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Environmental Assessment for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

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List of Abbreviations

AETX	aetokthonotoxin
ATSDR	Agency for Toxic Substances and Disease Registry
BA	bottom ash
BAT	best available technology economically achievable
BCA	benefit and cost analysis
BINWOE	binary weight-of-evidence
BLM	Biotic Ligand Model
Br-DBP	brominated disinfection byproduct
CCR	coal combustion residuals
CFR	Code of Federal Regulations
CRL	combustion residual leachate
CSF	cancer slope factor
CWA	clean Water Act
DBP	disinfection byproduct
DCN	document control number
D-FATE	Downstream Fate and Transport Equations
DNA	deoxyribonucleic acid
DWTP	drinking water treatment plant
EA	environmental assessment
EGU	electric generating unit
EJ	environmental justice
ELGs	effluent limitations guidelines and standards
EPA	U.S. Environmental Protection Agency
FGD	flue gas desulfurization
FR	*Federal Register*
FW	freshwater
HAAs	haloacetic acids
HANs	haloacetonitriles
HH O	human health for the consumption of organism only
HH WO	human health for the consumption of water and organism
HI	hazard index
HQ	hazard quotient
I-DBP	iodinated disinfection byproduct
IRIS	Integrated Risk Information System
IRW	immediate receiving water
JTA	joint toxic action
lb/year	pounds per year
LC_{50}	median lethal concentration
LECR	lifetime excess cancer risk
MCL	maximum contaminant level
MRL	minimal risk level
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
µg/g	micrograms per gram
N	nitrogen
NEHC	no effect hazard concentration
NHDPlus	National Hydrography Dataset Plus
NRWQC	National Recommended Water Quality Criteria
POTW	publicly owned treatment works
ppm	parts per million

PSES	pretreatment standards for existing sources
RfD	reference dose
RIA	regulatory impact analysis
SI	surface impoundment
SO_2	sulfur dioxide
T3	trophic level 3
T4	trophic level 4
TDD	Technical Development Document
TDS	total dissolved solids
TEC	threshold effect concentration
THMs	trihalomethanes
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
TTD	target-organ toxicity dose
UV	ultraviolet
VM	vacuolar myelinopathy
WHO	World Health Organization
WOE	weight of evidence

1. Introduction

The U.S. Environmental Protection Agency (EPA) promulgated revised effluent limitations guidelines and standards (ELGs) for the Steam Electric Power Generating Point Source Category (40 CFR 423) on November 3, 2015 (80 FR 67838), referred to hereinafter as the "2015 rule." Following promulgation, EPA received seven petitions for review of the 2015 rule and the Administrator announced his decision to reconsider the 2015 rule. EPA finalized a revision to the regulations for the Steam Electric Power Generating category (85 FR 64650, October 13, 2020), which established revised ELGs for flue gas desulfurization (FGD) wastewater and bottom ash (BA) transport water discharged from steam electric power plants. See the *Technical Development Document for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category,* or TDD (EPA-821-R-23-005) for more background and information on the rulemaking history.

This proposed rulemaking is based on a review of the ELGs promulgated in 2020 (referred to as the "2020 rule") under Executive Order 13990. The proposed revisions cover best available technology economically achievable (BAT) and pretreatment standards for existing sources (PSES) requirements for FGD wastewater, BA transport water, combustion residual leachate (CRL), and legacy wastewater from steam electric power plants.

In support of the development of the 2015 rule and the 2020 rule, EPA conducted an environmental assessment (EA) to evaluate the environmental impact of pollutant loadings discharged by steam electric power plants and assess the potential environmental improvement from pollutant loading changes under the rules. EPA documented the EA in the September 2015 report *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-15-006) (U.S. EPA, 2015a), referred to hereinafter as the "2015 EA," and the *Supplemental Environmental Assessment for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-20-002) (U.S. EPA, 2020a), referred to hereinafter as the "2020 EA." To support this proposed rulemaking, EPA updated its EA for the 2015 rule and 2020 rule and performed an additional analysis on cumulative impacts from multiple pollutants (Joint Toxic Action analysis).

The Clean Water Act does not require that EPA assess the water quality-related environmental impacts, or the benefits, of its ELGs, and the Agency did not make its decisions in the proposed rule based on the expected benefits of the rule. EPA does, however, inform itself and the public of the benefits of its proposed and final rules, as required by Executive Order 12866. See the *Benefit and Cost Analysis for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, or BCA Report (EPA-821-R-23-003). This EA report presents EPA's evaluation of the potential environmental impacts due to pollutant loadings under baseline discharge practices (*i.e.*, following full implementation of the requirements under the 2015 rule and 2020 rule and any known retirements, fuel conversions, and treatment technologies in place at in-scope steam electric power plants) and the improvements to those impacts under the evaluated regulatory options.

1.1 Background on Steam Electric Power Plant Wastewater Discharges

Based on demonstrated impacts documented in literature and modeled receiving water pollutant concentrations, discharges of steam electric power plant wastewater and its discharge practices can affect the water quality in receiving waters, affect the wildlife in the surrounding environments, and pose a human health risk to nearby communities. There is substantial evidence that certain pollutants found in these wastewater discharges, such as mercury and selenium, propagate from the aquatic environment to terrestrial food webs, indicating a potential for broader impacts on surrounding ecological systems by diminishing population diversity and disrupting community dynamics. Ecosystem recovery from exposure to these pollutants can be extremely slow, and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years.

Steam electric power plants often discharge wastewater into waterbodies used for fishing, for recreation, and/or as sources of drinking water. Many studies have raised concerns about the toxicity of these wastestreams and their impacts on downstream drinking water treatment systems. For example, these discharges can elevate halogen levels in surface water, which may contribute to disinfection byproduct formation at downstream drinking water treatment plants. Leaching of pollutants from surface impoundments and landfills containing combustion residuals is known to affect off-site groundwater and drinking water wells at concentrations above maximum contaminant level drinking water standards, posing a threat to human health.

1.1 Scope of the EA

The Steam Electric Power Generating Point Source Category ELGs apply to establishments whose generation of electricity is the predominant source of revenue or principal reason for operation, and whose generation results primarily from a process using fossil-type fuels (coal, oil, or gas), fuel derived from fossil fuel (*e.g.*, petroleum coke, synthesis gas), or nuclear fuel in conjunction with a thermal cycle using the steam water system as the thermodynamic medium. EPA evaluated four wastestreams from steam electric power plants whose limitations and standards would be revised under the new rulemaking: FGD wastewater, BA transport water, CRL, and legacy wastewater, as described in Table 1.

Table 1. Wastestreams Evaluated in the EA

Evaluated Wastestream	Description
FGD wastewater	Wastewater generated from a wet FGD scrubber system. Wet FGD systems are used to control sulfur dioxide (SO_2) and mercury emissions from the flue gas generated in the plant's boiler. The pollutant concentrations in FGD wastewater vary from plant to plant depending on the coal type, the burning of refined coal, the sorbents and additives used, the materials used to construct the FGD system, the FGD system operation, the level of recycle within the absorber, and the air pollution control systems operated upstream of the FGD system. FGD wastewater contains chlorides, total dissolved solids (TDS), total suspended solids (TSS), nutrients, halogens, metals, and other toxic and bioaccumulative pollutants, such as arsenic and selenium (see the TDD for further details).
BA transport water	Water used to convey the BA particles collected at the bottom of the boiler. BA transport waters contain halogens, TDS, TSS, metals, and other toxic and bioaccumulative pollutants, such as arsenic and selenium (see the TDD for details). The effluent from surface impoundments typically contains low concentrations of TSS; however, arsenic, bromide, selenium, and metals are still present in the wastewater, predominantly in dissolved form.
CRL	Leachate is composed of liquid, including any suspended or dissolved constituents in the liquid, that has percolated through waste or other materials emplaced in a landfill, or that passes through the surface impoundment's containment structure (*e.g.*, bottom, dikes, berms). CRL includes seepage and/or leakage from a combustion residual landfill or impoundment unit. CRL contains pollutants similar to those in FGD wastewater.
Legacy wastewater	As described in the preamble to the proposed rule, legacy wastewater is comprised of FGD wastewater, BA transport water, fly ash transport water, CRL, gasification wastewater, and/or flue gas mercury control wastewater generated before the "as soon as possible" date that more stringent effluent limitations from the 2015 or 2020 rules would apply. Legacy wastewater contains pollutants similar to those in the other wastestreams described in this table.

The goal of the EA is to answer the following questions about pollutant loadings from the four evaluated wastestreams:

- What are the environmental concerns?
- What are baseline environmental impacts to water quality and wildlife and impacts to human health?
- What are the potential improvements to water quality, wildlife, and human health under the regulatory options?

This EA report presents EPA's evaluation of environmental concerns and potential exposures (ecological and human) to pollutants commonly found in wastewater discharges from steam electric power plants. EPA carried out both qualitative and quantitative analyses. Qualitative analyses included reviewing additional literature documenting site impacts and pollutant-specific research; assessing the pollutant loadings to receiving waters—including those designated as impaired or with a fish consumption advisory—under baseline and the evaluated regulatory options; and reviewing the effects of pollutant exposure, including cumulative impacts, on ecological and human receptors. To quantify impacts associated with these discharges, EPA used a computer model to estimate pollutant concentrations in the immediate receiving waters, pollutant concentrations in fish tissue, and potential exposure doses to ecological and human receptors from fish consumption. EPA compared the values calculated by the model to benchmark values to assess the extent of the environmental impacts nationwide. EPA evaluated the impacts of FGD wastewater, BA transport water, and CRL discharges.[1]

EPA evaluated four regulatory options, summarized in Table VII-1 of the preamble to the proposed rule. EPA evaluated 91 plants[2] that discharge FGD wastewater, BA transport water, and/or CRL directly or indirectly to surface waters under baseline and/or the regulatory options evaluated and performed the quantitative modeling of pollutants in the immediate receiving water on a subset of 85 of these plants. The analyses presented in this report account for notice of planned participation filings for 90 steam electric generating units (EGUs) at 38 plants (see section VI of the preamble to the proposed rule). This includes steam electric power plants that wished to participate in the low utilization EGU subcategory, the permanent cessation of coal combustion subcategory (by December 31, 2028), and EPA's voluntary incentive program promulgated in 2020. See Section 3.8 of this report for additional details on the scope of this EA.

The assessments described in this EA report focus on environmental impacts caused by exposure to pollutants in the evaluated wastestreams through the surface water exposure pathway. However, the regulatory options under the proposed rule may have other environmental impacts unrelated to exposure to pollutants in wastewater discharges. Examples include changes in groundwater and surface water withdrawals by plants; changes in the amount of dredging activity necessary to maintain capacities in reservoirs and navigational channels downstream from plants; and changes in air emissions due to changes in electricity use, transportation requirements, and the profile of electricity generation. These impacts are discussed in EPA's *Benefit and Cost Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-23-003) (U.S. EPA, 2023b).

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[1] EPA is soliciting comments on the proposed supplemental rule (as described in its preamble), which leaves legacy wastewater discharge requirements to be derived on a site-specific basis by the permitting authorities, using their best professional judgment. Although EPA estimated pollutant discharges from legacy wastewater (U.S. EPA, 2023l), EPA did not conduct an EA for discharges of legacy wastewater. Based on additional information, EPA will update its analyses.

[2] EPA excluded one plant from the EA that indirectly discharges to a publicly owned treatment works that does not discharge to any receiving water (see U.S. EPA, 2022a).

This EA report does not discuss impacts caused by migration of pollutants from landfills and surface impoundments into groundwater. However, EPA does consider these discharges through groundwater in *Evaluation of Potential CRL in Groundwater* (U.S. EPA, 2023m).[3]

This report presents the methodology and results of the qualitative and quantitative analyses performed for the EA to support the proposed supplemental rule. In addition to this EA, the proposed rule is supported by several reports:

- Technical Development *Document for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD)*, Document No. EPA-821-R-23-005 (U.S. EPA, 2023a). This report includes background on the proposed rule, the industry, and treatment technologies and pollution prevention techniques; it also documents EPA's engineering analyses to support the proposed rule, including cost estimates, wastewater characterization and pollutant loadings, and a non-water-quality environmental impact assessment.
- *Benefit and Cost Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report), Document No. EPA-821-R-23-003 (U.S. EPA, 2023b). This report summarizes the monetary benefits and societal costs of implementing the regulatory options.
- *Regulatory Impact Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (RIA)*, Document No. EPA-821-R-23-002 (U.S. EPA, 2023c). This report presents a profile of the steam electric power generating industry, a summary of the costs and impacts associated with the regulatory options, and an assessment of the proposed rule's impact on employment and small businesses.
- *Environmental Justice Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (EJ Report)*. Document No. EPA-821-R-23-001 (U.S. EPA, 2023d). This report presents the environmental justice (EJ) analysis to support the proposed rule, including screening analysis to identify communities with potential EJ concerns, community outreach, literature review, and risk analysis.

The ELGs for the Steam Electric Power Generating Category are based on data generated or obtained in accordance with EPA's Quality System and Information Quality Guidelines. EPA's quality assurance and quality control activities for this rulemaking include developing, approving, and implementing quality assurance project plans for the use of environmental data generated or collected from sampling and analyses, existing databases, and literature searches, and for developing any models that used environmental data.

[3] The preamble also discusses some of the major provisions of companion disposal rules that would also address issues relating to groundwater.

2. Literature Review of the Environmental and Human Health Concerns Associated with the Evaluated Wastestreams

Discharges of the evaluated wastestreams from steam electric power plants—flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater—contain toxic and bioaccumulative pollutants (*e.g.*, selenium, mercury, arsenic, nickel), halogen compounds (containing bromide, chloride, or iodide), nutrients, and total dissolved solids (TDS), which can cause environmental harm through the contamination of surface waters. Certain pollutants in the discharges pose a danger to ecological communities due to their persistence in the environment and bioaccumulation in organisms. These factors can slow ecological recovery and can have long-term impacts on aquatic organisms, wildlife, and human health. Many studies document ecological impacts such as fish mortality, genotoxicity, and lower fish survival and reproduction rates resulting from exposure to pollutants in steam electric power plant discharges (Brandt et al., 2017 and 2019; Carlson and Adriano, 1993; Hopkins et al., 2000; Javed et al., 2016; Lemly, 1997b and 2018; Rowe et al., 1996 and 2002). Halogen compounds associated with steam electric power plant discharges also raise ecological and human health concerns. Halogens in source water for drinking water treatment plants (DWTPs) can interact with disinfection processes to form halogenated disinfection byproducts (DBPs), which can pose a risk to human health (Cantor et al., 2010; Chisholm, 2008; Dong et al., 2019; Hanigan et al., 2017; National Toxicology Program, 2018; Regli et al., 2015; Richardson et al., 2007 and 2008; Richardson and Plewa, 2020; U.S. EPA, 2016a; Villanueva et al., 2004, 2007, and 2015; Wagner and Plewa, 2017; Wei et al., 2013; Yang et al., 2014).

EPA documented environmental and human health concerns from steam electric power plant discharges in the 2015 final environmental assessment, or EA (U.S. EPA, 2015a) and the 2020 EA (U.S. EPA, 2020a). For this EA, EPA conducted supplemental literature reviews that consisted of identifying and evaluating peer-reviewed journal articles and other materials published since its last full literature review (2010) that focus on current environmental, ecological, and human health impacts resulting from discharges of pollutants in the evaluated wastestreams. This section summarizes relevant findings from the 2015, 2020, and 2022 literature reviews, including an overview of the pollutants discharged in the evaluated wastestreams and their associated environmental concerns. Some of the articles documented impacts of steam electric power plant discharges but did not provide specific wastestream details. When such details were documented in reviewed articles, EPA included details on applicable wastestreams. See the memorandum *Methodology and Results for a Targeted Literature Search for the 2022 Steam Electric Power Generating Industry Environmental Assessment* (U.S. EPA, 2023e) for details.

2.1 Pollutants Discharged in the Evaluated Wastestreams

Several variables can affect the composition of steam electric power plant wastewater, including fuel composition (*e.g.*, parent coal composition varies by coal type and geographic region and inclusion of other fuels in the combustion process), air pollution control technologies (*e.g.*, use of dry versus wet systems), and management techniques used to dispose of the wastewater (*e.g.*, whether the plant commingles its wastestreams) (Carlson and Adriano, 1993; Rowe et al., 2002). Commingling steam electric power plant wastewaters in surface impoundments can result in a complex mixture of pollutants in the effluent that is released to the environment (Rowe et al., 2002).

2.1.1 Metals and Toxic Bioaccumulative Pollutants

Studies commonly cite metals and toxic bioaccumulative pollutants (*e.g.*, arsenic, mercury, and selenium) as the primary cause of ecological damage following exposure to steam electric power plant wastewater (U.S. EPA, 2015a). An important consideration in evaluating these pollutants is their bioavailability, defined as the ability of a particular contaminant to be assimilated into the tissues of exposed organisms. A pollutant’s bioavailability is affected by the characteristics of both the pollutant (*e.g.*, speciation, particle size) and the surrounding environment (*e.g.*, temperature, pH, salinity, oxidation-reduction potential, total organic content, suspended particulate content, and water velocity). Metals and toxic bioaccumulative pollutants in steam electric power plant wastewater are present in both soluble (*i.e.*, dissolved) and particulate (*i.e.*, suspended) form. For example, EPA collected sampling data for FGD wastewater in support of the steam electric effluent limitations guidelines and standards. These data show that some pollutants, such as arsenic, are present mostly in particulate form while other pollutants, such as selenium and boron, are present mostly in soluble form (ERG, 2012). Environmental conditions influence the tendency of a dissolved pollutant to remain in solution or precipitate out of solution, sorb to either organic or inorganic suspended matter in the water column, or sorb to the mixture of materials (*e.g.*, clays and humic matter) found in sediments (U.S. EPA, 2007). Pollutants that precipitate out of solution can become concentrated in the sediments of a waterbody. Organisms will bioaccumulate pollutants by consuming pollutant-enriched sediments and suspended particles, filtering ambient water containing dissolved pollutants, or both.

Appendix A of the 2020 EA (U.S. EPA, 2020a) provides examples of potential adverse impacts to humans, wildlife, and aquatic organisms resulting from exposure to metals and toxic bioaccumulative pollutants in the evaluated wastestreams and provides the minimal risk level (MRL) for human oral exposure (or similar benchmark value) for reference. Adverse impacts from steam electric power plant discharges of these pollutants are discussed further in the 2015 EA (U.S. EPA, 2015a).

2.1.2 Nutrients

Nutrients (*e.g.*, phosphorus and nitrogen) are essential components for plants and animals to grow and develop; however, increased nutrient concentrations can upset the delicate balance of nutrient supply and demand required to maintain aquatic life in surface waters. For example, excess nutrients can cause harmful algal blooms and low oxygen (hypoxia) in surface waters. These are primarily problems for estuaries, such as the Chesapeake Bay, and coastal waters, such as the Gulf of Mexico. Nutrient loadings from multiple power plants are especially a concern for waterbodies that are nutrient-impaired or in watersheds that have nutrient problems downstream. Nutrient concentrations present in steam electric power plant wastewater are primarily attributed to the fuel composition and air pollution controls in the combustion process.

Nutrient loadings to surface waters can affect the ecological stability of freshwater and saltwater aquatic systems. For example, elevated levels of nutrients can stimulate rapid growth of plants, algae, and cyanobacteria on or near the waterbody surface, which in turn can obstruct sunlight penetration, increase turbidity, and decrease dissolved oxygen levels (U.S. EPA, 2015b). Adverse impacts from steam electric power plant discharges of nutrients are discussed further in the 2015 EA (U.S. EPA, 2015a).

2.1.3 TDS and Salinity

TDS represents the concentration of combined dissolved organic and inorganic matter, whereas salinity represents the total concentration of dissolved inorganic salts. Common inorganic salts found in TDS can include cations (positively charged ions), such as calcium, magnesium, potassium, and sodium, and anions (negatively charged ions), such as carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS concentrations in steam electric power plants wastestreams include contributions from dissolved metals and halogens (*e.g.*, chlorides, bromides, and iodides).

Salts can enter water naturally through erosion of soils and geologic formations and introduction of their dominant ions to local freshwater systems (Hem, 1985; Olson and Hawkins, 2012; Pond, 2004; U.S. EPA, 2011). In addition to steam electric power plants, other sources of TDS are widespread in the environment, making it more likely that receiving waters for the discharges of the evaluated wastestreams already carry excessive TDS loadings. These other sources include mining activities, use of road salt for de-icing, and discharge of sewage and industrial wastewater (Cañedo-Argüelles et al., 2013; Corsi et al., 2010). Once salinity has increased in freshwater systems, the effect can be persistent. In lentic waters such as lakes and ponds, even small increases in salt levels can result in long-term increases in salinity, lasting months or years (Evans and Frick, 2001). Kaushal et al. (2005) reported that, after application of deicing salts in winter, chloride concentrations in urban streams remain elevated into spring, summer, and fall and contribute to an accumulation of salts in groundwater and aquifers that may persist over several decades.

Harb et al. (2021) studied how changes in freshwater salinity can have environmental impacts on (1) spray aerosol generation from the breaking of waves and (2) diversity of aquatic bacteria. As waves break, aquatic bacteria can be aerosolized (*i.e.*, transferred from water to air). Changes in the bacteria being transferred from water to air could affect regional climate by altering aerosolized bacteria that act as cloud condensation nuclei (*i.e.*, particles in the air onto which water vapor will condense) and ice-nucleating particles (*i.e.*, particles for formation of cloud ice crystals). In addition, alterations in the aerosolized bacteria could affect public health by increasing inhalation exposure to airborne pathogens (Harb et al., 2021). Harb et al. (2021) sought to understand how increased freshwater salinity can impact the abundance and diversity of aerosolized aquatic bacteria. In freshwater salinity ranges, researchers found that aerosolization of bacteria increased as salinity increased. The study found that salinity altered the transfer of some bacterial families to an aerosol, with some families exhibiting enhanced, diminished, or no change in water to air transfer (Harb et al., 2021).

