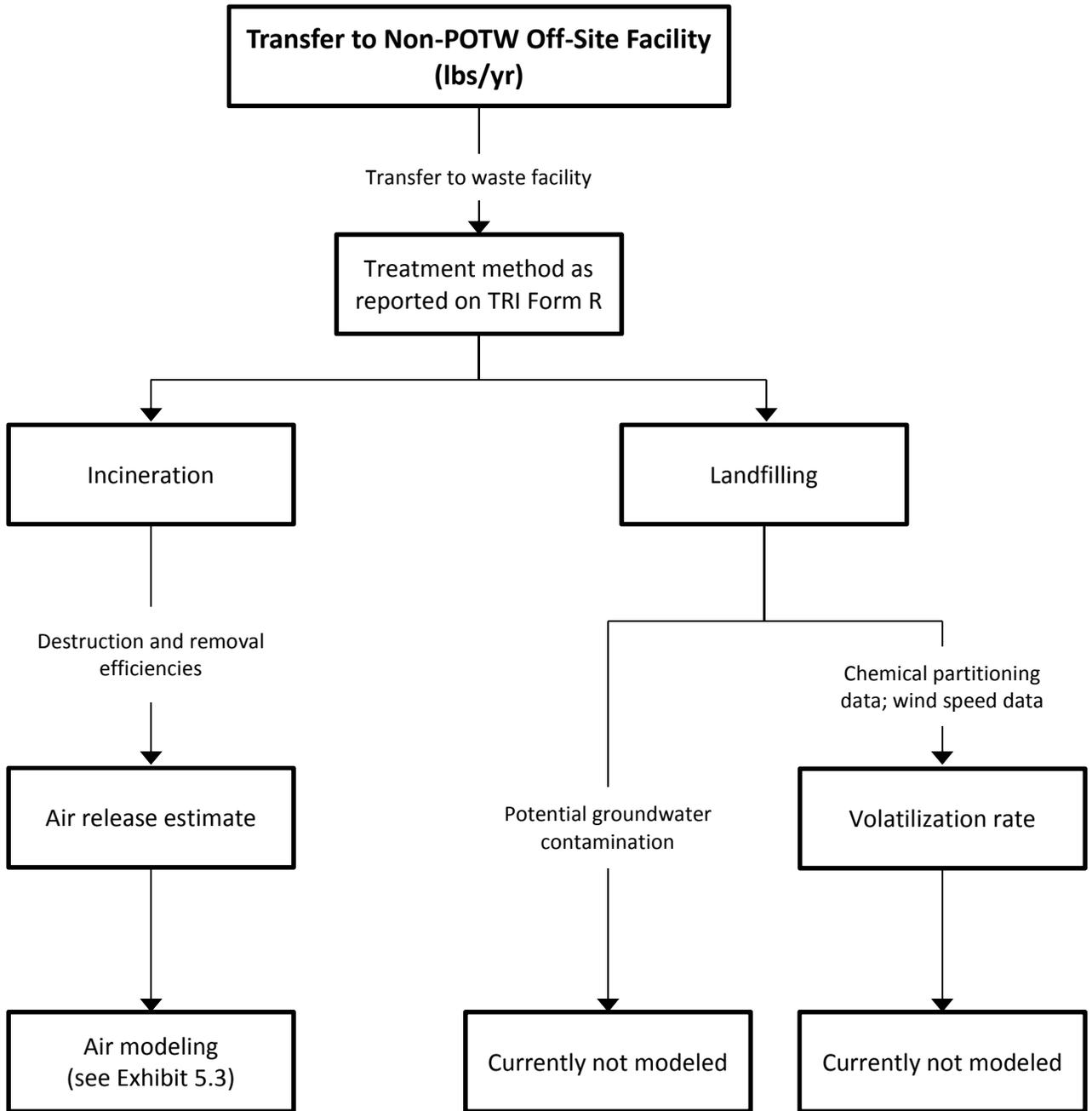
1998; this does not represent a drop in total potential risk, but rather just the shift from the off-site transfer category to on-site stack releases.

For off-site transfers that are not dropped, destruction and removal efficiencies (DREs) are applied to the transfer amount. Once DREs have been applied, the releases are modeled using the AERMOD-based air modeling algorithms described earlier.

5.6.2 Estimating Population for Off-Site Transfers

Similar to on-site air releases, the population exposed to air releases from off-site transfers is the population within 49 km around the off-site incinerator.

Exhibit 5.13
Modeling Approach for Off-site Transfers



5.6.3 Off-site Transfers: Data

5.6.3.1 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 PCBs and dioxin and dioxin-related compounds, which are assumed to have a DRE of 99.9999 percent, as required by TSCA regulation. For inorganics, values are taken from multiple hearth sludge incinerator studies (EPA, 1992a).