Exposure to dissolved bioaccumulative pollutants and halogens found in the evaluated wastestreams may cause human health and ecological effects. Researchers have documented the potential consequences of elevated salinity on aquatic ecosystems. Increased salinity has been linked to adverse effects including increases in invasive species, lower rates of organic matter processing, changes in biogeochemical cycles, decreased riparian vegetation, and altered composition of primary producers (*i.e.*, plants, bacteria, and algae) (Cañedo-Argüelles et al., 2013). Increases in aquatic salinity may cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species, and result in acute or chronic effects at specific life stages (Weber-Scannell and Duffy, 2007). Salt additions can lead to loss of exchangeable cations in soil, and the mobility and toxicity of some pollutants, especially metals, can be enhanced at high salt concentrations (Stets et al., 2020). Because interactions between ions can affect the bioavailability and toxicity of individual TDS constituents, the net ecological effect of elevated TDS levels in the aquatic environment depends on its ionic composition (Moore et al., 2017; Mount et al., 1993 and 1997). The 2020 EA (U.S. EPA, 2020a) provides further details on adverse impacts from discharges of TDS and increased salinity in freshwater systems.

2.1.4 Bromine/Bromide

Bromine is naturally present in coal. Some coal-fired steam electric power plants also add bromine, in the form of bromide compounds, to their combustion processes to enhance mercury emissions control or burn refined coal amended with bromide compounds (U.S. EPA, 2020b). After combustion, bromine partitions in part to FGD wastewater and BA transport water in its anion form, known as bromide (EPRI, 2014; Peng et al., 2013). Documented bromide levels in FGD wastewater vary widely and can exceed 175 milligrams per liter (mg/L) (EPRI, 2009; Good, 2018; U.S. EPA, 2015c and 2020b). Average bromide levels of 5.1 mg/L have been documented in BA transport wastewaters (U.S. EPA, 2020b). These levels are higher than the average levels of 0.014 mg/L to 0.2 mg/L reported for freshwater surface waters (Flury and Papritz, 1993; Health Canada, 2015; McGuire et al., 2002). Field-based and modeling studies document elevated bromide levels in surface waters downstream of steam electric power plants and identify FGD wastewater discharges as a substantial source of bromide loadings from the plants (Cornwell et al., 2018; Good and VanBriesen, 2016, 2017, and 2019; Kolb et al., 2020; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013; U.S. DOJ, 2015; U.S. EPA, 2015c).

Bromide has a low toxicity in freshwater aquatic environments compared to substances such as copper or cadmium cations. Flury and Papritz (1993) present the results from two previous studies on the median lethal toxic concentration (LC_{50}) of bromide compared to other chemicals.

- For golden orfe (*Leuciscus idus melanotus*), the LC_{50} for bromide is greater than 7,765 mg/L, compared to 0.32 mg/L for copper and 4.5 to 35.4 mg/L for cadmium (Juhnke and Lüdemann, 1978).

- For fathead minnow (*Pimephales promelas*), the LC_{50} for bromide is greater than 67 mg/L, compared to 0.555 to 1.4 mg/L for copper (Ewell et al., 1986).

Reviews of freshwater aquatic organism toxicology studies cite effect concentrations of bromide that range from 110 to 4,600 mg/L for single-celled organisms, 2.2 to 11,000 mg/L for invertebrates, and 7.8 to 24,000 mg/L for fish (EPRI, 2014; Flury and Papritz, 1993).

The World Health Organization (WHO) estimates that consumption of drinking water supplies with bromide concentrations below 2.0 mg/L would meet acceptable daily intake levels for both children and adults (WHO, 2009). Bromide's toxicity associated with its contribution to DBP formation in drinking water treatment and distribution systems can be of a greater concern (Krasner et al., 2006; Krasner, 2009; Regli et al., 2015; Richardson and Postigo, 2011; U.S. EPA, 2016a; Yang et al., 2014). DBPs are a broad class of compounds that form as byproducts of drinking water disinfection, and some of them have toxic properties. Bromide in source water becomes highly reactive in the presence of commonly used drinking water disinfectants and can form brominated DBPs (Br-DBPs) at low source water concentrations (Bond et al., 2014; Chang et al., 2001; Heeb et al., 2014; Landis et al., 2016; Parker et al., 2014; Richardson et al., 2007; U.S. EPA, 2016a; Wang et al., 2017; Westerhoff et al., 2004). Although multiple factors affect DBP formation, increases and decreases in source water bromide levels are generally associated with concurrent increases and decreases in both total DBP and bromide speciation levels in treated water (AWWARF and U.S. EPA, 2007; Bond et al., 2014; Cornwell et al., 2018; Ged and Boyer, 2014; Hua et al., 2006; Huang et al., 2019; Landis et al., 2016; McTigue et al., 2014; Obolensky and Singer, 2008; Pan and Zhang, 2013; Regli et al., 2015; Sawade et al., 2016; States et al., 2013; Yang and Shang, 2004; Zha et al., 2014).

The 2020 EA (U.S. EPA, 2020a) provides further details on bromide in freshwater systems and adverse impacts in source water for DWTPs.

2.1.5 Iodine/Iodide

Iodine is naturally present in coal.[4] Some coal-fired steam electric power plants also add iodine, in the form of iodide compounds, to their combustion processes to enhance mercury emissions control or burn refined coal amended with iodide compounds (ADES, 2016; Gadgil, 2016; ICAC, 2019; Sahu, 2017; Senior et al., 2016; Sjostrom et al., 2016; Sjostrom and Senior, 2019; Tinuum, 2020).[5] Iodine volatilizes during combustion and partitions to FGD wastewaters and, to a lesser extent, to BA transport waters (ADES, 2016; ICAC, 2019; Meij, 1994; Peng et al., 2013; Sjostrom et al., 2016). In FGD wastewaters, iodine occurs as iodide/triiodide anions and elemental iodine (Sjostrom et al., 2016). Data on typical iodine concentrations in FGD wastewater and BA transport waters are limited. One study (Sjostrom et al., 2016) indicated that iodine concentrations in FGD wastewater should be below about 100 mg/L to ensure normal FGD system operation and to recover iodine for reuse.

Typical iodine levels in freshwater surface waters are less than 0.020 mg/L, though levels ranging from 0.00001 to 0.212 mg/L have been reported.[6] In freshwater, elemental iodine dissociates to its anionic form and/or reacts with organic material to form iodinated organic compounds. Iodide is highly soluble and exhibits conservative fate and transport in freshwater (Fuge and Johnson, 1986; Moran et al., 2002).

According to available data, iodide has lower ecotoxicity in freshwater aquatic environments than other substances such as copper or cadmium cations. For golden orfe (*Leuciscus idus melanotus*), the LC_{50} for

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[4] Native iodine levels in coal range from 0.14 to 12.9 ppm (Bettinelli et al., 2002; Gluskoter et al., 1977; Good, 2018). One source states that many coals used by utility plants have iodine levels greater than 3 ppm (Sjostrom et al., 2016).

[5] Addition rates are reported to range from 1 to 30 ppm and are typically less than 10 ppm (Gadgil, 2016; ICAC, 2019; Sahu, 2017; Sjostrom et al., 2016).

[6] The highest measured levels reflect influence of irrigation water return flows in arid areas.

iodide is greater than 4,525 mg/L compared to 0.32 mg/L for copper and 4.5 to 35.4 mg/L for cadmium (Juhnke and Lüdemann, 1978). Estimates of LC_{50} for iodide range from 860 to 8,230 mg/L for freshwater fish and from 0.17 to 0.83 mg/L for *Daphnia magna*, an aquatic invertebrate (Flury and Papritz, 1993; Laverock et al., 1995). Toxicity to single-celled organisms is reported to be similar to that of bromide (Bringmann and Kühn, 1980; Flury and Papritz, 1993). In comparison, elemental iodine toxicity is higher for freshwater fish, with LC_{50} concentrations from 0.53 mg/L to greater than 10 mg/L, and is similar to iodide toxicity for *D. magna,* with LC_{50} concentrations from 0.16 to 1.75 mg/L (Laverock et al., 1995; LeValley, 1982).

For humans, iodine is an essential element for thyroid hormone production and metabolic regulation. Excessive consumption can lead to hypothyroidism (diminished production of thyroid hormones), hyperthyroidism (excessive production and/or secretion of thyroid hormones), or thyroiditis (inflammation of the thyroid gland) (ATSDR, 2004a). The MRL for acute and chronic oral exposure to iodide is 0.01 milligrams per kilogram per day based on endocrine effects (ATSDR, 2020).

As with bromide, most toxicity concerns for iodine/iodide are associated with its contribution to DBP formation in drinking water treatment and distribution systems. Iodine in source water becomes reactive during chlorine-, chlorine dioxide-, chloramine-, or ultraviolet (UV)-based disinfection, when it can combine with organic material in source waters to form iodinated DBPs (I-DBPs) (Bichsel and Von Gunten, 2000; Criquet et al., 2012; Dong et al., 2019; Ersan et al., 2019; Hua et al., 2006; Hua and Reckhow, 2007; Krasner, 2009; Krasner et al., 2006; Postigo and Zonja, 2019; Richardson et al., 2008; Tugulea et al., 2018; U.S. EPA, 2016a; Weinberg et al., 2002). Both iodide and iodinated organic compounds in source waters can contribute to I-DBP formation during drinking water disinfection (Ackerson et al., 2018; Dong et al., 2019; Duirk et al., 2011; MacKeown et al., 2020; Pantelaki and Voutsa, 2018; Tugulea et al., 2018). Iodate, a non-toxic iodine compound that can form in the presence of oxidants (including certain DWTP disinfectants), can also contribute to I-DBP formation under certain conditions (Dong et al., 2019; Postigo and Zonja, 2019; Tian et al., 2017; Xia et al., 2017; Yan et al., 2016; Zhang et al., 2016). I-DBP levels are influenced by multiple factors and have been found to increase with iodide or total iodine levels in source water (Criquet et al., 2012; Dong et al., 2019; Gruchlik et al., 2015; Postigo and Zonja, 2019; Tugulea et al., 2018; Ye et al., 2013; Zha et al., 2014).[7]

The 2020 EA (U.S. EPA, 2020a) provides further details on iodine and adverse impacts in source water for DWTPs.

2.2 Potential Impacts from the Evaluated Wastestreams

Changes in surface water chemistry due to contamination from steam electric power plant wastewater can harm all levels of an ecosystem, including organisms at lower trophic levels; this in turn affects the ecosystem's food web and fish inhabiting the surface water. Pollutants in surface water can bioaccumulate in aquatic organisms such as fish. When wildlife or humans ingest these aquatic organisms, they can be exposed to a higher dose of contamination than through direct exposure to the surface water. Surface water impacts associated with discharges of steam electric power plant wastewater include damage to fish populations (*i.e.*, physiological and morphological abnormalities and various behavioral, reproductive, and developmental effects), decreased diversity in insect populations, and decline of aquatic macroinvertebrate population. Impacts that affect humans include exceedances of National Recommended Water Quality Criteria, fish consumption advisories, designation of surface waters as impaired (limiting recreational activities), and contamination of downstream drinking water sources.

[7] Other factors influencing I-DBP formation include pH, temperature, disinfection process type and dosage level, bromide levels, ammonium levels, organic material levels and type, and treatment and distribution system residence time.

This section provides an overview of the environmental impacts caused by exposure to pollutants in discharges of the evaluated wastestreams. It also summarizes additional studies identified as part of the literature review conducted to support this EA and the proposed rulemaking. Details of previous literature reviews are included in the 2015 EA (U.S. EPA, 2015a) and the 2020 EA (U.S. EPA, 2020a).

2.2.1 Ecological Impacts

Many of the pollutants in steam electric power plant wastewater (*e.g.*, arsenic, mercury, selenium) readily accumulate in exposed biota. This bioaccumulation is of particular concern due to their impact on higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater. Aquatic systems with long residence times and potential contamination with bioaccumulative pollutants often experience persistent environmental effects following exposure to steam electric power plant wastewater.

Population decline attributed to exposure to steam electric power plant wastewater can alter the structure of aquatic communities and cause cascading effects within the food web that result in long-term impacts to ecosystem dynamics (Rowe et al., 2002). Reductions in organism survival rates from abnormalities caused by exposure to power plant wastewater and alterations in interspecies relationships, such as declining abundance or quality of prey, can delay ecosystem recovery until key organisms within the food web return to levels prior to power plant wastewater exposure. In a 1980 study of a creek in Wisconsin, fungal decomposition of detritus was limited due to the effects of power plant wastewater. Because of this reduction in available resources, the population of benthic invertebrates (which graze on detrital material) declined, as did benthic fish that prey upon small invertebrates (Magnuson et al., 1980).

Ecological impacts associated with exposure to steam electric power plant wastewater include lethal impacts, such as fish kills, and sublethal impacts, such as teratogenic deformities, oxidative stress, deoxyribonucleic acid (DNA) damage, reduced growth, and genotoxicity (Brandt et al., 2017 and 2019; Carlson and Adriano, 1993; Javed et al., 2016; Lemly, 2018; Rowe et al., 2002). Much of the scientific literature focuses on selenium as a key pollutant of environmental concern in steam electric power plant wastewater. Selenium can bioaccumulate to toxic levels in organisms inhabiting environments with low selenium concentrations. As studied by Lemly (1985), the extent of selenium bioaccumulation depends on the trophic level of the fish present in the water. Lemly observed that selenium accumulation increased as the trophic level increased, which potentially correlates with the observed elimination of multiple higher-tropic-level fish species. The study also found that selenium discharges also affect species diversity in receiving waters (Lemly, 1985). Selenium discharges can lead to long-term issues in ecosystems due to prolonged retention in the environment and cycling and propagation in the food chain (Brandt et al., 2019).

The sublethal effects of selenium vary widely and can affect growth, reproduction, and survival of susceptible organisms. Scientists have demonstrated that various fish and amphibian species are sensitive to elevated selenium concentrations similar to those found in steam electric power plant wastewater. In addition to lethal effects, these fish and amphibian species have developed sublethal symptoms such as accumulation of selenium in tissue (histopathological effects) and in the blood (hematological effects), resulting in decreased growth, changes in weight, abnormal morphology, and reduced hatching success (Coughlan and Velte, 1989; Lemly, 1993 and 2018; Sager and Colfield, 1984; Sorensen, 1988; Sorensen and Bauer, 1984; Sorensen et al., 1982, 1983, 1984). In addition, selenium is highly teratogenic (*i.e.*, able to disturb the growth and development of an embryo or fetus) and readily transferable from mother to egg (Chapman et al., 2009; Janz et al., 2010; Lemly, 1997a; Maier and Knight, 1994).

Although effects documented in the literature primarily focus on selenium, several studies discussed the sublethal effects of other pollutants, such as arsenic, cadmium, chromium, copper, and lead (Rowe et al., 2002), and decreased diversity in receiving water fish species (Javed et al., 2016). Sublethal effects from exposure to pollutants other than selenium in power plant wastewater can include changes to morphology (*e.g.*, fin erosion, oral deformities), behavior (*e.g.*, ability to swim, catch prey, and escape from predators), and metabolism that can negatively affect long-term survival (Rowe et al., 2002).

In the most recent literature review, EPA identified studies that discussed concerns with bromide and halogenated DBPs' impact on ecological receptors. As noted in Section 2.1.4, bromide is one of the pollutants discharged by steam electric power plants, and the discharge of bromide and iodine (see Section 2.1.5) can lead to increased DBP formation at downstream DWTPs.

Since 1994, scientists noted the spread of vacuolar myelinopathy (VM), a neurological disease, in bald eagles, other birds of prey, and waterfowl. At DeGray Lake in Arkansas, more than 70 eagle mortalities were found in two years, and investigators began noticing eagles and other waterbirds with neurological impairments across the southeastern United States (Breinlinger et al., 2021). VM has also been found in other wildlife including amphibians, reptiles, and fish. Field and laboratory studies have shown that VM can be transferred up the food chain from fish to wildlife and birds of prey. Documented cases in avian species have been found near artificial waterbodies with abundant aquatic vegetation located in the southeastern United States. Breinlinger et al. (2021) conducted field studies in southeastern U.S. waters and laboratory studies to identify the causative agent of VM. The scientist showed that a neurotoxin, which they termed aetokthonotoxin (AETX), was the causative agent of VM. AETX is produced by *Aetokthonos hydrillicola* (cyanobacterium) growing on aquatic vegetation (*Hydrilla verticillata*). The researchers noted that AETX's structure has characteristics not previously observed in nature and investigated the biosynthesis of the neurotoxin. Breinlinger et al. (2021) determined that the biosynthesis of AETX depends on the bioavailability of bromide, along with other factors (*e.g.*, temperature).

Cui et al. (2021) investigated the potential toxicity and ecological risk to freshwater organisms from exposure to halogenated DBPs. Research was prompted by the increased use of chlorine as a disinfecting agent due to the SARS-CoV-2 outbreak and increased DBP levels in wastewater treatment effluent. The organisms studied covered three trophic levels: phytoplankton (*Scenedesmus sp.*), zooplankton (*Daphnia magna*), and fish (*Danio rerio*). Cui et al. (2021) found that *Scenedesmus sp.* were most sensitive to haloacetic acids (HAAs) and *Daphnia magna* were most sensitive to haloacetonitriles (HANs) and trihalomethanes (THMs). Cui et al. (2021) cited other research on the toxicity of brominated DBPs to aquatic organisms and findings that DBPs can have reproductive impacts on *Daphnia magna* and adversely affect embryonic development of zebrafish. Observed impacts from the DBP exposure (for most of the DBPs tested) included the following:

- Inhibited growth for phytoplankton (*Scenedesmus sp.*).
- Decreased swimming ability (immobilization) for zooplankton (*Daphnia magna*).
- Induced mortality and abnormal development for fish (*Danio rerio*).

2.2.2 Human Health Effects

Exposure to pollutants can cause non-cancer effects in humans, including damage to the circulatory, respiratory, or digestive systems and neurological and developmental effects. Steam electric power plant wastewater includes toxic pollutants and known or suspected carcinogens (*e.g.*, arsenic and cadmium). Documented exceedances of drinking water maximum contaminant levels (MCLs) downstream of steam electric power plants, and the issuance of fish advisories in receiving waters, indicate an ongoing human health concern caused by power plant wastewater discharges. The primary exposure route investigated in this EA is through fish consumption (see Sections 3 and 4). As noted in Section 2.1, pollutants in steam electric power plant discharges can bioaccumulate in fish that are then consumed by recreational and subsistence fishers. For example, Lemly (2014) studied selenium contamination in fish found in Lake Sutton—a popular fishing location that is also used as a cooling reservoir for discharges from the L.V. Sutton Steam Plant settling pond before the water moves downstream into the Cape Fear River. Based on data collected between 1987 and 2011, the selenium concentration in bluegill (*Lepomis macrochirus*) exceeded the toxic thresholds established by researchers, and physical examination showed elevated deformities in the fish (*e.g.*, skeletal and craniofacial defects) compared to a reference lake (29 percent in

Lake Sutton to 0.5 percent in the reference lake). Researchers noted similar results in morphological abnormalities at other lakes that receive power plant discharges (*e.g.*, Belews Lake and Hyco Reservoir).

In addition, groundwater and drinking water supplies can be degraded by pollutants in steam electric power plant wastewater (Cross, 1981). Power plants may dispose of or store coal combustion residuals (CCR), or coal ash, in landfills or surface impoundments. Leachate and legacy wastewater (see Section 1), which contain pollutants from the CCR, can migrate from the power plant landfills and surface impoundments via the groundwater at concentrations that could contaminate public or private drinking water wells and surface waters, even years following disposal of combustion residuals (NRC, 2006).

As discussed in Sections 2.1.4 and 2.1.5, the discharge of bromide and iodine into drinking water sources is a concern due to the formation of DBPs in DWTPs and their distribution systems.

- Toxicology and epidemiology studies have documented evidence of genotoxic (including mutagenic), cytotoxic, and carcinogenic properties of DBPs, including Br-DBPs (National Toxicology Program, 2018; Richardson et al., 2007; U.S. EPA, 2016a). Studies have documented evidence of a link between DBP exposure and bladder cancer and, to a lesser degree, colon and rectal cancer, other cancers, and reproductive and developmental effects (Cantor et al., 2010; Chisholm, 2008; Regli et al., 2015; Richardson et al., 2007; U.S. EPA, 2016a; Villanueva et al., 2004, 2007, and 2015). Br-DBPs typically have higher toxicity than their chlorinated analogues (Cortés and Marcos, 2018; Plewa et al., 2008; Richardson et al., 2007; Sawade et al., 2016; U.S. EPA, 2016a; Yang et al., 2014). Due to bromide's reactivity and DBP toxicity, elevated bromide levels in source waters have been associated with elevated health risks from disinfected water (Hong et al., 2007; Kolb et al., 2017; Regli et al., 2015; Sawade et al., 2016; Wang et al., 2017; Yang et al., 2014).
- *In vitro* toxicology studies with bacteria and mammalian cells have documented evidence of genotoxic (including mutagenic), cytotoxic, tumorigenic, and developmental toxicity properties of I-DBPs. Individual I-DBP species have higher toxicity than their chlorinated and brominated analogues and are among the most cytotoxic DBPs identified to date (Dong et al., 2019; Hanigan et al., 2017; National Toxicology Program, 2018; Richardson et al., 2007 and 2008; Richardson and Plewa, 2020; U.S. EPA, 2016a; Wagner and Plewa, 2017; Wei et al., 2013; Yang et al., 2014). While studies have documented evidence linking disinfected drinking water and DBP exposure to adverse human health effects (see the 2020 EA: U.S. EPA, 2020a), more research is needed to characterize the contribution of I-DBPs to these effects (Cortés and Marcos, 2018; Dong et al., 2019; Postigo and Zonja, 2019; U.S. EPA, 2016a). In a 2021 study, Long et al. concluded that iodoacetic acid exposure results in reproductive and developmental toxicity effects. Because conventional drinking water treatment processes do not effectively remove iodide from source waters and vary in their reduction of organic material levels (U.S. EPA, 2016a; Watson et al., 2015), they have the potential to generate I-DBPs when their source waters contain iodine.

2.2.3 Groundwater Impacts

Pollutants in CCR can leach into groundwater from surface impoundments and landfills. Older surface impoundments and landfills are of particular concern because they were often built without liners and leachate collection systems. Liners are typically made of synthetic material, asphalt, clay, or a composite of materials (*e.g.*, synthetic and clay) and are designed to collect leachate and prevent groundwater contamination. CCR held in unlined surface impoundments can enter the subsurface and contaminate groundwater. Pollutants in unlined landfills, used for the dry disposal of CCRs, can also leach as precipitation flows through the residuals pile and dissolves pollutants; the CRL can eventually migrate into groundwater. EPA has promulgated a series of rules to mitigate CCR disposal issues (*e.g.*, seeping of pollutants into groundwater, airborne pollutants as dust, and surface impoundment failures resulting in larger coal ash spills), starting with the Disposal of Coal Combustion Residuals from Electric Utilities final rule (80 FR 21301), which established requirements for the safe disposal of CCR nationwide. Even with additional requirements in place, pollutants can still enter the groundwater when liners fail or when a disposal site is situated such that natural groundwater fluctuations come into contact with the disposed waste.

Before the CCR rules, EPA identified more than 30 documented cases where groundwater contamination from surface impoundments extended beyond the plant boundaries, illustrating the threat to groundwater and drinking water sources (ERG, 2015a). Based on a review of exceedances of state or federal groundwater quality standards at surface impoundments, exceedances were most often due to boron, sulfate, or arsenic (Lewis et al., 2017).

Landfills pose their own groundwater contamination risks. If the landfills are not properly lined, the pollutants in CCR can leach into the soil during precipitation. In areas with acid rain, the precipitation's low pH can accelerate the leaching of contaminants into groundwater. In addition, heavy precipitation can not only accelerate leaching, but also carry pollutants in stormwater runoff, potentially contaminating groundwater or surface water resources (Andersen and Madsen, 1983). Based on a review of CCR landfill damage cases compiled by EPA, Lewis et al. (2017) noted that all the landfills were constructed before 1990 (before the Resource Conservation and Recovery Act requirements for liners went into effect), and only four of the 32 cited landfills were fully lined. As with groundwater exceedances from surface impoundments, the most common pollutants with exceedances included boron and sulfate. Iron and manganese had exceedances at more than half of the landfills (Lewis et al., 2017).

2.2.4 CCR Surface Impoundments as Attractive Nuisances

An "attractive nuisance" is an area or habitat that attracts wildlife and is contaminated with pollutants at concentrations high enough to potentially harm exposed organisms. Two methods of handling steam electric power plant wastewater, surface impoundments and constructed wetlands, are classified as lentic systems supporting aquatic vegetation and organisms. These methods have been known to attract wildlife from other terrestrial habitats and therefore can be considered attractive nuisances. For example, a surface impoundment can affect local wildlife as well as transient species that might rely on them during critical reproduction periods such as seasonal breeding events (Rowe et al., 2002). Exposure to steam electric power plant wastewater during sensitive life cycle events is a concern, given that it has been associated with complete reproductive failure in various vertebrate species (Cumbie and Van Horn, 1978; Gillespie and Baumann, 1986; Lemly, 1997b; Pruitt, 2000).

Several studies have shown that terrestrial fauna nesting near CCR surface impoundments can have higher levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium than the same species at reference sites (Bryan et al., 2003; Burger et al., 2002; Hopkins et al., 1997, 1998, 2000, 2006; Nagle et al., 2001; Rattner et al., 2006). Field studies have also documented adverse effects on reproduction for turtles and toads living near selenium-laden CCR surface impoundments (Hopkins et al., 2006; Nagle et al., 2001).

In addition to being attractive nuisances, surface impoundments near surface waters can be a source of coal ash spills that damage the environment, ecosystems, and downstream waters. Concerns with these spills include the large economic loss and costs to remediate, along with ecological damage, potential effects on human health, recreational impacts, and losses of consumptive use and aesthetic value. Researchers and state agencies have monitored the receiving water ecosystems following coal ash spills, notably the 2008 coal ash spill that affected the Emory River and Clinch River and the 2014 coal ash spill to the Dan River.

- Following the 2008 coal ash spill at the Tennessee Valley Authority's Kingston Plant, the Tennessee Department of Environment and Conservation found exceedances of the more stringent criteria for chronic exposure of fish and aquatic life at least once in January 2009 for several metals (*e.g.*, aluminum, cadmium, iron, and lead). Seven months after the spill, all fish collected had concentrations of selenium above a toxic threshold, and most were still contaminated at that level 14 months after the spill. Twenty-one months after the spill, a high percentage of fish were found with lesions, deformities, and infections, all symptoms of extreme stress. In addition, studies have shown elevated levels of arsenic and mercury in sediments near the ash spill, as well as selenium levels exceeding the MCL in three wells underneath the Kingston Plant's coal ash disposal area, ash processing area, and gypsum disposal facility (U.S. EPA, 2014).

- In 2011 and 2012, Van Dyke et al. (2017) measured trace contaminant concentrations in freshwater turtles in the Emory River, Clinch River, and a reference (unaffected) river. Turtles in the Emory River and Clinch River had higher concentrations of arsenic, copper, iron, mercury, manganese, selenium, and zinc than turtles in the reference river. However, the concentrations were low relative to values known to be toxic to other vertebrates. Researchers stated that they found little evidence that the residual coal ash in the affected rivers had an effect on contaminant bioaccumulation in turtles.
- Ku et al. (2020) evaluated mercury concentration in the Dan River 17 to 29 months following the coal ash spill, which was much smaller than the spill at the Emory and Clinch rivers. They found that mercury contamination in the Dan River surface sediments (0–16 centimeters) could be accounted for by organic matter, rather than the coal ash spill. The study also examined methylmercury bioaccumulation in invertebrates and fish and did not find evidence of elevated methylmercury bioaccumulation. The researchers concluded that the mercury contamination from the coal ash spill was largely absent in the surface sediment and biota three years after the spill. Alternatively, they suggested that the mercury from the coal ash spill was not generally bioavailable.

3. Environmental Assessment Methodology

This section presents EPA's evaluation of environmental concerns and potential exposures to pollutants commonly found in wastewater discharges from steam electric power plants. It describes the following:

- Pollutant loadings for the evaluated wastestreams.
- Pollutant exposure pathways.
- Methodologies used to quantify the environmental, ecological, and human health effects of pollutants discharged to surface waters from the evaluated wastestreams.
- Environmental assessment (EA) scope (*i.e.*, plants and immediate receiving waters).

3.1 Pollutant Loadings for the Evaluated Wastestreams

As discussed in Section 2, the pollutants commonly found in steam electric power plant wastewater—such as metals, total dissolved solids (TDS), and halogens—can result in impacts to water quality, aquatic life, wildlife, and human health. EPA analyzed four regulatory options for the proposed supplemental rule, as shown in Table VII-1 of the rule's preamble. EPA estimated pollutant loadings for the evaluated wastestreams considered as part of the proposed supplemental rule as described in Section 6 of the technical development document (TDD). EPA calculated plant-specific and receiving-water specific *baseline* and *regulatory option* pollutant loadings (in pounds per year) for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, and combustion residual leachate (CRL) being discharged to surface water or through publicly owned treatment works (POTWs) to surface water.

Most steam electric power plants (over 95 percent) evaluated for the proposed supplemental rule discharge directly to surface water. Three plants reported transferring CRL to a POTW rather than discharging directly to surface water.[8] For these POTW transfers, EPA adjusted the baseline and regulatory option loadings to account for pollutant removals expected during treatment at the POTW for each analyte. See Section 6 of the TDD for industry-wide annual baseline pollutant loadings for the evaluated wastestreams, as well as the reductions in pollutant loadings (relative to baseline) for each of the regulatory options.

EPA used these pollutant loadings as inputs to support the quantitative evaluation of environmental impacts via the surface water exposure pathway (see Section 3.2). Table 2 presents baseline pollutant loadings and the estimated reduction in pollutant loadings under the evaluated regulatory options for select pollutants. The memorandum *Pollutant Loadings Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023f) discusses EPA's methodology for estimating pollutant loadings for each immediate receiving water.

The pollutants with the greatest estimated reductions in annual mass loadings under the preferred option (Option 3), if finalized as proposed, are TDS (583 million pounds per year, or lb/year, decrease relative to baseline), chlorides (171 million lb/year decrease), magnesium (79 million lb/year decrease), bromide (between 959,000 and 7.76 million lb/year decrease),[9] and boron (5.3 million lb/year decrease).

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[8] EPA excluded one plant from the EA that indirectly discharges to a POTW that does not discharge to any receiving waters (see U.S. EPA, 2022a).

[9] EPA did not identify data indicating the specific halogen additive (*i.e.*, bromine or iodine) used at each plant to reduce mercury emissions. Therefore, EPA estimated potential ranges of bromide and iodine loadings. EPA defined the ranges' lower and upper bounds as follows (U.S. EPA, 2022b and 2023a):

Bromide (min): Bromide loadings in BA transport water and FGD wastewater from native coal content and the addition of bromide in the flue gas (*i.e.*, as brominated activated carbon). EPA did not estimate bromide loadings in

Implementation timing for each plant varies by regulatory option, wastestream, subcategorization, and the plant's permit renewal schedule. See the preamble for further discussion of the regulatory options and associated deadlines. Due to the differing timelines for individual wastestreams and plants, the net reduction in pollutant loadings and corresponding environmental changes will be staggered over time as the plants implement control technologies. The EA presents EPA's estimates of environmental improvements associated with each regulatory option using steady-state annual average pollutant loadings reflecting full implementation of the effluent limitations and standards. Therefore, the results presented in the EA may underestimate short-term environmental impacts for the period before full implementation of the regulatory options during which plants transition from current discharges to discharges associated with full implementation. In addition, the EA did not evaluate the impacts of any discharges other than the three evaluated wastestreams; therefore, the pollutant loadings and subsequent quantitative analyses do not represent a complete assessment of environmental impacts from steam electric power plants.

Table 2. Estimated Annual Baseline Mass Pollutant Loadings and Estimated Reduction in Loadings Under Regulatory Options for the Evaluated Wastestreams[a]

Pollutant	Estimated Baseline Pollutant Loadings (lb/year)	Estimated Reduction in Pollutant Loadings Relative to Baseline (lb/year)			
		Option 1	Option 2	Option 3	Option 4
Aluminum	73,900	63,000	65,800	71,200	71,600
Arsenic	1,030	712	847	907	922
Boron	6,250,000	71,900	5,270,000	5,310,000	5,820,000
Bromide (min) [b]	1,170,000	69,100	926,000	959,000	1,170,000
Bromide (max) [b]	8,910,000	69,100	7,640,000	7,670,000	8,910,000
Cadmium	307	116	213	218	227
Chloride	195,000,000	4,340,000	169,000,000	171,000,000	187,000,000
Chromium	38,200	37,900	38,100	38,100	38,100
Copper	315	122	209	234	244
Iodine (min) [b]	71,600	0	56,800	56,800	71,600
Iodine (max) [b]	275,000	0	214,000	214,000	275,000
Iron	691,000	682,000	684,000	688,000	689,000
Lead	296	141	219	286	296
Magnesium	89,200,000	755,000	78,900,000	79,200,000	86,900,000
Manganese	372,000	2,070	291,000	292,000	321,000
Mercury	22.4	17.9	19.1	19.8	19.9

CRL but did collect data to potentially estimate loadings for the final rule. See the memorandum *Combustion Residual Leachate (CRL) Analytical Data Evaluation* (U.S. EPA, 2023n).

- Bromide (max): Same as "Bromide (min)" plus bromide loadings due to the use of refined coal or halogen addition at the boiler. Assumes all plants burning refined coal or adding halogens at the boiler use bromine additives.
- Iodine (min): Iodine loadings in FGD wastewater from native coal content only. EPA had insufficient data to estimate iodine loadings in BA transport water and CRL.
- Iodine (max): Same as "Iodine (min)" plus iodine loadings due to the use of refined coal or halogen addition at the boiler. Assumes all plants burning refined coal or adding halogens at the boiler use iodine additives.

Table 2. Estimated Annual Baseline Mass Pollutant Loadings and Estimated Reduction in Loadings Under Regulatory Options for the Evaluated Wastestreams[a]

Pollutant	Estimated Baseline Pollutant Loadings (lb/year)	Estimated Reduction in Pollutant Loadings Relative to Baseline (lb/year)			
		Option 1	Option 2	Option 3	Option 4
Molybdenum	28,900	23,200	26,100	26,200	26,500
Nickel	1,360	910	1,060	1,170	1,190
Nitrogen, total[c]	244,000	35,700	209,000	226,000	244,000
Phosphorus, Total	12,600	3,000	10,400	11,800	12,600
Selenium	2,410	166	298	377	392
Total dissolved solids	705,000,000	17,400,000	574,000,000	583,000,000	638,000,000
Thallium	294	15.4	242	250	272
Vanadium	35,300	34,600	34,900	35,000	35,000
Zinc	4,990	3,880	4,340	4,560	4,610

Sources: U.S. EPA, 2022b, 2023a, and 2023f.

Abbreviations: lb/year (pounds per year).

Note: Pollutant loadings and removals are rounded to three significant figures.

a—Includes a subset of all steam electric pollutants of concern. EPA chose to present the pollutants in this table based on the following factors: presence of the pollutant in the evaluated wastestreams; documented elevated levels of the pollutant in surface waters or wildlife from exposure to steam electric power plant wastewater; and magnitude of the pollutant loadings to receiving waters.

b—EPA did not identify data indicating the specific halogen additive (*i.e.*, bromine or iodine) used at each plant to reduce mercury emissions. Therefore, EPA estimated potential ranges of bromide and iodine loadings.

c—Total nitrogen loadings are the sum of ammonia, nitrate-nitrite (as N), and total Kjeldahl nitrogen (TKN).

3.2 Pollutant Exposure Pathways

An exposure pathway is defined as the route a pollutant takes from its source (*e.g.*, combustion residual surface impoundments) to its endpoint (*e.g.*, a surface water), and how receptors (*e.g.*, fish, wildlife, or people) can come into contact with it. Exposure pathways are typically described in terms of five components:

- Source of contamination (*e.g.*, steam electric power plant wastewater).
- Environmental pathway—the environmental medium or transport mechanism that moves the pollutant away from the source through the environment (*e.g.*, discharges to surface waters).
- Point of exposure—the place (*e.g.*, private drinking water well) where receptors (*e.g.*, people) come into contact with a pollutant from the source of contamination.
- Route of exposure—the way (*e.g.*, ingestion, skin contact) receptors come into contact with the pollutant.
- Receptor population—the aquatic life, wildlife, or people exposed to the pollutant.

The exposure pathway plays an important role in determining the potential effects of steam electric power plant wastewater on the environment. For example, the physical and chemical characteristics of receiving waters can affect the fate and transport of pollutants from combustion residual surface impoundments to the environment and ultimately impact how the pollutants interact with the biological community.

EPA identified four primary exposure pathways of concern for steam electric power plant wastewater entering the environment. Table 3 presents the environmental pathways, routes of exposure, and environmental concerns identified during the literature review and the types of analyses conducted to determine the impacts under baseline and potential environmental improvements under the regulatory options. In its analyses to determine environmental impacts and improvements, EPA evaluated each environmental concern via a given route of exposure and pathway individually (*i.e.*, the combined impact of multiple routes of exposure were not jointly evaluated).

Table 3. Steam Electric Power Plant Wastewater Environmental Pathways and Routes of Exposure Evaluated in the Environmental Assessment for the Proposed Supplemental Rule

Environmental Pathway	Route of Exposure	Environmental Concern	Analysis to Determine Environmental Impact
Steam electric power plant wastewater discharges to surface waters	Direct contact with surface water	Toxic effects on aquatic organisms[a]	Water quality impacts analysis (quantitative)—see Sections 4.1.1 and 4.4
	Ingestion of surface water	Degradation of surface water quality used as intake to drinking water plants	
	Direct contact with sediment	Toxic effects on benthic organisms[a]	Wildlife impacts analysis (quantitative)—see Sections 4.1.2 and 4.4
	Consumption of aquatic organisms	Bioaccumulation of contaminants and resulting toxic effects on wildlife[a]	
		Toxic effects on humans consuming contaminated fish[a]	Human health impacts analysis (quantitative)—see Sections 4.1.3, 4.3, and 4.4
		Degradation of fish availability for recreational and subsistence fishers	Human health impacts analysis (quantitative)—see Sections 4.1.3 and 4.2
Uncollected CRL infiltration to nearby surface waters from combustion residual landfill	Direct contact with surface water or sediment	Toxic effects on humans and aquatic wildlife[a]	Groundwater quality impacts (qualitative)—see Section 2.2.3
Uncollected CRL entering groundwater from combustion residual landfill	Ingestion of groundwater	Changes in groundwater quality	
		Contaminated private drinking water wells	
Combustion residual surface impoundment	Direct contact with or ingestion of surface water	Toxic effects on wildlife[a]	Attractive nuisances (qualitative)—see Section 2.2.4
		Bioaccumulation of contaminants in wildlife	

a—The term "toxic effects" refers to impacts upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains. These effects can include death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations, in receptors (*e.g.*, aquatic organisms, wildlife, humans) or their offspring.

3.3 Environmental Impacts Selected for Qualitative and Quantitative Assessments in the EA

EPA used both qualitative and quantitative assessments to describe the potential environmental impacts of the evaluated wastestreams (*i.e.*, FGD wastewater, BA transport water, and CRL) from steam electric power plants:

- Qualitative analysis focused on the impacts of uncollected CRL on groundwater quality and the potential for combustion residual surface impoundments to serve as attractive nuisances. Section 2.2.3 describes EPA's findings on the potential for uncollected CRL to cause changes in groundwater quality and contaminate drinking water sources. Section 2.2.4 presents EPA's findings on the potential toxic effects and bioaccumulation of contaminants in wildlife exposed to combustion residual surface impoundments.
- Quantitative analyses focused on the surface water exposure pathway. EPA conducted a proximity analysis to determine whether evaluated wastestreams discharge into sensitive environments. See Section 3.5.

EPA also evaluated the following wildlife and human health impacts caused by discharges of the evaluated wastestreams to surface waters under baseline (as well as the potential reductions in those impacts under the regulatory options):

- Wildlife impacts:
    - Potential toxic effects to aquatic life based on changes in surface water quality—specifically, exceedances of the acute and chronic National Recommended Water Quality Criteria (NRWQC) for freshwater aquatic life.
    - Potential toxic effects on sediment biota based on changes in sediment quality within surface waters—specifically, exceedances of threshold effect concentrations (TECs) for sediment biota.
    - Bioaccumulation of contaminants and potential toxic effects on wildlife from consuming contaminated aquatic organisms—specifically, exceedances of no effect hazard concentrations (NEHCs), indicating a potential risk of reduced reproduction rates in piscivorous wildlife.
- Human health impacts:
    - Exceedances of the human health NRWQC based on two standards: (1) the standard for the consumption of water and organisms and (2) the standard for the consumption of organisms only.
    - Exceedances of drinking water maximum contaminant levels (MCLs). Although MCLs apply to drinking water produced by public water systems and not surface waters themselves, EPA identified the extent to which immediate receiving waters exceeded an MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams.
    - Elevated cancer risk due to consuming fish caught from contaminated receiving waters—specifically, instances where the calculated lifetime excess cancer risk due to inorganic arsenic is greater than one excess cancer case risk per one million lifetimes (also expressed as 10^{-6}).
    - Elevated non-cancer health risks (*e.g.*, reproductive or neurological impacts) due to consuming fish caught from contaminated receiving waters—specifically, instances where the calculated average daily dose of a pollutant exceeds the oral reference dose (RfD) for that pollutant.

EPA used its Immediate Receiving Water (IRW) Model to perform the quantitative assessment. Section 3.4 provides an overview of the modeling. Section 3 and Appendices C, D, and E of the 2020 EA (U.S. EPA, 2020a) provide more details on the IRW Model.

EPA also evaluated additional wildlife and human health impacts resulting from changes in surface water quality, including impacts on threatened and endangered species, changes in ecosystem services, and neurological effects from exposure to lead and mercury. The methodologies and results of these analyses are presented in the BCA Report (U.S. EPA, 2023b). All analyses compare reductions under the regulatory options to baseline.

3.4 Overview of the IRW Model

EPA used the IRW Model to carry out the quantitative assessment of potential wildlife and human health impacts described in Section 3.3. This is the same model—including parameters and benchmark values—described in the 2020 EA (U.S. EPA, 2020a). It is a steady-state equilibrium-partitioning model that evaluates impacts within the immediate surface water[10] where discharges occur. An equilibrium-partitioning model assumes that dissolved and sorbed pollutants in a receiving water will quickly attain equilibrium in the immediate vicinity of the discharge point because they dissolve or sorb in the surface water faster than they can be transported or dispersed outside that area. The model also assumes that the equilibrium state for each pollutant can be represented by a partition coefficient that divides the total mass of a pollutant in the waterbody into four compartments:

- Constituents dissolved in the water column.
- Constituents sorbed onto suspended solids in the water column.
- Constituents sorbed onto sediments at the bottom of the waterbody.
- Constituents dissolved in pore water in the sediments at the bottom of the waterbody.

As described in Section 5 of the 2015 EA (U.S. EPA, 2015a), EPA developed the IRW Model to quantify the environmental impacts to surface waters, wildlife, and human health from the wastestreams evaluated for the regulatory options. In developing the model, EPA considered the type of receiving waters commonly affected by steam electric power plants and the pollutants typically found in the evaluated wastestreams. The IRW Model quantified the environmental risks within rivers/streams and lakes/ponds/reservoirs and evaluated impacts from nine toxic, bioaccumulative pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. Section 4.1 presents the results of the IRW Model analyses based on baseline and regulatory option pollutant loadings for the evaluated wastestreams, along with the limitations and uncertainties of the IRW Model.