5.7 Modeling On-site Land Releases

In 2016, approximately 34 percent of TRI emissions and transfers were released as on-site land releases. On-site land releases include releases to landfills, surface impoundments, land treatment units, and underground injection wells. For these releases, two major exposure pathways are of interest—volatilization to air and leaching into groundwater. Volatilization of chemicals from on-site land releases is reported to TRI under the fugitive emission estimate for the facility, and is modeled by RSEI as part of the facility’s fugitive air release. For more information on RSEI modeling of fugitive air releases, see Section 5.3 above. EPA is evaluating screening-level methodologies which might be used to assess risk-related exposures pertaining to groundwater exposure from on- and off-site land releases and volatilization from off-site land releases, so this version of RSEI does not provide risk modeling for reported land releases. However, RSEI does provide the capability for users to examine the pounds of releases to land that are reported to TRI, as well as viewing these releases from a hazard-based perspective.

The potential for groundwater contamination from land releases depends on the regulatory status of the unit in which the chemical is released. For example, chemicals could be deposited in an on-site RCRA-regulated, subtitle C hazardous waste unit, or in an on-site nonhazardous solid waste management unit. RCRA standards for hazardous waste units are, by regulation, 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 RSEI assigns a zero value to the risk-related scores for such releases. If chemicals are placed in nonhazardous land disposal units (landfills, etc.), there is a potential for exposure. This exposure pathway and volatilization from off-site landfills are currently under review for inclusion in a future version of RSEI.

On- and off-site land releases to underground injection will not be modeled for exposure by RSEI. The hydrogeological, spatial, and temporal considerations that are associated with exposures to toxic chemicals in underground injection wells are situation- and site-specific, so RSEI is only able to provide pounds-based and hazard-based perspectives for this type of land release. Note, however, that under well-managed conditions, Class I wells (there are five classes of wells) are specifically designed to pose minimal risk to human health or the environment.

6. Calculating Results

This section summarizes the computation of the principal types of RSEI results. Because of the multi-functional nature of the 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	Surrogate Dose x Toxicity Weight x Population
Hazard-based results	Pounds x Toxicity Weight
Pounds-based results	TRI Pounds released

Risk-related results. The surrogate dose, toxicity, 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 subpopulation-specific exposure factors. Risk-related scores are unitless, and each of the components (toxicity weight, surrogate dose, and population) when multiplied provide scores that are relevant only when compared to each other. The unitless RSEI scores are *not* a physically meaningful measure of quantitative risk associated with the facility, but are approximate measures of relative risk-related impacts that are comparable to approximate measures for other facilities (or other chemicals, pathways, etc.) calculated using the same methods within RSEI. If the RSEI score cannot be modeled, because of a lack of toxicity data or data required for modeling, or because the pathway is not currently modeled, then the risk-related score is zero.

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

Higher component “weights” are associated with higher relative risk-related values (and lower weights are associated with lower relative risks). For chemicals with cancer effects, multiplying the 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 noncancer effects, the multiplicative nature of the toxicity and exposure weights 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 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 exposure level, a chemical with a more stringent (i.e., lower) RfD will receive a higher

score value than a chemical with a less stringent (i.e., higher) RfD, 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, one could argue that releases that result in surrogate doses below the RfD 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 to another in a relative way, and should never be considered an actual calculation of exposure. To exclude releases resulting in surrogate doses below the RfD would incorrectly imply that the method could predict precisely when doses would occur below the RfD. 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 risk, even if each release individually did not exceed the RfD. Finally, if the surrogate dose is low, this will be reflected by a correspondingly low score relative to other releases for that chemical.

Hazard-based results. Hazard-based results (“Hazard”) are calculated by multiplying the pounds released by the appropriate chemical-specific toxicity weight (the toxicity weight also depends on the exposure pathway). The inhalation toxicity weight is used for releases or transfers to fugitive air, stack air, and off-site incineration. The oral toxicity weight is used for releases to direct water or transfers to POTWs. For releases that are not modeled (because the pathway is not modeled or because other necessary data, such as physicochemical properties, are lacking), the higher toxicity weight is used. 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.

- **Cancer Hazard-** Product of TRI Pounds and the IUR toxicity weight or the OSF toxicity weight (see Table ES.2 for details).
- **NonCancer Hazard-** Product of TRI Pounds and the RfC toxicity weight or the RfD toxicity weight (see Table ES.2 for details).
- **RSEI Hazard-** Product of TRI Pounds and the higher toxicity weight for each exposure route (see Table ES.2 for details).

Pounds-based results. These results (“TRI Pounds”) reflect only the number of pounds released or transferred that are reported to TRI, and are available for all releases and transfers.

6.1 Combining RSEI Scores

Once 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 releases⁶⁰.

This method is very flexible, allowing for countless variation in the creation of results. For example, results can be calculated for various subsets of variables (e.g., chemical, facility, 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 calculated, to assess the general trend in pounds-based, hazard-based, or risk-related impact 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 facilities or chemicals with the highest potential for hazard or risk, the score does not represent a quantitative estimate or provide an exact indication of the magnitude of individual hazard or risk associated with that facility or chemical.