3.4.1 Structure of the IRW Model

The IRW Model has three interrelated modules: the Water Quality Module, the Wildlife Module, and the Human Health Module, which are described in further detail in this section. Figure 1 provides an overview of the model's inputs and the connections among the three modules.

- The Water Quality Module uses plant-specific input data (annual average pollutant loadings and cooling water flow rates) and receiving-water-specific input data (*e.g.*, annual average flow rate, lake volume) to calculate annual average total and dissolved pollutant concentrations in the water column and sediment. The module compares these concentrations to selected water quality benchmark values (NRWQC and MCLs) as an indicator of potential impacts on aquatic life and human health.

[10] The length of the immediate receiving waters for the EA, as defined in the National Hydrography Dataset Plus (NHDPlus) Version 2, ranges from about 0.26 to 9.1 miles. The upstream and downstream boundaries are defined in NHDPlus Version 2, and each plant outfall is located somewhere along the associated immediate receiving water (*i.e.*, the outfalls are not specifically indexed to the upstream end, midpoint, or downstream end). See the memorandum *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2022a) for details on the immediate discharge zone and length of stream reach represented at each discharge location.

- The Wildlife Module uses the annual average water column pollutant concentrations from the Water Quality Module to calculate the bioaccumulation of pollutants in fish tissue, providing results for both trophic level 3 (T3) and trophic level 4 (T4) fish.[11] The module compares these concentrations, and the sediment concentrations calculated by the Water Quality Module, to benchmark values that represent potential impacts on exposed sediment biota (TECs)[12] and piscivorous wildlife (NEHCs). EPA chose minks and eagles as representative piscivorous wildlife that consume T3 and T4 fish, respectively.
- The Human Health Module uses the fish tissue concentrations from the Wildlife Module to calculate non-cancer and cancer risks to human populations from consuming fish caught from contaminated receiving waters. EPA performed this analysis using two sets of fish consumption rates:[13]
  - A "standard cohort" data set with consumption rates for recreational fishers and subsistence fishers (and their families), with separate age categories for adult and child fishers. Subsistence fishers are people who rely on self-caught fish for a larger share of their food intake than recreational fishers.
  - A data set with consumption rates for recreational and subsistence fishers in different race/ethnicity categories (non-Hispanic White; non-Hispanic Black; Mexican-American; other Hispanic; and other, including multiple races). EPA used this data set to evaluate whether the human health impacts under baseline or reductions under the regulatory options (relative to baseline) will disproportionately affect minority groups.[14]

Appendices C, D, and E to the 2020 EA (U.S. EPA, 2020a) describe the IRW Model equations, input data, and environmental parameters in detail. The appendices also describe the limitations and assumptions for each module. Section 5.1 of the 2015 EA (U.S. EPA, 2015a) provides more information on the IRW Model, including a detailed discussion of the equilibrium-partition modeling methodology used in the Water Quality Module.

[11] T3 fish (*e.g.*, carp, smelt, perch, catfish, sucker, bullhead, sauger) are those that primarily consume invertebrates and plankton, while T4 fish (*e.g.*, salmon, trout, walleye, bass) are those that primarily consume other fish.

[12] In the case of the TEC for selenium, exceedances of the TEC represent potential impacts on higher trophic levels due to consumption of sediment biota with elevated levels of selenium.

[13] See the memorandum *Fish Consumption Rates Used in the EA Human Health Module* (ERG, 2015b) for details on the selection of fish consumption rates for these analyses.

[14] EPA also conducted an environmental justice (EJ) analysis using data from EPA's EJScreen, the EA, and the benefits analysis. See *Environmental Justice Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (U.S. EPA, 2023d) for more details.

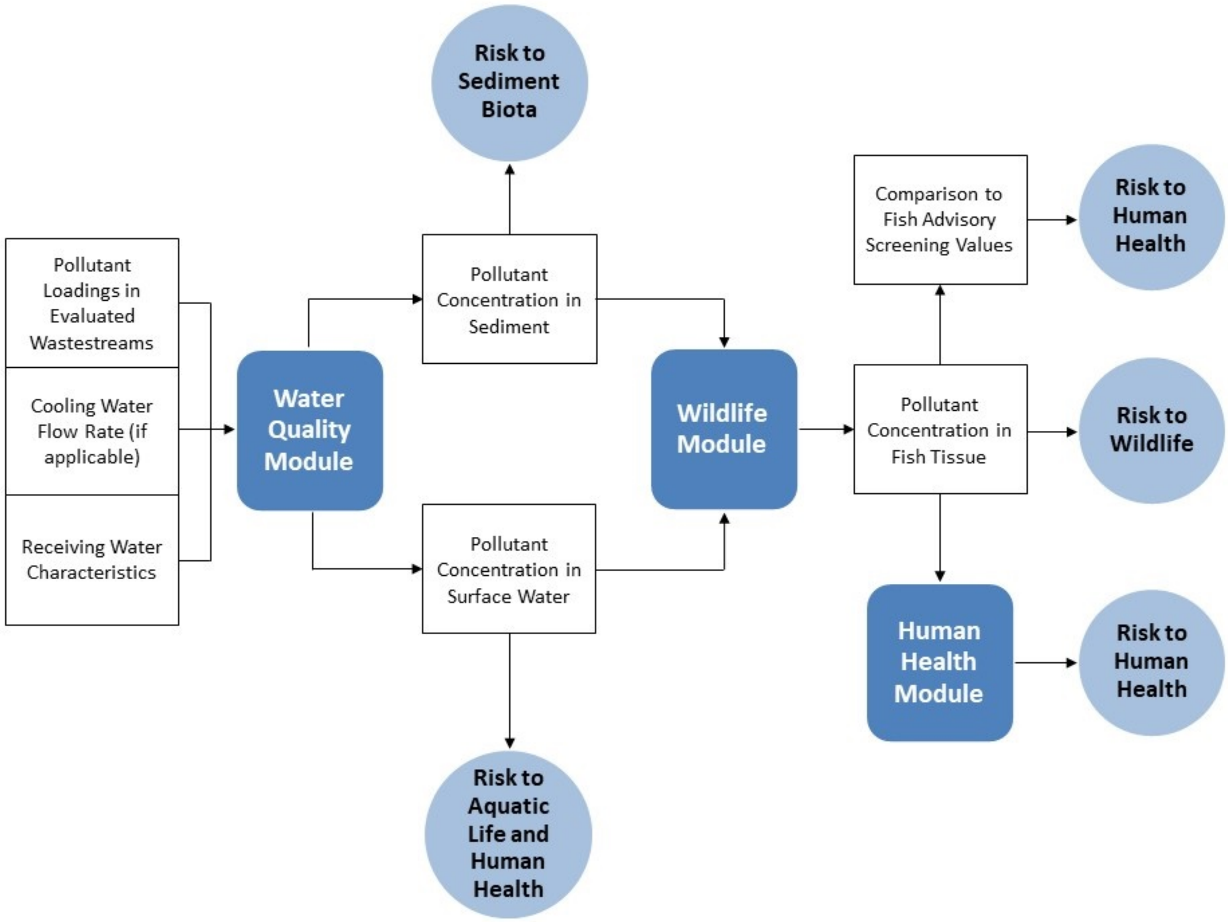

Figure 1. Overview of the IRW Model

3.4.2 Pollutants Evaluated by the IRW Model

The IRW Model analyzed nine toxic pollutants, all of which can bioaccumulate in fish and impact wildlife and human receptors via fish consumption. These pollutants were arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. EPA evaluated the same pollutants in the 2020 EA. Table 4 through Table 6 include the benchmarks used in the IRW Model.

Table 4. Water Quality Benchmarks: NRWQC and MCLs

Pollutant	FW Acute NRWQC[a,b,c] (mg/L)	FW Chronic NRWQC[a,b,c] (mg/L)	HH WO NRWQC[a,b] (mg/L)	HH O NRWQC[a,b] (mg/L)	MCL[a,d] (mg/L)
Arsenic	0.34	0.15	0.000018[e]	0.00014[e]	0.01
Cadmium	0.0018[f,g]	0.00072[f,g]	—	—	0.005
Copper	0.014[h]	0.009[h]	1.3	—	1.3 (action level); 1.0[i]
Lead	0.065[f]	0.0025[f]	—	—	0.015 (action level)
Mercury	0.0014	0.00077	—	—	0.002[e]
Nickel	0.47[f]	0.052[f]	0.61	4.6	—
Selenium	Lentic: 0.045[j] Lotic: 0.094[j]	Lentic: 0.0015[k] Lotic: 0.0031[k]	0.17	4.2	0.05
Thallium	—	—	0.00024	0.00047	0.002
Zinc	0.12[f]	0.12[f]	7.4	26	5[l]

Sources: U.S. EPA, 2009a, 2009b, 2016b, 2016c, and 2020c.

Abbreviations: FW (freshwater); HH O (human health organisms only); HH WO (human health water and organisms); MCL (maximum contaminant level); mg/L (milligrams per liter); NRWQC (National Recommended Water Quality Criteria).

a—"—" designates instances where a benchmark value does not exist for the pollutant, or the benchmark value is a secondary (nonenforceable) standard.

b—Unless otherwise noted, pollutant concentrations were compared to NRWQC from EPA's *National Recommended Water Quality Criteria* (U.S. EPA, 2009b).

c—Benchmark value is expressed in terms of the dissolved pollutant in the water column. For all pollutants except selenium, this is calculated using a total-to-dissolved conversion factor (U.S. EPA, 2009b).

d—Unless otherwise noted, pollutant concentrations were compared to the MCL from EPA's *National Primary Drinking Water Regulations* (U.S. EPA, 2009a).

e—Benchmark value is for inorganic form of pollutant.

f—The FW NRWQC for this metal is expressed as a function of hardness (mg/L) in the water column. The values given here correspond to a hardness of 100 mg/L.

g—The cadmium benchmark values are based on the FW NRWQC from EPA's *Aquatic Life Ambient Water Quality Criteria for Cadmium—2016* (U.S. EPA, 2016c).

h—For this analysis, EPA calculated FW NRWQC for copper using the Biotic Ligand Model and input water quality data that are representative of the ecoregions containing surface waters that receive discharges of the evaluated wastestreams (and their downstream waters) (U.S. EPA, 2020c).

i—EPA evaluated both the action level of 1.3 mg/L and the secondary (nonenforceable) drinking water standard of 1.0 mg/L for copper (U.S. EPA, 2020d). The results presented in Section 4 and Appendix A are based on the number of immediate receiving waters with exceedances of the lower secondary drinking water standard (1.0 mg/L).

j—The selenium benchmark values are based on the NRWQC from EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium—Freshwater 2016* (U.S. EPA, 2016b). The selenium acute NRWQC, as calculated here, assumes a background selenium concentration of zero and an intermittent exposure duration of one day, which is the shortest exposure period to be used when applying the criterion. This serves as an intermittent exposure element of the chronic water quality criterion, intended to address short-term exposures that contribute to chronic effects through selenium bioaccumulation. "Lentic" pertains to still or slow-moving water, such as lakes or ponds. "Lotic" pertains to flowing water, such as streams and rivers.

k—The selenium benchmark values are based on the NRWQC from EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium—Freshwater 2016* (U.S. EPA, 2016b). The selenium chronic water column NRWQC applies only in the absence of fish tissue measurements. Use of this water column benchmark value may therefore over- or underestimate the number of exceedances.

l—EPA has not defined an MCL or action level for zinc. This benchmark value represents the secondary (nonenforceable) drinking water standard for zinc (U.S. EPA, 2020d).

Table 5. Sediment Biota and Wildlife Benchmarks: TECs and NEHCs

Pollutant	TEC (mg/kg)[a]	NEHC for Minks (T3 Fish) (µg/g)[b]	NEHC for Eagle (T4 Fish) (µg/g)[b]
Arsenic	9.79	7.65	22.4
Cadmium	0.99	5.66	14.7
Copper	31.6	41.2	40.5
Lead	35.8	34.6	16.3
Mercury/methylmercury	0.18	0.37[c]	0.5[c]
Nickel	22.7	12.5	67.1
Selenium	2	1.13	4
Thallium	—[d]	—[d]	—[d]
Zinc	121	904	145

Abbreviations: mg/kg (milligrams per kilogram); NEHC (no effect hazard concentration); T3 (trophic level 3); T4 (trophic level 4); TEC (threshold effect concentration); µg/g (micrograms per gram).

a—Sources: Lemly (2018) for selenium; MacDonald et al. (2000) for all other pollutants.

b—Source: USGS, 2008.

c—No NEHC benchmark for methylmercury. EPA compared the modeled methylmercury concentrations to the total mercury NEHC, which may underestimate the impact to wildlife.

d—No benchmark value identified; pollutant excluded from evaluation.

Table 6. Human Health Benchmarks: Oral RfDs and CSFs

Pollutant	Oral RfD (mg/kg-day)	CSF $(mg/kg\text{-}day)^{-1}$	Notes
Arsenic, inorganic	3.00×10^{-4}	1.50	Oral RfD and CSF for drinking water ingestion
Cadmium	1.00×10^{-3}	—[a]	Oral RfD for food consumption
Copper	1.00×10^{-2}	—[a]	Used the intermediate oral MRL as the oral RfD (ATSDR, 2020)
Lead, total	—[b]	—[a]	
Methylmercury	1.00×10^{-4}	—[a]	Oral RfD for fish consumption only
Nickel	2.00×10^{-2}	—[a]	Oral RfD for soluble salts; used for food consumption
Selenium	5.00×10^{-3}	—[a]	Oral RfD for food consumption
Thallium	1.00×10^{-5}	—[a]	Used value cited in U.S. EPA, 2012, for soluble thallium as the oral RfD; used for chronic oral exposure
Zinc	3.00×10^{-1}	—[a]	Oral RfD for food consumption

Table 6. Human Health Benchmarks: Oral RfDs and CSFs

Pollutant	Oral RfD (mg/kg-day)	CSF (mg/kg-day) $^{-1}$	Notes

Sources: ATSDR (2020) for copper, U.S. EPA (2012) for thallium, and U.S. EPA (2019) for all other pollutants.
Abbreviations: CSF (cancer slope factor); mg/kg/day (milligrams per kilogram body weight per day); MRL (minimal risk level); RfD (reference dose).
a—No benchmark value identified; pollutant excluded from evaluation.
b - As documented in IRIS (https://www.epa.gov/iris), EPA concluded that it was inappropriate to develop an RfD as some of the effects from lead exposure, "particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold." The CDC identified 10 micrograms per deciliter (µg/dL) as the blood lead level of concern in children; see the *BCA Report* for EPA's analysis of lead impacts.

Like the 2020 EA, this EA did not use water quality modeling to assess the impacts associated with discharges of TDS, bromides, chlorides, or nutrients (total nitrogen and total phosphorus). EPA did not have partition coefficients needed to model the pollutants in receiving water using the equilibrium-partition equations presented in Appendix C of the 2020 EA (U.S. EPA, 2020a). EPA did include some of these pollutants in the surface water quality modeling of immediate and downstream waters, which was performed for the economic benefits analysis (see the BCA Report, U.S. EPA, 2023b).

3.5 Proximity Analysis

The pollutant loadings, ecological impacts, and human health concerns discussed in Section 2 and Section 3.2 are also of concern due to the proximity of many steam electric power plants to sensitive environments where the characteristics of plant wastewater may contribute to the impairment of water quality (*e.g.*, 303(d)-listed waters and waters with fish advisories) or pose a threat to threatened and endangered species (see the BCA Report, U.S. EPA, 2023b). EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located near the following sensitive environments:

- Immediate receiving waters that states, territories, and authorized tribes have identified, pursuant to Section 303(d) of the Clean Water Act (CWA), as impaired waterbodies that can no longer meet their designated uses (*e.g.*, drinking, recreation, aquatic habitat) due to pollutant concentrations above water quality standards. These are also known as "CWA Section 303(d)–listed waterbodies."
- Immediate receiving waters for which states, territories, and authorized tribes have issued fish consumption advisories, which indicates that pollutant concentrations in the tissues of fish inhabiting those waters are considered unsafe for human consumption at any or some consumption levels.
- Immediate receiving waters within five miles of drinking water resources, including intakes and reservoirs, public wells, and sole-source aquifers.

EPA also assessed the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories, thereby posing a human health risk. EPA compared the T4 fish tissue concentrations from the Wildlife Module to fish consumption advisory screening values. Screening values are concentrations of target analytes in fish or shellfish tissue that are of potential public health concern; they are used as threshold values to which levels of contamination in similar tissue collected from the ambient environment can be compared. Exceedance of screening values indicates that more intensive site-specific monitoring and/or evaluation of human health risks should be conducted (U.S. EPA, 2000a, Table 5-3).[15]

[15] See the memorandum *IRW Model: Water Quality, Wildlife, and Human Health Analyses and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023g) for documentation of the fish advisory screening level analysis.

EPA's memorandum Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule (U.S. EPA, 2023h) describes the methodology used to evaluate the proximity of steam electric power plant discharges to sensitive environments. Section 4.2 of this report presents the results of the proximity analysis.

EPA also performed further spatial analyses to identify public drinking water supply intakes downstream from discharges of the evaluated wastestreams. See the BCA Report for details on the methodology and results of that analysis.

3.6 Endpoint-Specific Analysis of Potential Cumulative Impacts

For the 2023 proposed supplemental rule, EPA expanded the EA to include an evaluation of the potential impact to human health of pollutant mixtures present in steam electric power plant discharges. EPA evaluated the joint toxic action (JTA) of multiple pollutants in plant discharges, following the framework developed by the Agency for Toxic Substances and Disease Registry (ATSDR) (ATSDR, 2004b, 2004c, 2004d, 2006, and 2018) and consistent with EPA's guidance for conducting health risk assessments of chemical mixtures (U.S. EPA, 2000b). ATSDR's framework outlines a three-tiered approach for evaluating human health effects from multiple pollutants in a mixture:

- Tier 1, which assesses potential human health impacts for individual pollutants within a mixture using the hazard quotient (HQ) method or by calculating a cancer risk estimate (ATSDR, 2018). Hazard quotients are the ratio of the exposure estimate to an established human health-based metric such as an ATSDR minimal risk level (MRL) or RfD benchmark, as used in the Human Health Module. For the JTA analysis, individual pollutants with an HQ greater than or equal to 0.1 are considered to pose a potential human health threat and are retained for the Tier 2 analysis (ATSDR, 2018).[16] The EA conducted to support the proposed supplemental rule only includes one carcinogenic pollutant (arsenic); therefore, the JTA analysis does not include cancer risk estimates.
- Tier 2, conducted if multiple pollutants are identified with an HQ greater than or equal to 0.1 in an immediate receiving water. Under a Tier 2 analysis for assessing human health impacts, pollutants with an HQ less than 0.1 are removed from further consideration. A preliminary hazard index (HI) is calculated as the sum of the HQs for the remaining pollutants within the mixture. A preliminary HI greater than one indicates the potential for human health impacts caused by additive effects of the pollutants within the mixture. A Tier 2 analysis is considered a preliminary assessment because it does not limit the analysis to a single human health effect or mode of action among the pollutants—for example, a specific target organ (ATSDR, 2018).
- Tier 3, which refines the human health assessment to a specific health effect from a common mode of action and duration. In a Tier 3 analysis, benchmark values—*i.e.*, RfD, MRL, or target-organ toxicity dose (TTD)—established for similar health effects and modes of action are used to calculate endpoint-specific HQ values. An RfD or MRL value is used when the critical effect is equal to the human health effect being evaluated in the hazard index. A TTD value is used when the pollutant is known to cause an effect of concern at a concentration greater than the critical effect associated with

[16] For the IRW Model: Human Health Module results, EPA uses RfD values, which are an expression of the consumption dose that is protective against a specific endpoint (*e.g.*, immunological, reproductive, neurological) and counts exceedances based on the number of plant-receiving waters where the pollutant-specific RfD is exceeded (*i.e.*, HQ > 1.0). If the HQ is greater than one, then EPA concludes that the pollutant in the steam electric power plant discharge is a potential threat to humans for the endpoint associated with the RfD. In the ATSDR framework (ATSDR, 2018) used for the JTA, individual pollutants are retained from the Tier 1 analysis if the HQ value is greater than or equal to 0.1, which differs from the EA results methodology.

the pollutant's RfD or MRL value (ATSDR, 2004b).[17] The endpoint-specific HQ values are then summed to calculate an endpoint-specific HI value for each immediate receiving water.

The final step in a Tier 3 analysis involves incorporating information on the interactions among the pollutants within a mixture for a given health effect. EPA used a qualitative binary weight-of-evidence (BINWOE) assessment for evaluating interactions among pollutant pairs within a mixture. In the analysis, two BINWOEs are needed for each pair of pollutants that exceed an endpoint-specific HQ of 0.1 or greater: one for the effect of chemical A on the toxicity of chemical B, another for the effect of chemical B on the toxicity of chemical A (ATSDR, 2004b). A BINWOE analysis provides an indication of the direction of a given interaction among pollutants and assigns qualitative statements to the endpoint-specific HI such as "greater than additive," "additive," "less than additive," and "indeterminate." BINWOE factors for pollutant pairs included in the Tier 3 analysis are summed to determine whether the potential for a health effect may be greater or less than what is predicted based on the endpoint-specific HI alone. Positive combined BINWOE scores that are significantly different than zero indicate that the mixture is likely to pose a greater hazard than indicated by an HI alone. Negative combined BINWOE scores that are significantly different from zero suggest that the mixture poses less of a hazard than indicated by the endpoint-specific HI alone. Combined BINWOE scores of zero or close to zero indicate the endpoint-specific HI is a reasonable prediction of the potential threat posed by the mixture (ATSDR, 2004b).

Figure 2 presents the inputs and calculation steps to conduct the Tier1, Tier 2, and Tier 3 analyses for the JTA module developed for the EA. For details on the methodology and JTA analysis, see the memoranda *Methodology for Assessing Human Health Impacts from Multiple Pollutants in Steam Electric Power Plant Discharges* and *JTA Module Development and Instructions* (U.S. EPA, 2023i and 2002h).

[17] A TTD value is specific for a route and exposure period and based on the highest no-observed-adverse-effect level (NOAEL) that does not exceed the lowest-observed-adverse-effect level (LOAEL) for a given human health effect (ATSDR, 2004b).

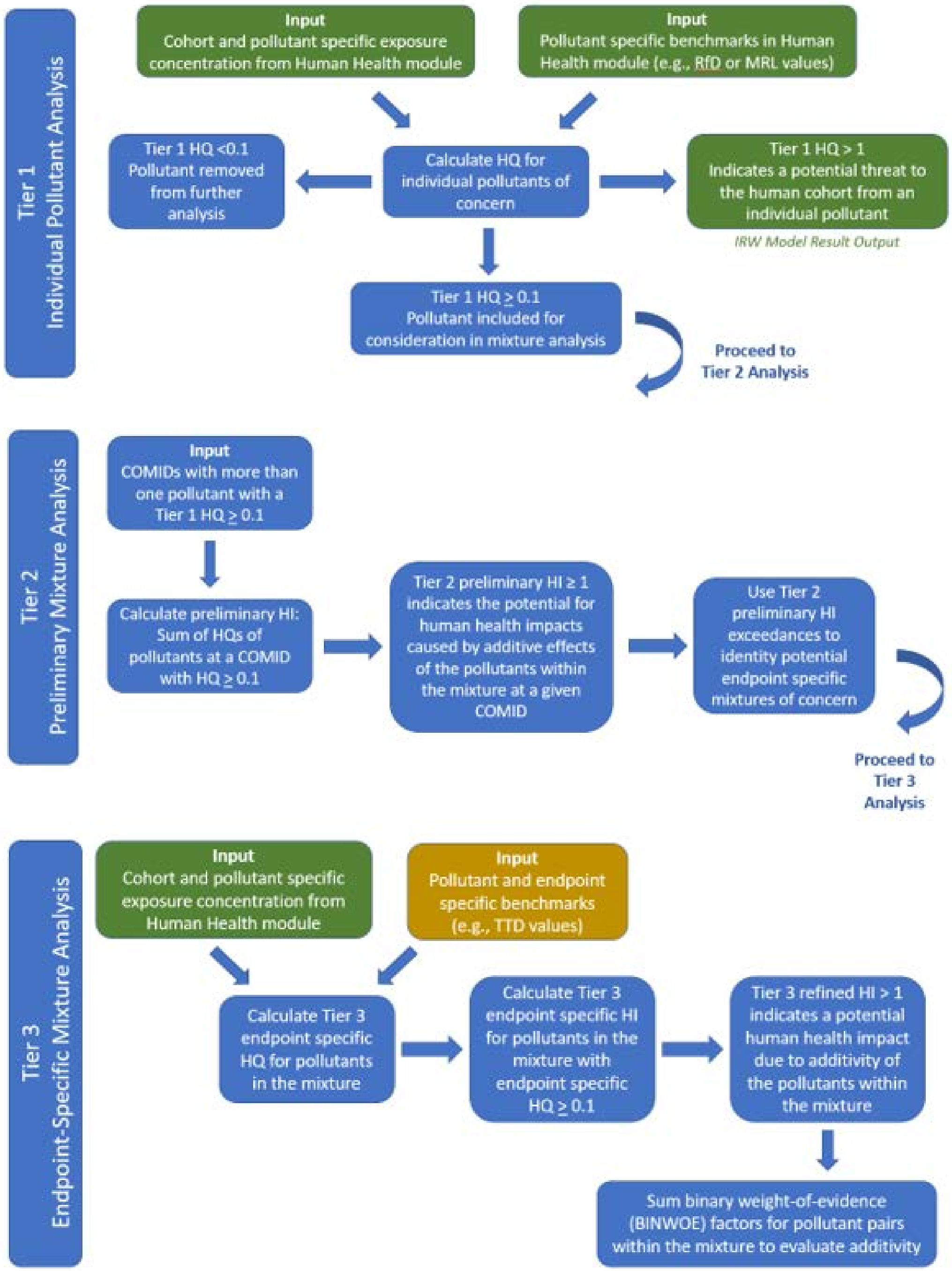

Figure 2. Joint Toxic Action Analysis for the EA Based on ATSDR Framework

Abbreviations: HI (hazard index); HQ (hazard quotient); IRW (immediate receiving water); TTD (target-organ toxicity dose).

3.7 Downstream Analysis

As part of the economic benefits analysis, EPA used a separate pollutant fate and transport model (D-FATE) to calculate the concentrations of pollutants in surface waters downstream from the immediate receiving water for each plant that discharges the evaluated wastestreams. See the BCA Report (U.S. EPA, 2023b) for a detailed discussion of the D-FATE model and the analysis, which uses annual average pollutant loadings and surface water flow rates.

EPA used these downstream concentrations from D-FATE as inputs for an analysis that identified which downstream reaches would have at least one exceedance of a water quality, wildlife, or human health benchmark value under baseline or regulatory option loadings. EPA used this approach to estimate the extent (in river miles) of impacts in downstream surface waters under baseline and the changes in these impacts under the regulatory options evaluated. Results are presented in Section 4.4 of this report. See the memorandum *Downstream Modeling Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023k) for details on the methodology for this analysis.

3.8 Scope of the Evaluated Plants and Immediate Receiving Waters

EPA estimates that 304 coal-fired electric generating units operated at 163 plants will be operating after December 31, 2028. Section 3 of the TDD (U.S. EPA, 2023a) describes how EPA updated the industry profile to reflect changes since the 2020 rule, including an assessment of impacts of other regulations affecting steam electric power plants (*i.e.*, the Coal Combustion Residual Part A rule). Section 5 and Section 6 of the TDD describe the population of plants and electric generating units that EPA estimated compliance costs and pollutant loadings under baseline (for 219 coal-fired electric generating units operated at 92 plants) and the regulatory options.

Within this industry profile, EPA limited the scope of the EA to the subset of 91 plants that discharge one or more of the evaluated wastestreams (FGD wastewater, BA transport water, or CRL) directly or indirectly to surface waters under baseline and/or one or more regulatory options.[18] EPA performed quantitative assessments to support the EA using its IRW Model, described in Section 3.4. The IRW Model, which excludes discharges to the Great Lakes and estuaries, encompasses 85 plants that discharge to 98 immediate receiving waters.[19] The IRW Model excludes Great Lake and estuarine immediate receiving waters because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model.

Table 7 presents the number of plants, generating units, and immediate receiving waters evaluated in the EA. Figure 3 shows the locations of the immediate receiving waters evaluated in the EA proximity analysis and indicates those that are included in the IRW Model. See the memorandum *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2022a) for the list of immediate receiving waters and details on EPA's methodology for identifying them.

The number of evaluated plants and generating units, and the number of the associated immediate receiving waters, vary across baseline and the regulatory options evaluated for the final rule. This is due to differences in the stringency of controls, applicability of these controls based on subcategorization, and estimates of the control technologies that plants would implement to meet requirements (see the

[18] Of the 91 plants in the EA, 89 discharge directly to surface water and two discharge indirectly to POTWs. EPA excluded one plant from the EA that indirectly discharges to a POTW that does not discharge to any receiving waters (see U.S. EPA, 2022a).

[19] Eleven of the 91 plants included in the EA discharge to more than one immediate receiving water.

preamble for details). Table 8 presents the number of plants, generating units, and immediate receiving waters with nonzero pollutant loadings for baseline and each regulatory option evaluated.

Table 7. Plants, Generating Units, and Immediate Receiving Waters Evaluated in the Environmental Assessment for the Proposed Supplemental Rule

Category	Number Evaluated in Pollutant Loadings Analysis	Number Evaluated in the Proximity Analysis	Number Evaluated in IRW Model[a]
Plants	92[b]	91	85
Electric generating units	219	215	201
Immediate Receiving Waters			
River/stream	87	87	87
Lake/pond/reservoir	11	11	11
Great Lakes	3[c]	3[c]	—
Estuary/bay/other	2	2	—
Total Immediate Receiving Waters	**103**[b,c]	**103**[c]	**98**

Sources: U.S. EPA, 2022a and 2023f.

Abbreviations: IRW (immediate receiving water).

a—The IRW Model excludes discharges to the Great Lakes and estuaries because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model. The excluded waterbodies include Lake Erie, Lake Michigan (two locations), Hillsborough Bay, and Big Lake; see *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2022a) for further details.

b—One plant discharges the evaluated wastestreams to a zero discharge publicly owned treatment works; therefore, no immediate receiving water is associated with the plant's pollutant loadings.

c—Eleven plants included discharge to more than one immediate receiving water. One Great Lake immediate receiving water receives discharges from two plants.

Table 8. Plants, Generating Units, and Immediate Receiving Waters with Pollutant Loadings Under Baseline and Regulatory Options for the Proposed Supplemental Rule

Category	Baseline	Option 1	Option 2	Option 3	Option 4
Pollutant Loadings, Downstream, and Proximity Analyses[a]					
Plants[b]	92	92	88	71	70
Electric generating units	219	219	212	175	171
Immediate receiving waters	103	103	97	77	76
Subset Also Evaluated in IRW Model					
Plants	85	85	83	67	66
Electric generating units	201	201	197	164	160
Immediate receiving waters	98	98	93	74	73

Sources: U.S. EPA, 2022a and 2023f.

Abbreviations: IRW (immediate receiving water).

a—The IRW Model excludes discharges to the Great Lakes and estuaries because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model.

b—One plant discharges the evaluated wastestreams to a zero discharge publicly owned treatment works; therefore, no immediate receiving water is associated with the plant's pollutant loadings.

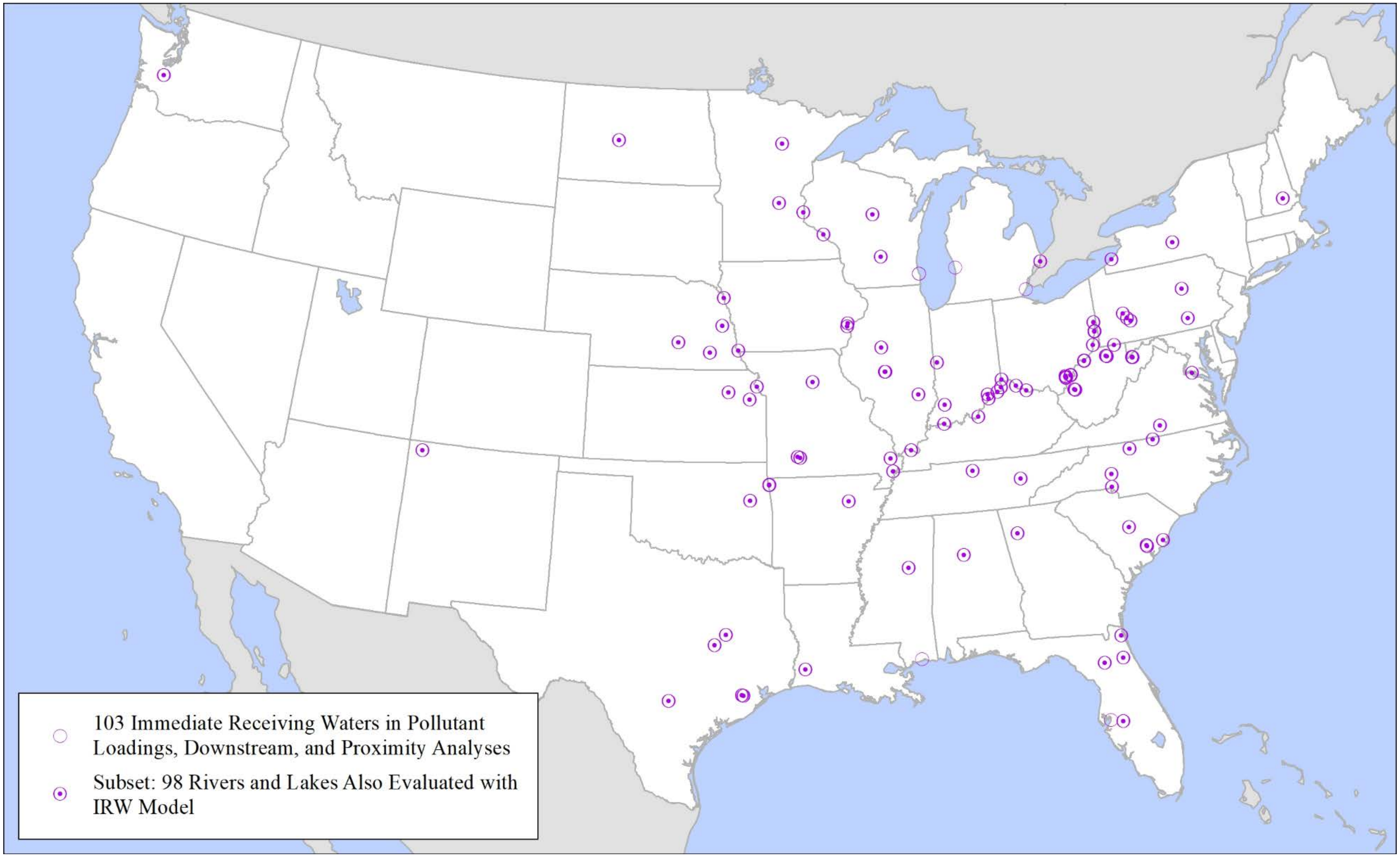

Figure 3. Locations of Immediate Receiving Waters Evaluated in the Environmental Assessment for the Proposed Supplemental Rule

4. Results of the Quantitative Environmental Assessment for the Proposed Supplemental Rule

EPA used the plant-specific and receiving-water-specific pollutant loadings, described in Section 3.1, to determine the environmental impacts of the evaluated wastestreams—*i.e.*, flue gas desulfurization (FGD) wastewater, bottom ash transport water, and combustion residual leachate (CRL)—from steam electric power plants. This section presents the results of the quantitative analyses described in Sections 3.3 through 3.7, which include the following:

- Use of EPA's Immediate Receiving Water (IRW) Model to:
    - Estimate the annual average pollutant concentrations in immediate receiving waters due to discharges of the evaluated wastestreams under baseline and the regulatory options, estimate the bioaccumulation of pollutants in fish tissue within those waters, and estimate the daily and lifetime pollutant exposure doses among humans who consume those fish.
    - Compare the estimated concentrations and estimated exposure doses to various benchmark values as indicators of potential water quality, wildlife, and human health impacts.
    - Evaluate the estimated changes in those impacts under the regulatory options, as compared to baseline.
- A proximity analysis to identify immediate receiving waters that are designated as Clean Water Act (CWA) Section 303(d)–listed impaired waterbodies; have been issued fish consumption advisories; or are within five miles of drinking water resources, including intakes and reservoirs, public wells, and sole-source aquifers.
- A joint toxic action (JTA) analysis to identify the immediate receiving waters with potential cumulative impact concerns due to multiple pollutants in plant discharges and evaluate the estimated improvements under the regulatory options as compared to baseline.
- Use of pollutant fate and transport model (D-FATE) outputs to estimate potential water quality, wildlife, and human health impacts in downstream surface waters under baseline and evaluate the estimated changes in those impacts under the regulatory options.

The BCA Report (U.S. EPA, 2023b) discusses EPA's evaluation of other impacts that were not quantified in the environmental assessment.

4.1 Environmental Impacts Identified by the IRW Model

The IRW Model includes modules assessing potential changes in impacts on water quality, wildlife, and human health in waters receiving discharges of the evaluated wastestreams from steam electric power plants.[20] See Section 3.4 of this document and Appendices C, D, and E of the 2020 environmental assessment (EA) (U.S. EPA, 2020a) for details on the IRW Model's structure and methodology, including equations, input data, and environmental parameters.

The following sections present the environmental impact results estimated from each module for the nine modeled pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. The results identify modeled exceedances of water quality, wildlife, and human health benchmark values

[20] The EA encompasses a total of 103 immediate receiving waters and loadings from 91 plants (some of which discharge to multiple receiving waters). The IRW Model, which excludes the Great Lakes and estuaries, analyzes a total of 98 immediate receiving waters and loadings from 85 plants.

under baseline and the reduction in those exceedances under each regulatory option. Appendix A includes additional IRW Model outputs.

4.1.1 Water Quality Impacts

The IRW Water Quality Module assesses the quality of surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the water column to the National Recommended Water Quality Criteria (NRWQC) and drinking water maximum contaminant levels (MCLs)[21] under baseline and each regulatory option. The Water Quality Module results described in this section are based on estimated annual average pollutant loadings and flow rates. The module considers modeled exceedances of the freshwater acute NRWQC, freshwater chronic NRWQC, human health water and organism NRWQC, human health organism only NRWQC, and drinking water MCL.

EPA compared the modeled receiving water concentrations to the water quality benchmarks presented in Table 4. Table 9 summarizes the number of immediate receiving waters exceeding the water quality benchmarks. Table 10 presents the number of immediate receiving waters with exceedances of any NRWQC or MCL by pollutant. EPA identified water quality benchmark exceedances for arsenic, cadmium, selenium, and thallium for one or more immediate receiving waters. EPA did not identify exceedances for five of the modeled pollutants: copper, lead, mercury, nickel, and zinc. Under baseline, EPA estimated that 34 of the 98 immediate receiving waters (35 percent) exceeded one or more water quality benchmark. Under the preferred regulatory option (Option 3), if finalized as proposed, the number of immediate receiving waters exceeding a benchmark will decrease by 15 immediate receiving waters.

Table 9. Modeled IRWs with Exceedances of NRWQC and MCLs Under Baseline and Regulatory Options

Water Quality Evaluation Benchmark	Pollutant	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Freshwater acute NRWQC	Any pollutant	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Cadmium	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Freshwater chronic NRWQC	Any pollutant	10	10 (0)	10 (0)	9 (-1)	9 (-1)
	Cadmium	1	1 (0)	1 (0)	1 (0)	1 (0)
	Selenium	10	10 (0)	10 (0)	9 (-1)	9 (-1)
Human health water and organism NRWQC	Any pollutant	34	25 (-9)	24 (-10)	19 (-15)	19 (-15)
	Arsenic	34	25 (-9)	24 (-10)	19 (-15)	19 (-15)
	Thallium	3	3 (0)	2 (-1)	1 (-2)	1 (-2)
Human health organism only NRWQC	Any pollutant	20	16 (-4)	16 (-4)	14 (-6)	14 (-6)
	Arsenic	20	16 (-4)	16 (-4)	14 (-6)	14 (-6)
	Thallium	3	3 (0)	2 (-1)	1 (-2)	1 (-2)
Drinking water MCL	Any pollutant	2	2(0)	1 (-1)	1 (-1)	1 (-1)
	Cadmium	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Selenium	1	1 (0)	1 (0)	1 (0)	1 (0)
	Thallium	1	1 (0)	0 (-1)	0 (-1)	0 (-1)
Total Number of Unique Immediate Receiving Waters[b]		34	25 (-9)	24 (-10)	19 (-15)	19 (-15)

[21] Table 4 in Section 3 presents the benchmarks values for the pollutants evaluated.

Table 9. Modeled IRWs with Exceedances of NRWQC and MCLs Under Baseline and Regulatory Options

Water Quality Evaluation Benchmark	Pollutant	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Table 10. Modeled IRWs with Exceedances of NRWQC and MCLs, by Pollutant, Under Baseline and Regulatory Options

	Number of Modeled IRWs Exceeding Benchmark Value (Different Relative to Baseline)[a]				
Pollutant	Baseline	Option 1	Option 2	Option 3	Option 4
Arsenic	34	25 (-9)	24 (-10)	19 (-15)	19 (-15)
Cadmium	1	1 (0)	1 (0)	1 (0)	1 (0)
Copper	0	0 (0)	0 (0)	0 (0)	0 (0)
Lead	0	0 (0)	0 (0)	0 (0)	0 (0)
Mercury	0	0 (0)	0 (0)	0 (0)	0 (0)
Nickel	0	0 (0)	0 (0)	0 (0)	0 (0)
Selenium	10	10 (0)	10 (0)	9 (-1)	9 (-1)
Thallium	3	3 (0)	2 (-1)	1 (-2)	1 (-2)
Zinc	0	0 (0)	0 (0)	0 (0)	0 (0)
Any Pollutant[b]	**34**	**25 (-9)**	**24 (-10)**	**19 (-15)**	**19 (-15)**

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

In the 2020 EA, EPA conducted a water quality analysis using estimated monthly pollutant loadings and flow rates to assess the significance of monthly variability in the modeled water quality impacts. The results were similar to those using the annual average analysis and EPA determined the following key takeaways:

- Most worst-case months occur during the summer, whereas most best-case months occur during the winter and early spring.
- There is potential for impacts on aquatic life during certain periods characterized by low flows, high loadings, or a combination of the two.

- Certain geographic areas could experience adverse seasonal cumulative effects due to concurrent, or nearly concurrent, discharges of evaluated wastestreams from multiple plants.

These results suggest that seasonal water quality impacts from discharges of the evaluated wastestreams, may be more prevalent than indicated by the annual average analysis. Seasonal cumulative effects in affected watersheds could be particularly pronounced during summer and early autumn. EPA expects that swimming, fishing, and boating in local waterways are more common during these seasons, potentially increasing opportunities for exposure to degraded water quality conditions in the immediate receiving waters. In addition, fish species that spawn in the affected waterways during these periods (including federally threatened or endangered species) could have an increased potential for adverse impacts from pollutant exposure, since the timing of their sensitive life stages would align with worst-case water quality conditions. See the 2020 EA (U.S. EPA, 2020a) for more details.