6.2 Accounting for Changes in TRI Reporting

When a change occurs in the number of, or reporting requirements for, chemicals and facilities represented in TRI, 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 would reflect a broader understanding of the impacts that may have always existed.

A change in the number of chemicals and facilities in the TRI can occur through several mechanisms. First, the addition to or deletion of individual chemicals from the TRI chemical list will occur as EPA responds to petitions or initiates its own action through the chemical listing or delisting process. Several additions and deletions to the data set have already occurred since 1987 (the first year of TRI reporting). Furthermore, the Agency added 245 chemicals and chemical categories to the TRI chemical list in a single year, effective in 1995. The deletion of chemicals would presumably have a minor effect since such chemicals would be deleted due to their low hazard. Delisted chemicals are removed from RSEI. 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. These identifiers allow users to exclude chemicals whose emissions changes over time are caused by reporting requirement changes.

Facility-level changes can also affect year-to-year scores generated using RSEI. For instance, compliance with TRI reporting has improved over time, which has led to more facilities

⁶⁰ Separate results can also be calculated for the pathway components of a release, such as the drinking water exposure or fish ingestion components of a direct water release; however, in most user-facing applications, the RSEI results are presented at the release level.

reporting. Increases in the number of reporting facilities may occur as a result of changes in reporting requirements. For instance, in the first two years of reporting, facilities that manufactured or processed more than 50,000 pounds were required to report their releases. However, EPCRA lowered this threshold to 25,000 pounds in 1989. For reporting year 2000, thresholds and other reporting requirements for 18 Persistent Bioaccumulative Chemicals (PBTs) have been changed. These modifications can act to alter the total emissions reported to the TRI and the model's estimates of associated hazard- and relative risk-based impacts. Also, effective in the 1998 reporting year, certain industries were added to TRI reporting, adding to the universe of reporting facilities.⁶¹ To assist users in separating out the effects of the 1998 expansion, RSEI allows for the exclusion of facilities in the newly-required industries when doing trend analyses.

The yearly TRI reporting data for a given list of chemicals and facilities are the subject of ongoing quality control review and revision. As a result, yearly comparisons could be flawed if ongoing revisions by individual facilities were not included in each year's results. Therefore, the RSEI results are re-computed for all years in the database on an annual basis in order to incorporate revisions to the reporting data. This annual calculation is based on the corrections incorporated in annual TRI National Analysis available from EPA's TRI program.

⁶¹ This facility expansion rule required the affected facilities to report their releases for the 1998 reporting year. Additional information is available on the TRI website: <https://www.epa.gov/toxics-release-inventory-tri-program/addition-facilities-certain-industry-sectors>

7. Current Implementation of the RSEI Method

RSEI results are currently distributed in several different formats, for different users. Additional data products may be created in the future. Users are advised to check the [RSEI website](#) for updates and new products.

7.1 EasyRSEI Dashboard

RSEI model results are currently distributed in the EasyRSEI dashboard, accessible on the Qlik Sense platform through an internet browser. The dashboard allows users to view and query all RSEI results for TRI reporting years 2006-2016 for modeled media. Pounds- and hazard-based results for non-modeled media are not available in this interface. A separate Qlik Sense dashboard is available for users who are interested in the full TRI time series (1988-2016), and a RSEI Queries database for users comfortable in Microsoft Access is also available for download. Additional dashboards, including a full time series with TRI pounds and hazard results for all TRI waste management categories (including Section 8), are provided for EPA users.

Users of the 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 evaluation.

As noted above, users can evaluate releases using a number of variables, such as chemical, 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 release pathway for a particular chemical poses the greatest risk-related impacts?

7.2 RSEI Geographic Microdata

Users should note that, as implemented in EasyRSEI, RSEI employs a facility-based approach. All modeled impacts are attributed to the facility originally releasing or transferring the chemical. For instance, an air release from an off-site incinerator is modeled as exposing the population around the 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 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.

The last three years of Microdata, using the current version (2.3.6) are available on the [RSEI ftp site](#). An [all-years dataset](#) that uses Version 2.3.4 is available on Amazon Web Services (AWS). Separate state level files are also available.

National data files (disaggregated and aggregated) for Version 2.3.4 are also available on the [RSEI site](#) hosted by the National Socio-Environmental Synthesis Center (SESYNC).

Users should note that there have been major methodological and data changes since Version 2.3.4, so the older data should be used with care.

7.3 Other RSEI Data Products

RSEI results can also be accessed in EPA data products like [Envirofacts](#), [TRI.NET](#) (hazard results only) 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 the RSEI website.

7.4 Conclusion

As an indication of improvements in environmental quality over time, RSEI 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 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 and industrial sectors to 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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