Appendix C of the 2020 EA (U.S. EPA, 2020a) provides details on the following limitations and uncertainties of the IRW Water Quality Module:

- Estimated pollutant loadings are based on data from a subset of steam electric power plants.
- The module uses annual-average pollutant loadings and flow rates.
- It does not consider temporal variability and pollutant speciation.
- It does not account for ambient background pollutant concentrations or contributions from other point and nonpoint sources.
- It assumes that equilibrium is quickly attained within the waterbody following discharge and is consistently maintained between the water column and surficial bottom sediments.
- It assumes that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a partition coefficient and other calculation assumptions.
- It assumes that pollutants sorbed to bottom sediments are considered a net loss from the water column and assumes a pollutant burial rate of zero within the bottom sediment.

4.1.2 Wildlife Impacts

As described in Section 3.4, the IRW Wildlife Module assesses impacts to sediment biota, minks, and eagles. This analysis expands on the evaluation of potential wildlife impacts based on the Freshwater Chronic and Acute NRWQC in the Water Quality Module. Table 11 presents the number of immediate receiving waters with modeled exceedances of the threshold effect concentrations (TECs) and no effect hazard concentrations (NEHCs)[22] under baseline and reduction in those exceedances under the regulatory options. Results are presented for all pollutants in aggregate and individually for pollutants with exceedances. EPA did not have benchmark data to compare thallium concentrations in the immediate receiving water; therefore, that pollutant is excluded from the wildlife impacts analysis.

Under baseline, EPA estimated that six of the eight evaluated pollutants had one or more immediate receiving water that exceeded sediment TECs. Copper and lead had no exceedances under baseline (or the regulatory options). Under the preferred option (Option 3), the number of immediate receiving waters with exceedances of TECs decreases by at least 67 percent for five of the six pollutants (arsenic, cadmium, mercury, nickel, and zinc). Selenium had the smallest improvement under the regulatory options, if finalized as proposed, with a reduction of only one immediate receiving water exceeding the selenium TEC.

Only two pollutants (mercury and selenium) exceeded the NEHCs for minks and eagles under baseline and the regulatory options, as proposed. Under the preferred option (Option 3), EPA calculated that the number of immediate receiving waters exceeding the NEHC for minks decreased by 12 immediate

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[22] Table 5 in Section 3 presents the benchmarks values for the pollutants evaluated.

receiving waters for mercury and one immediate receiving water for selenium. Under Option 3, EPA calculated that the number of immediate receiving waters exceeding the NEHC for eagle decreased by eight immediate receiving waters for mercury and one immediate receiving water for selenium.

Table 11. Modeled IRWs with Exceedances of TECs and NEHCs Under Baseline and Regulatory Options

Wildlife Evaluation Benchmark	Pollutant[a]	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Sediment TEC	Any pollutant	19	19 (0)	19 (0)	18 (-1)	18 (-1)
	Arsenic	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Cadmium	9	3 (-6)	3 (-6)	3 (-6)	3 (-6)
	Mercury	16	6 (-10)	5 (-11)	4 (-12)	4 (-12
	Nickel	13	2 (-11)	2 (-11)	1 (-12)	1 (-12)
	Selenium	19	19 (0)	19 (0)	18 (-1)	18 (-1)
	Zinc	8	1 (-7)	1 (-7)	1 (-7)	1 (-7)
Fish ingestion NEHC for minks	Any pollutant	15	15 (0)	15 (0)	14 (-1)	14 (-1)
	Mercury	14	3 (-11)	3 (-11)	2 (-12)	2 (-12)
	Selenium	15	15 (0)	15 (0)	14 (-1)	14 (-1)
Fish ingestion NEHC for eagles	Any pollutant	18	15 (-3)	15 (-3)	14 (-4)	14 (-4)
	Mercury	18	11 (-7)	11 (-7)	10 (-8)	10 (-8)
	Selenium	15	15 (0)	15 (0)	14 (-1)	14 (-1)
Any Wildlife Pollutant Benchmark for Any Pollutant[c]		19	19 (0)	19 (0)	18 (-1)	18 (-1)

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); TEC (threshold effect concentration); NEHC (no effect hazard concentration).

a—Thallium excluded from the analysis (no benchmarks for comparison). No immediate receiving waters exceeded the TEC for copper and lead. No immediate receiving waters exceeded NEHC benchmarks for arsenic, cadmium, copper, lead, nickel, or zinc.

b—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

c—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Appendix D of the 2020 EA (U.S. EPA, 2020a) provides details on the following limitations and uncertainties of the IRW Wildlife Module:

- Impact estimates are based on an individual exposure pathway and individual pollutant exposure rather than cumulative risks across exposure pathways and the interaction of multiple pollutants.
- Bioaccumulation factors are not available for all pollutants (use of bioconcentration factors does not account for the accumulation of pollutants via the food web).
- It does not consider indirect ecological effects such as depletion of food sources.
- It assumes the selected receptor species and receiving water occur together (*i.e.*, all immediate receiving waters are habitats for the receptor species).
- It assumes the diet of the receptor species consists of fish inhabiting the immediate receiving water.
- It assumes all forms of a pollutant are equally bioavailable to ecological receptors.

- Modeling assumes that the receiving water is fully mixed; however, water in lakes might stratify and affect chemical speciation by stratum.

4.1.3 Human Health Impacts

The IRW Human Health Module evaluates non-cancer and cancer human health impacts among various human cohorts (recreational and subsistence fishers; children and adults; and different race/ethnicity categories) from consuming fish caught from immediate receiving waters that are contaminated by discharges of the evaluated wastestreams. The module uses oral reference doses (RfDs) to evaluate changes in non-cancer health risks and a lifetime excess cancer risk (LECR) benchmark value of one-in-a-million, or 10^{-6}, to evaluate changes in cancer risk. This analysis expands on the evaluation of potential human health impacts based on the NRWQC and MCLs in the Water Quality Module.

Under baseline, EPA estimated the average daily dose of one or more individual pollutant from fish consumption among subsistence fishers exceed the oral RfDs (non-cancer) in 28 to 35 (29 to 36 percent) of immediate receiving waters, depending on the age group evaluated. Average daily doses among recreational fishers exceeded oral RfDs in 23 to 28 (23 to 29 percent) of immediate receiving waters. The lower prevalence of exceedances among recreational fishers is primarily due to their lower average fish tissue consumption rates. These results suggest that fish in immediate receiving waters can have health effects on surrounding fisher populations.

As shown in Table 12, the exceedances are primarily driven by mercury (as methylmercury), selenium, and thallium. EPA calculated no exceedances for arsenic (inorganic), copper, or nickel (total) under baseline and the regulatory options. EPA estimated that the number of immediate receiving waters contributing to oral RfD (non-cancer) exceedances decreased for all standard cohorts (*i.e.*, cohorts that are not split into different race/ethnicity categories) under all regulatory options, if finalized as proposed. Under the preferred option (Option 3), EPA estimated the following decreases in number of immediate receiving waters with fish that, if consumed, would exceed oral RfDs:

- Methylmercury—decrease by at least 10 immediate receiving waters for all standard cohorts.
- Selenium—decrease by at least one immediate receiving water for all standard cohorts.
- Thallium—decrease by at least two immediate receiving waters for all standard cohorts.

Although EPA did not directly assess the potential health effects posed by lead in this EA, Option 3, if finalized as proposed, decreases the annual loadings of lead to the environment by 286 pounds per year compared to baseline.[23] The monetized human health effects associated with changes in lead discharges are discussed in the BCA Report (U.S. EPA, 2023b).

Table 12. Modeled IRWs with Exceedances of Oral RfD (Non-Cancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Pollutant	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Any pollutant	28	19 (-9)	18 (-10)	16 (-12)	16 (-12)
	Cadmium	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Methylmercury	28	19 (-9)	18 (-10)	16 (-12)	16 (-12)
	Selenium	15	15 (0)	15 (0)	14 (-1)	14 (-1)
	Thallium	13	13 (0)	12 (-1)	11 (-2)	11 (-2)
	Zinc	0	0 (0)	0 (0)	0 (0)	0 (0)
	Any pollutant	35	25 (-10)	24 (-11)	21 (-14)	21 (-14)

[23] For comparison, the 2015 rule reduced lead discharges by 19,200 pounds per year (U.S. EPA, 2015a).

Table 12. Modeled IRWs with Exceedances of Oral RfD (Non-Cancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Pollutant	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—subsistence	Cadmium	3	1 (-2)	1 (-2)	1 (-2)	1 (-2)
	Methylmercury	34	24 (-10)	24 (-10)	21 (-13)	21 (-13)
	Selenium	17	17 (0)	17 (0)	16 (-1)	16 (-1)
	Thallium	17	17 (0)	15 (-2)	14 (-3)	14 (-3)
	Zinc	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Adult—recreational	Any pollutant	23	15 (-8)	15 (-8)	13 (-10)	13 (-10)
	Cadmium	0	0 (0)	0 (0)	0 (0)	0 (0)
	Methylmercury	23	15 (-8)	15 (-8)	13 (-10)	13 (-10)
	Selenium	13	13 (0)	13 (0)	12 (-1)	12 (-1)
	Thallium	6	6 (0)	6 (0)	4 (-2)	4 (-2)
	Zinc	0	0 (0)	0 (0)	0 (0)	0 (0)
Adult—subsistence	Any pollutant	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Cadmium	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Methylmercury	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Selenium	15	15 (0)	15 (0)	14 (-1)	14 (-1)
	Thallium	14	14 (0)	13 (-1)	12 (-2)	12 (-2)
	Zinc	0	0 (0)	0 (0)	0 (0)	0 (0)
Any Pollutant and Age/Fishing Mode Cohort[b]		**35**	**25 (-10)**	**24 (-11)**	**21 (-14)**	**21 (-14)**

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Under baseline, EPA estimated that nine immediate receiving waters (nine percent) could contain fish contaminated with inorganic arsenic that present cancer risks greater than the LECR benchmark value of one-in-a-million for the most sensitive, standard cohort (adult subsistence fishers). Under the preferred option (Option 3), if finalized as proposed, the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by eight (89 percent) for this cohort. Table 13 presents the number of immediate receiving waters where the LECR for inorganic arsenic exceeds one-in-a-million.

Table 13. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Number of Modeled IRWs with LECR Greater than One-in-a-Million (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	0	0 (0)	0 (0)	0 (0)	0 (0)
Child—subsistence	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Adult—recreational	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Adult—subsistence	9	2 (-7)	2 (-7)	1 (-8)	1 (-8)

Table 13. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Number of Modeled IRWs with LECR Greater than One-in-a-Million (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Total Number of Immediate Receiving Waters[b]	9	2 (-7)	2 (-7)	1 (-8)	1 (-8)

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

EPA also performed an analysis using fish consumption rates for recreational and subsistence fishers in different race/ethnicity categories to assess whether the steam electric power plant wastewater discharges disproportionately affect minority groups. Table 14 presents the number of immediate receiving waters in which the modeled average daily dose of any pollutant exceeds the oral RfD. Table 15 presents the number of immediate receiving waters that could contain fish contaminated with inorganic arsenic that present cancer risks greater than the LECR benchmark value of one-in-a-million. Results in the tables are presented by cohort (recreational and subsistence fisher) and race/ethnicity category.

As shown in Table 14, the number of immediate receiving waters where the average daily dose of at least one individual pollutant from fish consumption exceeds the oral RfDs is highest among subsistence fishers (child or adults) that fall in the "Other, Including Multiple Races" category. The increased prevalence of exceedances is primarily due to higher average fish tissue consumption rates for this category and fishing mode. EPA estimated reductions in the number of immediate receiving waters with exceedances of human health risk under all of the regulatory options, if finalized as proposed.

Inorganic arsenic concentrations in fish resulted in an estimated cancer risk greater than one-in-a-million to adult subsistence, minority fishers (*i.e.*, excluding the non-Hispanic white cohort) in 10 to 13 immediate receiving waters. Two to three immediate receiving waters had inorganic arsenic concentrations in fish above the LECR threshold of one-in-a-million for adult recreational, minority fishers. Cancer risks for the child cohorts are lower. The estimated cancer risk among adult minority fishers is higher than the risk among adult nonminority fishers. EPA estimated reductions in the number of immediate receiving waters with exceedances of cancer risk under all of the regulatory options, if finalized as proposed.

Appendix A presents the IRW Human Health Module results by pollutant for each age group and mode of fishing for both standard and race/ethnicity cohorts.

Table 14. Modeled IRWs with Exceedances of Oral RfDs by Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	23	15 (-8)	15 (-8)	13 (-10)	13 (-10)
	Non-Hispanic Black	23	16 (-7)	16 (-7)	14 (-9)	14 (-9)

Table 14. Modeled IRWs with Exceedances of Oral RfDs by Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
	Mexican-American	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
	Other Hispanic	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
	Other, Including multiple races	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
Child—subsistence	Non-Hispanic White	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Non-Hispanic Black	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Mexican-American	29	19 (-10)	19 (-10)	17 (-12)	17 (-12)
	Other Hispanic	29	19 (-10)	19 (-10)	17 (-12)	17 (-12)
	Other, including multiple races	33	24 (-9)	23 (-10)	21 (-12)	21 (-12)
Adult—recreational	Non-Hispanic White	23	15 (-8)	15 (-8)	13 (-10)	13 (-10)
	Non-Hispanic Black	23	16 (-7)	16 (-7)	14 (-9)	14 (-9)
	Mexican-American	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
	Other Hispanic	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
	Other, including multiple races	23	17 (-6)	16 (-7)	14 (-9)	14 (-9)
Adult—subsistence	Non-Hispanic White	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Non-Hispanic Black	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
	Mexican-American	29	19 (-10)	19 (-10)	17 (-12)	17 (-12)
	Other Hispanic	29	19 (-10)	19 (-10)	17 (-12)	17 (-12)
	Other, including multiple races	33	24 (-9)	23 (-10)	21 (-12)	21 (-12)

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

Table 15. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs with LECR Above One-in-a-Million (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0 (0)	0 (0)	0 (0)	0 (0)
	Non-Hispanic Black	0	0 (0)	0 (0)	0 (0)	0 (0)
	Mexican-American	0	0 (0)	0 (0)	0 (0)	0 (0)
	Other Hispanic	0	0 (0)	0 (0)	0 (0)	0 (0)
	Other, including multiple races	0	0 (0)	0 (0)	0 (0)	0 (0)
Child—subsistence	Non-Hispanic White	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Non-Hispanic Black	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)

Table 15. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs with LECR Above One-in-a-Million (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
	Mexican-American	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Other Hispanic	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Other, including multiple races	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Adult—recreational	Non-Hispanic White	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
	Non-Hispanic Black	2	1 (-1)	1 (-1)	0 (-2)	0 (-2)
	Mexican-American	3	1 (-2)	1 (-2)	0 (-3)	0 (-3)
	Other Hispanic	2	1 (-1)	1 (-1)	0 (-2)	0 (-2)
	Other, including multiple races	3	1 (-2)	1 (-2)	0 (-3)	0 (-3)
Adult—subsistence	Non-Hispanic White	9	2 (-7)	2 (-7)	1 (-8)	1 (-8)
	Non-Hispanic Black	10	2 (-8)	2 (-8)	1 (-9)	1 (-9)
	Mexican-American	12	3 (-9)	2 (-10)	1 (-11)	1 (-11)
	Other Hispanic	12	3 (-9)	2 (-10)	1 (-11)	1 (-11)
	Other, including multiple races	13	3 (-10)	2 (-11)	1 (-12)	1 (-12)

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

EPA also compared trophic level 4 (T4) fish tissue pollutant concentrations to fish consumption advisory screening values to assess the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories and pose a human health risk.[24] Based on the modeling results, up to 29 immediate receiving waters (30 percent) may contain fish with contamination levels that could trigger advisories for recreational and/or subsistence fishers under baseline; this decreases to 11 immediate receiving waters (17 percent) under the preferred regulatory option (Option 3), if finalized as proposed. Mercury and selenium are the pollutants most likely to exceed screening values. Table 16 presents the number of immediate receiving waters where the modeled T4 fish tissue concentrations exceed screening values used for fish advisories.[25]

[24] For this analysis, EPA used the fish consumption advisory screening values from EPA's *Guidance for Assessing Chemical Contaminant Data for Uses in Fish Advisories, Volume 1* (U.S. EPA, 2000a).

[25] As described in Section 4.2.2, none of the immediate receiving waters are under fish consumption advisories for arsenic or cadmium; each advisory screening value exceedance shown in Table 16 for these pollutants therefore indicates a "new" receiving water of concern that may warrant additional monitoring and/or evaluation of human health risk.

Table 16. Comparison of Modeled T4 Fish Tissue Concentrations to Fish Advisory Screening Values Under Baseline and Regulatory Options

Pollutant	Screening Value (ppm)	Number of IRWs with Modeled T4 Fish Tissue Concentrations Exceeding Screening Value (Difference Relative to Baseline)[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Recreational Fishers						
Arsenic (as inorganic arsenic)[b]	0.026	0	0 (0)	0 (0)	0 (0)	0 (0)
Cadmium	4	0	0 (0)	0 (0)	0 (0)	0 (0)
Mercury (as methylmercury)	0.4	18	12 (-6)	12 (-6)	11 (-7)	11 (-7)
Selenium	20	9	9 (0)	9 (0)	8 (-1)	8 (-1)
Total for Any Pollutant in Evaluated Wastestreams[c]	—	**18**	**12 (-6)**	**12 (-6)**	**11 (-7)**	**11 (-7)**
Subsistence Fishers						
Arsenic (as inorganic arsenic)[b]	0.00327	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Cadmium	0.491	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
Mercury (as methylmercury)	0.049	29	19 (-10)	19 (-10)	17 (-12)	17 (-12)
Selenium	2.457	16	16 (0)	16 (0)	15 (-1)	15 (-1)
Total for Any Pollutant in Evaluated Wastestreams[c]	—	**29**	**19 (-10)**	**19 (-10)**	**17 (-12)**	**17 (-12)**

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); ppm (parts per million); T4 (trophic level 4).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Screening value presented is for carcinogenic effects (lower value than noncarcinogenic effects).

c—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

Appendix E of the 2020 EA (U.S. EPA, 2020a) details the following limitations and uncertainties of the IRW Human Health Module:

- Impact estimates are based on individual exposure pathway and individual pollutant exposure rather than cumulative risks across exposure pathways and the interaction of multiple pollutants.
- Exposure factors will vary by individual physical characteristics.
- The uncertainties associated with human health benchmark values are present, as described in EPA's *Guidelines for Carcinogen Risk Assessment* (U.S. EPA, 2005) and Integrated Risk Information System (IRIS) (U.S. EPA, 2019).
- The module assumes that the diet of the human health cohorts consists of fish inhabiting the immediate receiving water.
- It assumes all forms of a pollutant are equally bioavailable to human health cohorts.

4.2 Discharges to Sensitive Environments

As discussed in Section 3.5, EPA evaluated pollutant discharges to sensitive environments (*i.e.*, impaired waters, fish consumption advisory waters, and drinking water resources). Discharges of the evaluated wastestreams to CWA Section 303(d) impaired waters and fish consumption advisory waters[26] may contribute to water quality impairments, increased health risk associated with consuming fish, and a reduction in the extent of viable downstream fisheries. Discharges of pollutants in the evaluated wastestreams to drinking water resources would likely be reduced to safe levels as part of intake water treatment; however, these pollutants could affect the effectiveness of the treatment processes, which could increase public drinking water treatment costs.[27] Table 17 summarizes the number of immediate receiving waters that are classified as either CWA Section 303(d) impaired waters, fish consumption advisory waters, or drinking water resources under baseline and each regulatory option. EPA evaluated 103 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via POTWs. Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4. Sections 4.2.1 through 4.2.3 present the results of EPA's assessment of immediate receiving waters that discharge into sensitive environments.[28]

Table 17. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters, Fish Consumption Advisory Waters, or Drinking Water Resources Under Baseline and Regulatory Options

Sensitive Environment Category	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
IRWs receiving discharges of the evaluated wastestreams	103	103	97	77	76
Impaired water	53	53 (0)	50 (-3)	40 (-13)	40 (-13)
Subset impaired for one or more pollutants associated with the evaluated wastestreams[b]	39	39 (0)	36 (-3)	28 (-11)	28 (-11)
Fish consumption advisory water	61	61 (0)	57 (-4)	46 (-15)	46 (-15)
Subset with a fish consumption advisory for one or more pollutants associated with the evaluated wastestreams[c]	42	42 (0)	39 (-3)	31 (-11)	31 (-11)
Drinking water resource within five miles[d]	98	98 (0)	92 (-6)	72 (-26)	71 (-27)

[26] Fish consumption advisory waters are waterbodies for which states, territories, and authorized tribes have issued fish consumption advisories, indicating that pollutant concentrations in the tissues of fish inhabiting those waters are considered unsafe to consume.

[27] For more information on drinking water treatment processes used to reduce or eliminate metals commonly detected in the evaluated wastestreams from steam electric power plants, see the memorandum *Drinking Water Treatment Technologies That Can Reduce Metal and Selenium Concentrations Associated with Discharges from Steam Electric Power Plants* (ERG, 2013).

[28] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023h) for a description of the methodology used to evaluate the proximity of plants to CWA Section 303(d) impaired waters, fish consumption advisory waters, and drinking water resources.

Table 17. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters, Fish Consumption Advisory Waters, or Drinking Water Resources Under Baseline and Regulatory Options

Sensitive Environment Category	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4

Source: U.S. EPA, 2023f.

Abbreviations: IRW (immediate receiving water).

a—For this proximity analysis, EPA evaluated 103 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

b—The subset of immediate receiving waters that were impaired with one or more of the following pollutants: arsenic, boron, cadmium, chlorides, chromium, copper, lead, manganese, mercury, metals (other than mercury), nitrogen (reported as ammonia, nitrate, or nitrite), nutrients, phosphorus, selenium, total dissolved solids, and zinc.

c—The subset of immediate receiving waters that had fish consumption advisories for one or more of the following pollutants: arsenic, cadmium, chromium, copper, lead, mercury, metals, selenium, and zinc.

d—Drinking water resources include intakes and reservoirs, public wells, and sole-source aquifers.

4.2.1 Impaired Waters

EPA estimated that more than half (53 of 103) of the immediate receiving waters analyzed in this EA are CWA Section 303(d) impaired waters.[29] As shown in Table 18, 15 of the immediate receiving waters under baseline are impaired for mercury, 15 are impaired for metals (other than mercury),[30] and eight are impaired for nutrients. Figure 4 through Figure 6 present the locations of immediate receiving waters that are classified as impaired by high concentrations of these three impairment categories. A total of 39 immediate receiving waters under baseline (38 percent) are impaired for a pollutant associated with the evaluated wastestreams.

Under the preferred option (Option 3), if finalized as proposed, 13 immediate receiving waters listed as impaired (25 percent) will no longer receive discharges of the evaluated wastestreams.

Table 18. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters for Pollutants Present in the Evaluated Wastestreams Under Baseline and Regulatory Options

Pollutant Causing Impairment	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mercury	15	15 (0)	14 (-1)	11 (-4)	11 (-4)
Metals, other than mercury[b]	15	15(0)	14 (-1)	10 (-5)	10 (-5)
Nutrients	8	8 (0)	7 (-1)	7 (-1)	7 (-1)
TDS	1	1 (0)	1 (0)	0 (-1)	0 (-1)
Total for Pollutants Associated with the Evaluated Wastestreams[c]	**39**	**39 (0)**	**36 (-3)**	**28 (-11)**	**28 (-11)**

[29] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023h) for a complete list of the impairment categories identified in EPA's CWA Section 303(d) waters proximity analysis.

[30] The "metals (other than mercury)" impairment category in EPA's national CWA Section 303(d) impaired waters data set includes impairments caused by metalloids and nonmetals such as arsenic, boron, and selenium.

Table 18. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters for Pollutants Present in the Evaluated Wastestreams Under Baseline and Regulatory Options

Pollutant Causing Impairment	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Total for Any Impairment Category	53	53 (0)	50 (-3)	40 (-13)	40 (-13)

Source: U.S. EPA, 2023h.

Abbreviations: CWA (Clean Water Act); IRW (immediate receiving water); TDS (total dissolved solids).

a—For this proximity analysis, EPA evaluated 103 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

b—Of the 15 immediate receiving waters classified as impaired for “metal, other than mercury” under baseline, five are specifically listed as impaired for one or more of the following individual pollutants evaluated in this environmental assessment: cadmium (1), copper (1), lead (2), manganese (1), selenium (1), and zinc (1). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

c—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

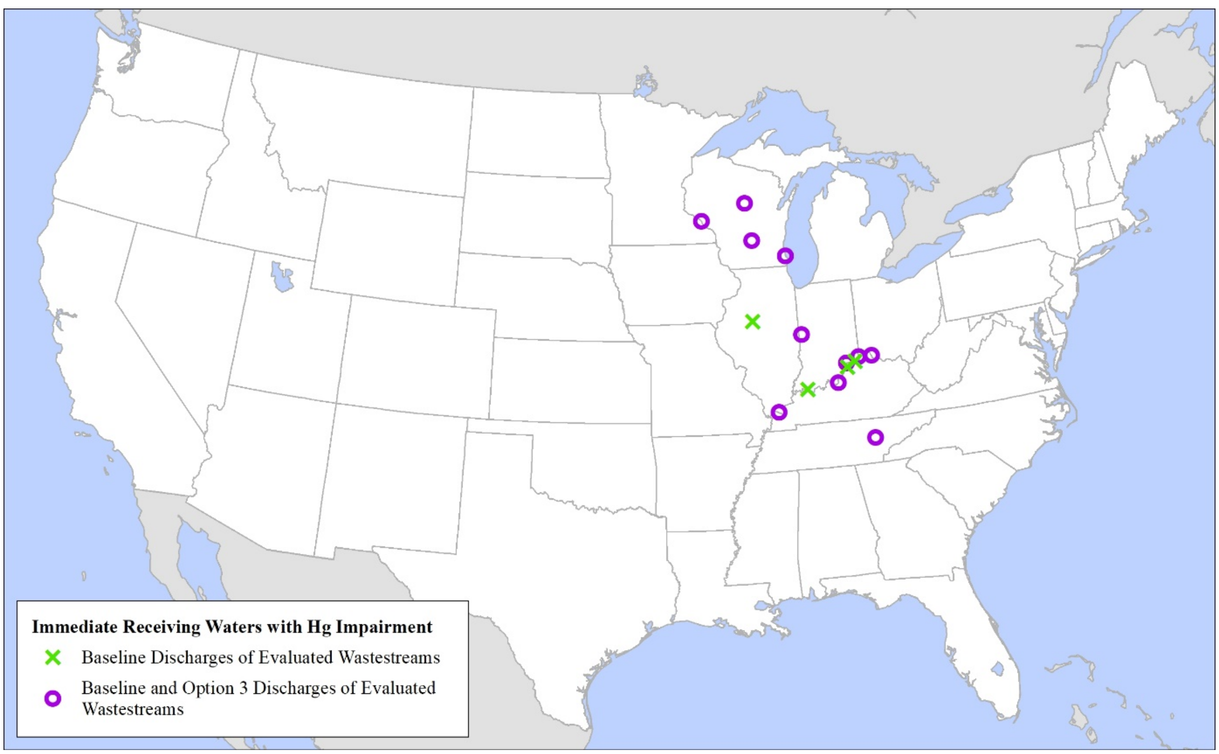

Figure 4. Immediate Receiving Waters Impaired by Mercury

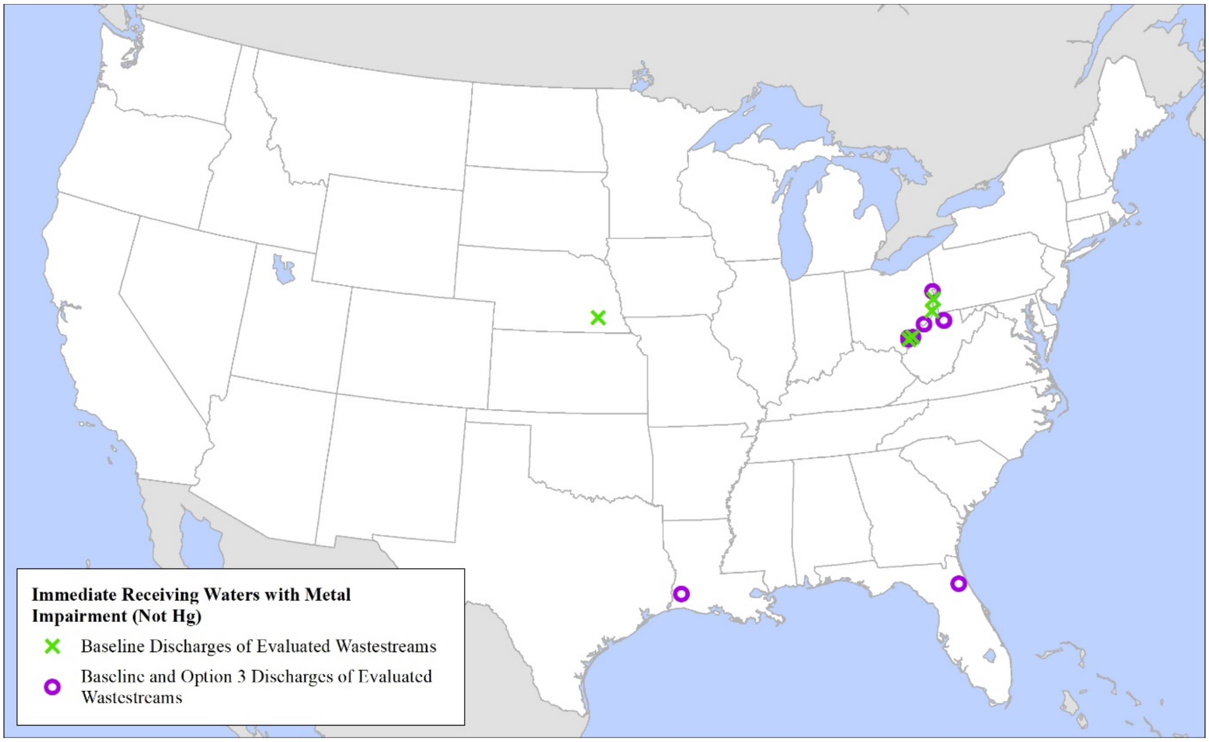

Figure 5. Immediate Receiving Waters Impaired by Metals Other Than Mercury

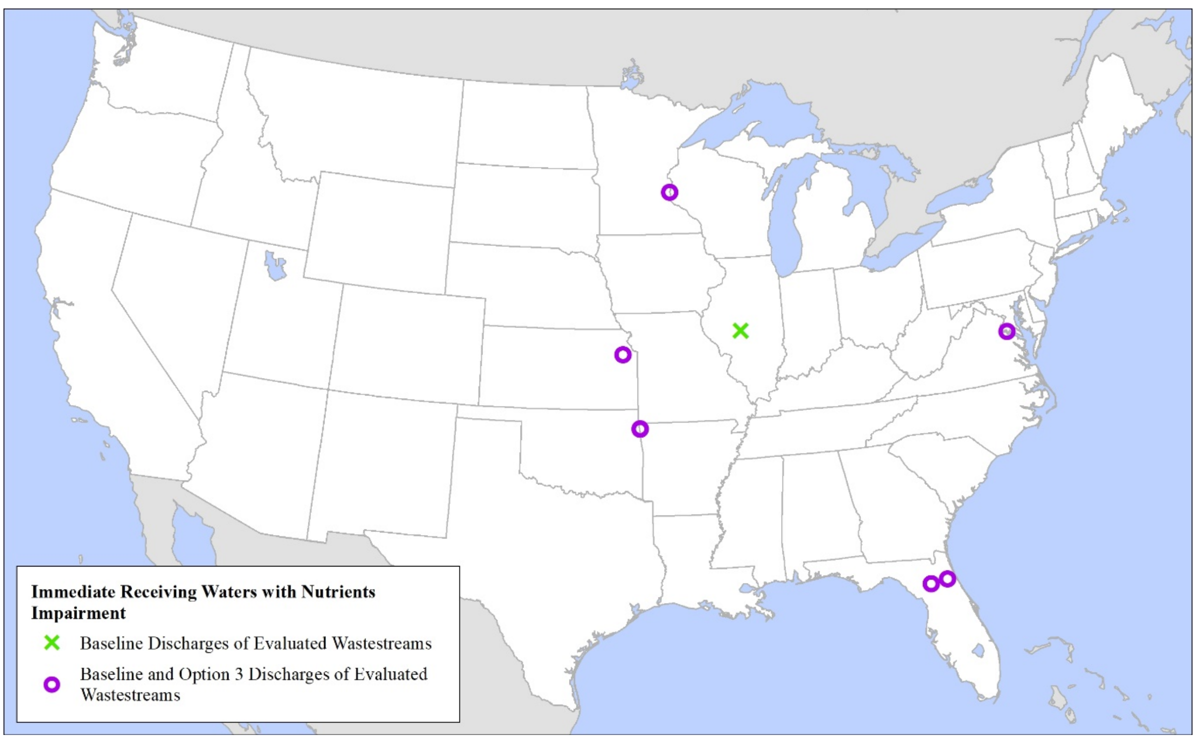

Figure 6. Immediate Receiving Waters Impaired by Nutrients

As shown in Table 2 of this report, all of the regulatory options, if finalized as proposed, result in a decrease in pollutant loadings to the immediate receiving waters, including sensitive environments. The reduction in loadings will help impaired waters to recover; decrease the bioaccumulation of toxic pollutants in fish, thereby reducing the number of fish advisories; and reduce stress on threatened and endangered species and sensitive watersheds such as drinking water resources.

The preferred regulatory option (Option 3), if finalized as proposed, has a net decrease on the loadings of pollutants to waters that are already impaired for those pollutants. EPA estimated the following net changes relative to baseline in pollutant loadings to impaired waters once requirements under Option 3 have been met by the steam electric power plants discharging the evaluated wastestreams to the impaired waterbodies:

- Decrease in nitrogen and phosphorus loadings of 6,110 pounds per year (lb/year) and 281 lb/year, respectively, to nutrient-impaired waters.
- Decrease in phosphorus loadings of 83.2 lb/year to phosphorus-impaired waters.
- Decrease in mercury loadings of 2.26 lb/year to mercury-impaired waters.
- Decrease in loadings to receiving waters impaired for a metal (except mercury), including:
    - Aluminum decrease of 5,770 lb/year.
    - Arsenic decrease of 83.8 lb/year.
    - Boron decrease of 954,000 lb/year.
    - Cadmium decrease of 27.2 lb/year.
    - Chromium decrease of 3,080 lb/year.
    - Copper decrease of 26.5 lb/year.
    - Iron decrease of 54,700 lb/year.
    - Lead decrease of 27.9 lb/year.
    - Magnesium decrease of 14,300,000 lb/year.
    - Manganese decrease of 52,900 lb/year.
    - Nickel decrease of 103 lb/year.
    - Selenium decrease of 40.1 lb/year.
    - Thallium decrease of 42.8 lb/year.
    - Vanadium decrease of 2,810 lb/year.
    - Zinc decrease of 404 lb/year.
- Decrease in TDS loadings of 135,000 lb/year to one TDS-impaired waterbody.

4.2.2 Fish Consumption Advisories

EPA estimated that 59 percent (61 of 103) of the immediate receiving waters analyzed in this EA are under a fish consumption advisory.[31] As shown in Table 19, 42 of the immediate receiving waters under baseline (41 percent) are under an advisory for a pollutant associated with the evaluated wastestreams. All but one of these immediate receiving waters are under a fish consumption advisory for mercury. EPA also reviewed fish consumption advisories for arsenic, cadmium, chromium, copper, lead, selenium, zinc, and unspecified metals, and identified immediate receiving waters under fish consumption advisories for lead and selenium. Figure 7 presents the locations of immediate receiving waters with fish consumption advisories for mercury.

Under the preferred option (Option 3), if finalized as proposed, 15 immediate receiving waters with a fish consumption advisory (25 percent) will no longer receive discharges of the evaluated wastestreams. Under Option 3, EPA estimated a decrease in the annual mercury loadings of 8.81 pounds per year to immediate receiving waters with a fish consumption advisory for mercury.

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[31] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023h) for a complete list of the types of advisories identified in EPA's fish consumption advisories proximity analysis, including advisories due to pollutants that are not associated with the evaluated wastestreams.

Table 19. Modeled IRWs Identified as Fish Consumption Advisory Waters for Pollutants Present in the Evaluated Wastestreams under Baseline and Regulatory Options

Pollutant Causing Fish Consumption Advisory	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Lead	1	1 (0)	1 (0)	1 (0)	1 (0)
Mercury	41	41 (0)	38 (-3)	30 (-11)	30 (-11)
Selenium	1	1 (0)	1 (0)	1 (0)	1 (0)
Total for Pollutants Associated with the Evaluated Wastestreams [b]	42	42 (0)	39 (-3)	31 (-11)	31 (-11)
Total for Any Fish Advisory	61	61 (0)	57 (-4)	46 (-15)	46 (-15)

Source: U.S. EPA, 2023h.

Abbreviations: IRW (immediate receiving water).

a—For this proximity analysis, EPA evaluated 103 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

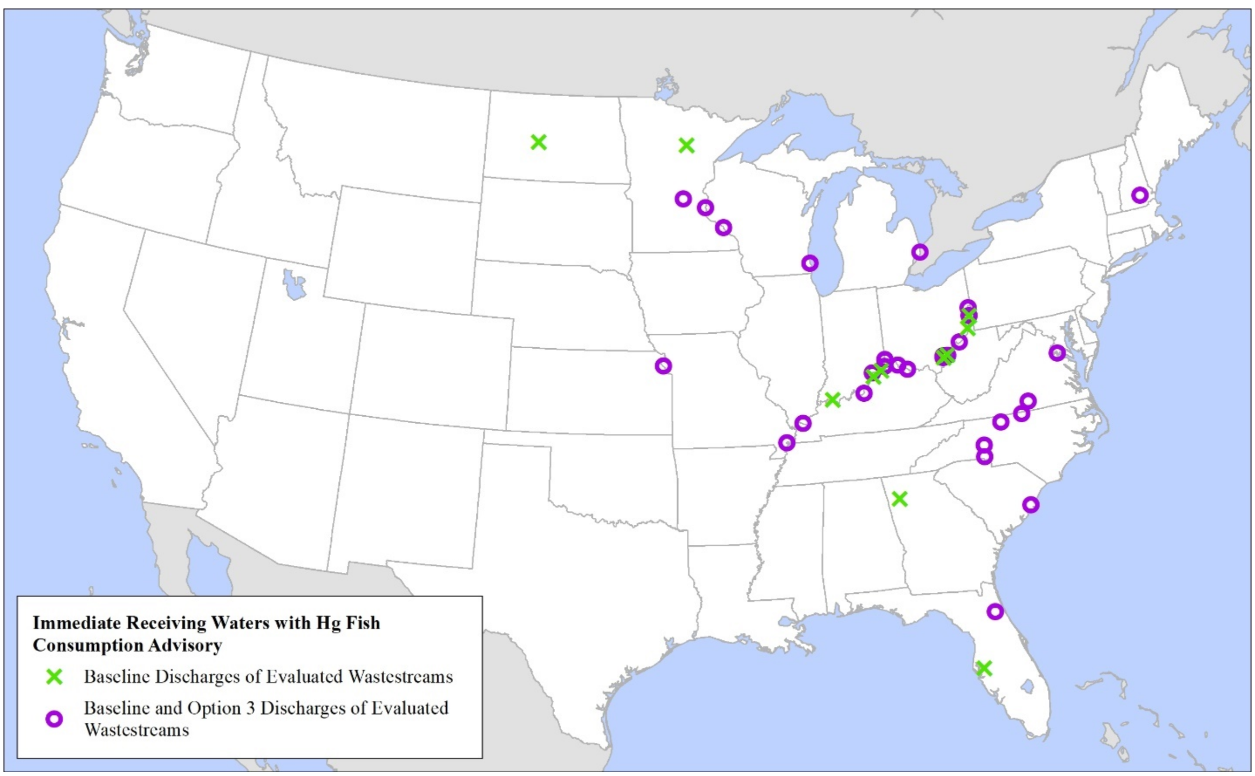

Figure 7. Immediate Receiving Waters with Fish Consumption Advisories for Mercury

4.2.3 Drinking Water Resources

EPA estimated that 95 percent (98 of 103) of the immediate receiving waters analyzed in this EA are located within five miles of a drinking water resource. Under baseline, 90 of the immediate receiving waters (87 percent) are located near public wells, 31 immediate receiving waters (30 percent) are located near drinking water intakes/reservoirs, and three immediate receiving waters (three percent) are located near sole-source aquifers. Table 20 presents the number of immediate receiving waters evaluated under baseline and the regulatory options and the number of those immediate receiving waters located within five miles of a drinking water resource.

Under the preferred option (Option 3), if finalized as proposed, 26 immediate receiving waters located within five miles of a drinking water resource (27 percent) will no longer receive discharges of the evaluated wastestreams.

As discussed in Section 2.2, drinking water supplies can be degraded by pollutants in steam electric power plant wastewater (Cross, 1981), and bromide and iodine discharges are of particular concern due to the formation of disinfection byproducts at drinking water treatment plants and their distribution systems. Under Option 3, EPA estimated a decrease in the bromide loadings between 796,000 and 7 million pounds per year and a decrease in iodine loadings between 45,800 and 186,000 pounds per year to immediate receiving waters located within five miles of drinking water resources.

Table 20. Modeled IRWs Identified as Located Within Five Miles of a Drinking Water Resource Under Baseline and Regulatory Options

Type of Drinking Water Resource	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Intakes and reservoirs	31	31 (0)	29 (-2)	23 (-8)	22 (-9)
Public wells[b]	90	90 (0)	84 (-6)	67 (-23)	67 (-23)
Sole-source aquifers	3	3 (0)	3 (0)	2 (-1)	2 (-1)
Total for Any Immediate Receiving Water[c]	**98**	**98 (0)**	**92 (-6)**	**72 (-26)**	**71 (-27)**

Source: U.S. EPA, 2023h.

Abbreviations: IRW (immediate receiving water; POTW (publicly owned treatment works).

a—For this proximity analysis, EPA evaluated 103 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a POTW. Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

b—Counts include one spring.

c—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

4.3 Cumulative Impacts from Multiple Pollutants

EPA evaluated the joint toxic action (JTA) of multiple pollutants discharged in the evaluated wastestreams from steam electric power plants to determine potential cumulative human health impacts at the immediate receiving waters.[32] The JTA analysis uses three interaction profiles published by the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the direction of interaction between multiple pollutants in steam electric power plant discharges (ATSDR, 2004c, 2004d, and 2006). EPA did not have modeled exposure data for all the pollutants included in each of the interaction profile; therefore, the interactions evaluated for this EA include the following:

- Arsenic, cadmium, lead.

[32] See Section 3.6 and the EPA memoranda Methodology for Assessing Human Health Impacts from Multiple Pollutants in Steam Electric Power Plant Discharges (U.S. EPA, 2023i) and JTA Module Development and Instructions (U.S. EPA, 2023j) for details.

- Lead, zinc.
- Lead, methylmercury.

EPA exposure data included child and adult cohorts (recreational and subsistence fishers) for arsenic, cadmium, methylmercury, and zinc. EPA's exposure data for lead are limited to child cohorts (recreational and subsistence fishers).

Under baseline, EPA did not identify any immediate receiving waters that contained arsenic concentrations above the hazard quotient (HQ) threshold of greater than or equal to 0.1; therefore, EPA's results included three sets of pollutant pairs: (1) lead and cadmium, (2) lead and zinc, and (3) lead and methylmercury. Because of the limitation in available lead data, all results were for child cohorts, as shown in Table 21. Table 21 presents the immediate receiving waters where the hazard index (HI), based on the summation of individual pollutant HQs, exceeded 1.0.

EPA used the ATSDR interaction profiles to predict the anticipated direction of interaction among the pollutants for each pollutant pair included in the JTA analysis. Based on the interaction/noninteraction categories, EPA predicted the direction of the JTA as one of the following:

- Greater than additive—weight of evidence (WOE) suggests that the mixture is likely to pose a greater hazard than indicated by the HI.
- Additive—WOE suggests that the HI is likely a reasonable prediction of the health hazard posed by the mixture.
- Less than additive—WOE suggests that the health hazard is unlikely to be greater than indicated by the HI.

EPA identified the following results from the JTA analysis:

- Neurological cumulative health impacts posed the greatest risk to child recreational and subsistence fishers.
- Under baseline, 28 of the 98 of immediate receiving waters (29 percent) have potential cumulative neurological impacts from lead and methylmercury discharges in the evaluated wastestreams. Under Option 3, if finalized as proposed, this is reduced to 17 immediate receiving waters (17 percent).
- Other JTAs with the potential for cumulative health impacts include lead and cadmium discharges with neurological, renal, and hematological impacts. All options, as proposed, resulted in a decrease in the number of immediate receiving waters with an HI greater than 1.0.
- EPA identified one immediate receiving water that exceeded the HI for cardiovascular impacts from lead and cadmium interaction and one immediate receiving water that exceeded the HI for hematological impacts from lead and zinc. Under all regulatory options, if finalized as proposed, the number of immediate receiving waters exceeding the HI for these interactions is zero.

Table 21. Modeled IRWs with Potential Cumulative Impacts Based on Interaction Profiles Under Baseline and Regulatory Options

Human Health Impact	Predicted Direction of JTA	Age and Fishing Mode Cohort	Number of Modeled IRWs with JTA (Difference Relative to Baseline)[a]				
			Baseline	Option 1	Option 2	Option 3	Option 4
Lead-Cadmium Interaction							
Cardiovascular	Additive	Child—recreational	0	0 (0)	0 (0)	0 (0)	0 (0)
		Child—subsistence	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
		Any cohort[b]	**1**	**0 (-1)**	**0 (-1)**	**0 (-1)**	**0 (-1)**
Hematological	Less than additive	Child—recreational	1	1 (0)	1 (0)	1 (0)	1 (0)
		Child—subsistence	8	2 (-6)	1 (-7)	1 (-7)	1 (-7)
		Any cohort[b]	**8**	**2 (-6)**	**1 (-7)**	**1 (-7)**	**1 (-7)**
Neurological	Greater than additive	Child—recreational	10	3 (-7)	2 (-8)	2 (-8)	2 (-8)
		Child—subsistence	15	12 (-3)	12 (-3)	11 (-4)	11 (-4)
		Any cohort[b]	**15**	**12 (-3)**	**12 (-3)**	**11 (-4)**	**11 (-4)**
Renal	Less than additive	Child—recreational	0	0 (0)	0 (0)	0 (0)	0 (0)
		Child—subsistence	11	9 (-2)	9 (-2)	8 (-3)	8 (-3)
		Any cohort[b]	**11**	**9 (-2)**	**9 (-2)**	**8 (-3)**	**8 (-3)**
Testicular	Greater than additive	Child—recreational	0	0 (0)	0 (0)	0 (0)	0 (0)
		Child—subsistence	0	0 (0)	0 (0)	0 (0)	0 (0)
		Any cohort[b]	**0**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
Lead-Zinc Interaction							
Hematological	Less than additive	Child—recreational	0	0 (0)	0 (0)	0 (0)	0 (0)
		Child—subsistence	1	0 (-1)	0 (-1)	0 (-1)	0 (-1)
		Any cohort[b]	**1**	**0 (-1)**	**0 (-1)**	**0 (-1)**	**0 (-1)**
Lead-Methylmercury Interaction							
Neurological	Additive	Child—recreational	23	16 (-7)	16 (-7)	14 (-9)	14 (-9)
		Child—subsistence	28	19 (-9)	19 (-9)	17 (-11)	17 (-11)
		Any cohort[b]	**28**	**19 (-9)**	**19 (-9)**	**17 (-11)**	**17 (-11)**

Sources: U.S. EPA, 2023i and 2023j.

Abbreviations: IRW (immediate receiving water); JTA (joint toxic action).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Total may not equal the sum of the individual values because some immediate receiving waters exceed a hazard index of 1.0 for multiple cohorts.

As the toxicological studies cited in the ATSDR reports are not specific to the industrial discharges or geographic locations evaluated in the EA, there are limitations and uncertainties associated with the analysis. At a particular immediate receiving water, the potential JTA impacts might be greater or less than EPA's estimates. In addition, exposure concentrations for arsenic, cadmium, methylmercury, and zinc are based on steam electric power plant discharges only and do not reflect other potential sources in the vicinity and are likely an underestimate of the total exposure to cohorts. The memorandum *Methodology for Assessing Human Health Impacts from Multiple Pollutants in Steam Electric Power Plant Discharges* (U.S. EPA, 2023i) provides details on the limitations and uncertainties of the JTA module.

4.4 Impacts in Downstream Surface Waters

EPA performed an analysis of surface waters downstream from the immediate receiving water for each plant that discharges the evaluated wastestreams. The downstream analysis uses the outputs from a separate pollutant fate and transport model (see the BCA Report, U.S. EPA, 2023b, for a description) to assess potential water quality, wildlife, and human health impacts in approximately 13,500 river miles of downstream surface waters. The methodology, which uses estimated annual average pollutant loadings and surface water flow rates, is summarized in Section 3.7 of this report and presented in further detail in the memorandum *Downstream Modeling Analysis and Supporting Documentation for the Environmental Assessment of the Proposed Supplemental Steam Electric Rule* (U.S. EPA, 2023k).

Table 22 presents the results of this downstream analysis. This table lists each of the water quality, wildlife, and human health benchmark values used in the IRW Model[33] and indicates the total length of downstream surface waters for which EPA calculated an exceedance of a benchmark value for at least one of the modeled pollutants. Based on the results of the downstream modeling, 576 downstream river miles are affected by steam electric power plant discharges. Under the preferred option (Option 3), if finalized as proposed, pollutant concentrations exceeding water quality, wildlife, and/or human health benchmarks will decrease to 123 river miles (78 percent reduction)

Table 22. Modeled Downstream River Miles with Exceedances of Any Pollutant Evaluation Benchmark Value Under Baseline and Regulatory Options

Evaluation Benchmark	Modeled Downstream River Miles Exceeding Benchmark Value (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater acute NRWQC	0	0 (0)	0 (0)	0 (0)	0 (0)
Freshwater chronic NRWQC	23.8	23.8 (0)	23.8 (0)	23.8 (0)	23.8 (0)
Human health water and organism NRWQC	376	140 (-236)	140 (-236)	98.4 (-277)	98.4 (-277)
Human health organism only NRWQC	84.1	43.7 (-40.4)	42.5 (-41.7)	36.2 (-47.9)	36.2 (-47.9)
Drinking water MCL	1.83	1.83 (0)	1.23 (-0.607)	1.23 (-0.607)	1.23 (-0.607)
Wildlife Results					
Fish ingestion NEHC for minks	63.6	43.5 (-20.1)	43.5 (-20.1)	43.5 (-20.1)	43.5 (-20.1)
Fish ingestion NEHC for eagles	83.0	47.2 (-35.8)	45.5 (-37.5)	43.5 (-39.5)	43.5 (-39.5)
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	237	79.2 (-158)	79.2 (-158)	76.9 (-160)	76.9 (-160)
Oral RfD for adult (recreational)	126	64.5 (-61.6)	64.5 (-61.6)	62.1 (-63.9)	62.1 (-63.9)
Oral RfD for child (subsistence)	567	143 (-424)	142 (-425)	123 (-443)	123 (-443)
Oral RfD for adult (subsistence)	324	89.2 (-235)	84.6 (-240)	76.9 (-248)	76.9 (-248)
Human Health Results—Cancer					
LECR for child (recreational)	0	0 (0)	0 (0)	0 (0)	0 (0)
LECR for adult (recreational)	3.37	0 (-3.37)	0 (-3.37)	0 (-3.37)	0 (-3.37)
LECR for child (subsistence)	1.23	0 (-1.23)	0 (-1.23)	0 (-1.23)	0 (-1.23)

[33] The water quality outputs used in the downstream analysis were derived from a pollutant fate and transport model that does not simulate pollutant partitioning to the benthic layer; therefore, this analysis does not include comparisons to the sediment TEC.

Table 22. Modeled Downstream River Miles with Exceedances of Any Pollutant Evaluation Benchmark Value Under Baseline and Regulatory Options

Evaluation Benchmark	Modeled Downstream River Miles Exceeding Benchmark Value (Difference Relative to Baseline)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
LECR for adult (subsistence)	18.2	1.23 (-17.0)	1.23 (-17.0)	1.23 (-17.0)	1.23 (-17.0)
Total for Any Benchmark [b]	**576**	**152 (-424)**	**151 (-425)**	**123 (-452)**	**123 (-452)**

Source: U.S. EPA, 2023k.

Abbreviations: LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose).

a—River miles are rounded to three significant figures. As part of this analysis, EPA evaluated approximately 13,500 river miles of surface waters downstream of immediate receiving waters. For this analysis, EPA estimated pollutant concentrations in the immediate receiving water and the downstream receiving waters using the D-FATE model.

b—Total may not equal the sum of the individual values because some river miles exceed multiple benchmarks.

4.5 Summary of Key Environmental and Human Health Improvements

EPA estimated that the environmental and human health improvements in the immediate receiving waters expected from the proposed supplemental rule will translate into improvements in water quality and reduction in pollutant exposures for wildlife and human health in the immediate receiving waters and further downstream from steam electric power plant discharges. The proposed supplemental rule will result in the following environmental improvements as estimated by the EAs for the preferred option (Option 3), if finalized as proposed:

- 44 percent reduction in the number of immediate receiving waters exceeding an NRWQC for the protection of human health.
- 44 to 86 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations exceed mercury benchmarks for the protection of piscivorous wildlife (represented by minks and eagles).
- 39 to 41 percent reduction in the number of immediate receiving waters whose fish tissue pollutant concentrations exceed fish consumption advisories.
- 40 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a risk of non-cancer health effects in exposed populations.
- 27 to 39 percent reduction in the number of immediate receiving waters with potential cumulative neurological impacts based on the interaction of lead-cadmium and lead-methylmercury, respectively.
- 89 percent reduction in the number of immediate receiving waters that support fish whose arsenic tissue concentration pose a cancer risk to exposed populations.

As shown in the downstream modeling analysis, discharges of the evaluated wastestreams affect surface waters beyond the immediate receiving waters. Pollutant removals associated with the proposed rule will improve the environmental and human health for communities beyond the area immediately surrounding steam electric power plants.

The environmental improvements quantified in the EA do not encompass the full range that will result from the proposed supplement rule, such as the following improvements that are not quantified (or have only limited analysis) in this EA:

- Reducing the loadings of bioaccumulative pollutants to the broader ecosystem, decreasing long-term exposures and sublethal ecological effects.

- Reducing sublethal chronic effects of toxic pollutants on aquatic life not captured by the NRWQC.
- Mitigating impacts to aquatic and aquatic-dependent wildlife population diversity and community structures.
- Reducing loadings of pollutants for which EPA did not perform water quality modeling in support of the EA (*e.g.*, aluminum, boron, iron, manganese, nutrients, TDS, and vanadium).
- Reducing loadings of bromide and iodine to drinking water resources.

EPA expects secondary improvements, associated directly or indirectly, as a result of the proposed supplemental rule. Pollutant removals not only improve water quality in surface waters but enhance their aesthetics (*e.g.*, by improving clarity and decreasing odor and discoloration). Improvements in surface water quality may improve the quality of source water for downstream drinking water treatment plants and wells that are influenced by surface water, water used for irrigation, and water used for industrial uses (less contaminants). Recreational benefits from water quality improvements include more enjoyment from swimming, fishing, and boating and potentially increased revenue from more people partaking of recreational activities. The proposed rule may also reduce economic impacts such as cleanup and treatment costs for contamination, reduced water usage, reduced potential for algal blooms, and decreased air emissions. The BCA Report (U.S. EPA, 2023b) provides further details on these secondary improvements and other benefits.

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Attachment A. Additional IRW Model Results

This appendix presents pollutant loadings and additional model outputs for all pollutants included in the Immediate Receiving Water (IRW) Model (arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc) beyond those discussed in Section 4 of this EA. It includes the following tables:

- Table A-1. Modeled IRWs with Exceedances of Benchmark Values for One or More Pollutants Under Baseline and Regulatory Options
- Table A-2. Modeled IRWs with Exceedances of Arsenic Benchmark Values Under Baseline and Regulatory Options
- Table A-3. Modeled IRWs with Exceedances of Cadmium Benchmark Values Under Baseline and Regulatory Options
- Table A-4. Modeled IRWs with Exceedances of Copper Benchmark Values Under Baseline and Regulatory Options
- Table A-5. Modeled IRWs with Exceedances of Lead Benchmark Values Under Baseline and Regulatory Options
- Table A-6. Modeled IRWs with Exceedances of Mercury Benchmark Values Under Baseline and Regulatory Options
- Table A-7. Modeled IRWs with Exceedances of Nickel Benchmark Values Under Baseline and Regulatory Options
- Table A-8. Modeled IRWs with Exceedances of Selenium Benchmark Values Under Baseline and Regulatory Options
- Table A-9. Modeled IRWs with Exceedances of Thallium Benchmark Values Under Baseline and Regulatory Options
- Table A-10. Modeled IRWs with Exceedances of Zinc Benchmark Values Under Baseline and Regulatory Options
- Table A-11. Modeled IRWs with Exceedances of Arsenic Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-12. Modeled IRWs with Exceedances of Cadmium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-13. Modeled IRWs with Exceedances of Copper Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-14. Modeled IRWs with Exceedances of Mercury (as Methylmercury) Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-15. Modeled IRWs with Exceedances of Nickel Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-16. Modeled IRWs with Exceedances of Selenium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-17. Modeled IRWs with Exceedances of Thallium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-18. Modeled IRWs with Exceedances of Zinc Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-19. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million by Race/Ethnicity Category Under Baseline and Regulatory Options

Table A-1. Modeled IRWs with Exceedances of Benchmark Values for One or More Pollutants Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Pollutant Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings for the nine modeled pollutants from all 92 steam electric power plants in pollutant loadings analysis[b]	11,000	4,940	3,570	3,000	2,850
Evaluation Benchmark	**Number of Modeled IRWs Exceeding Benchmark Value[c]**				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater acute NRWQC	1	0	0	0	0
Freshwater chronic NRWQC	10	10	10	9	9
Human health water and organism NRWQC	34	25	24	19	19
Human health organism only NRWQC	20	16	16	14	14
Drinking water MCL	2	2	1	1	1
Wildlife Results					
Sediment TEC	19	19	19	18	18
Fish ingestion NEHC for minks	15	15	15	14	14
Fish ingestion NEHC for eagles	18	15	15	14	14
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	18	12	12	11	11
T4 fish tissue concentration screening value (subsistence)	29	19	19	17	17
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	28	19	18	16	16
Oral RfD for child (subsistence)	35	25	24	21	21
Oral RfD for adult (recreational)	23	15	15	13	13
Oral RfD for adult (subsistence)	28	19	19	17	17
Human Health Results—Cancer					
LECR for child (recreational)	0	0	0	0	0
LECR for child (subsistence)	1	0	0	0	0
LECR for adult (recreational)	1	0	0	0	0
LECR for adult (subsistence)	9	2	2	1	1

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Values represent the industry loadings and the IRW Model outputs for the following nine evaluated pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

Table A-2. Modeled IRWs with Exceedances of Arsenic Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Arsenic Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	1,030	320	185	126	111
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC[f]	34	25	24	19	19
Human health organism only NRWQC[f]	20	16	16	14	14
Drinking water MCL	1	0	0	0	0
Wildlife Results					
Sediment TEC	1	0	0	0	0
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)[f,g]	0	0	0	0	0
T4 fish tissue concentration screening value (subsistence)[f,g]	1	0	0	0	0
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)[f]	0	0	0	0	0
Oral RfD for child (subsistence)[f]	0	0	0	0	0
Oral RfD for adult (recreational)[f]	0	0	0	0	0
Oral RfD for adult (subsistence)[f]	0	0	0	0	0
Human Health Results—Cancer					
LECR for child (recreational)[f]	0	0	0	0	0
LECR for child (subsistence)[f]	1	0	0	0	0
LECR for adult (recreational)[f]	1	0	0	0	0
LECR for adult (subsistence)[f]	9	2	2	1	1

Table A-2. Modeled IRWs with Exceedances of Arsenic Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Arsenic Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total arsenic concentration, unless otherwise stated.

d –The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved arsenic.

f—Benchmark value is based on inorganic arsenic.

g—Values represent number of immediate receiving waters exceeding either the noncarcinogenic or carcinogenic screening values.

Table A-3. Modeled IRWs with Exceedances of Cadmium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Cadmium Loadings (lb/year) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	307	191	93.7	89.1	79.4
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	1	0	0	0	0
Freshwater chronic NRWQC[e]	1	1	1	1	1
Human health water and organism NRWQC	[f]	[f]	[f]	[f]	[f]
Human health organism only NRWQC	[f]	[f]	[f]	[f]	[f]
Drinking water MCL	1	0	0	0	0
Wildlife Results					
Sediment TEC	9	3	3	3	3
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	0	0	0	0	0
T4 fish tissue concentration screening value (subsistence)	1	0	0	0	0
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	1	0	0	0	0
Oral RfD for child (subsistence)	3	1	1	1	1
Oral RfD for adult (recreational)	0	0	0	0	0
Oral RfD for adult (subsistence)	1	0	0	0	0
Human Health Results—Cancer					
LECR for child (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total cadmium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved cadmium.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-4. Modeled IRWs with Exceedances of Copper Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Copper Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	315	193	106	80.7	71.4
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC	0	0	0	0	0
Human health organism only NRWQC	f	f	f	f	f
Drinking water MCL	0	0	0	0	0
Wildlife Results					
Sediment TEC	0	0	0	0	0
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	f	f	f	f	f
T4 fish tissue concentration screening value (subsistence)	f	f	f	f	f
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	0	0	0	0	0
Oral RfD for child (subsistence)	0	0	0	0	0
Oral RfD for adult (recreational)	0	0	0	0	0
Oral RfD for adult (subsistence)	0	0	0	0	0
Human Health Results—Cancer					
LECR for child (recreational)	f	f	f	f	f
LECR for child (subsistence)	f	f	f	f	f
LECR for adult (recreational)	f	f	f	f	f
LECR for adult (subsistence)	f	f	f	f	f

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total copper concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved copper.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-5. Modeled IRWs with Exceedances of Lead Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Lead Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	296	155	76.4	9.80	0.250
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC	f	f	f	f	f
Human health organism only NRWQC	f	f	f	f	f
Drinking water MCL	0	0	0	0	0
Wildlife Results					
Sediment TEC	0	0	0	0	0
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	f	f	f	f	f
T4 fish tissue concentration screening value (subsistence)	f	f	f	f	f
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	f	f	f	f	f
Oral RfD for child (subsistence)	f	f	f	f	f
Oral RfD for adult (recreational)	f	f	f	f	f
Oral RfD for adult (subsistence)	f	f	f	f	f
Human Health Results—Cancer					
LECR for child (recreational)	f	f	f	f	f
LECR for child (subsistence)	f	f	f	f	f
LECR for adult (recreational)	f	f	f	f	f
LECR for adult (subsistence)	f	f	f	f	f

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total lead concentration, unless otherwise stated.

d –The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved lead.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-6. Modeled IRWs with Exceedances of Mercury Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Mercury Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 92 Steam Electric Power Plants in Pollutant Loadings Analysis[b]	22.4	4.50	3.33	2.67	2.54
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC	[f]	[f]	[f]	[f]	[f]
Human health organism only NRWQC	[f]	[f]	[f]	[f]	[f]
Drinking water MCL[g]	0	0	0	0	0
Wildlife Results					
Sediment TEC	16	6	5	4	4
Fish ingestion NEHC for minks[h]	14	3	3	2	2
Fish ingestion NEHC for eagles[h]	18	11	11	10	10
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)[h]	18	12	12	11	11
T4 fish tissue concentration screening value (subsistence)[h]	29	19	19	17	17
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)[h]	28	19	18	16	16
Oral RfD for child (subsistence)[h]	34	24	24	21	21
Oral RfD for adult (recreational)[h]	23	15	15	13	13
Oral RfD for adult (subsistence)[h]	28	19	19	17	17
Human Health Results—Cancer					
LECR for child (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total mercury concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved mercury.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

g—Benchmark value is based on inorganic mercury.

Table A-6. Modeled IRWs with Exceedances of Mercury Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Mercury Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4

h—Benchmark value is based on methylmercury.

Table A-7. Modeled IRWs with Exceedances of Nickel Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Nickel Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	1,360	446	300	188	171
Evaluation Benchmark[c]	Number of Modeled IRWs Exceeding Benchmark Value[d]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC	0	0	0	0	0
Human health organism only NRWQC	0	0	0	0	0
Drinking water MCL	[f]	[f]	[f]	[f]	[f]
Wildlife Results					
Sediment TEC	13	2	2	1	1
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	[f]	[f]	[f]	[f]	[f]
T4 fish tissue concentration screening value (subsistence)	[f]	[f]	[f]	[f]	[f]
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	0	0	0	0	0
Oral RfD for child (subsistence)	0	0	0	0	0
Oral RfD for adult (recreational)	0	0	0	0	0
Oral RfD for adult (subsistence)	0	0	0	0	0
Human Health Results—Cancer					
LECR for child (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]	[f]

Table A-7. Modeled IRWs with Exceedances of Nickel Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Nickel Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total nickel concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved nickel.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-8. Modeled IRWs with Exceedances of Selenium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Selenium Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	2,410	2,240	2,110	2,030	2,015
Evaluation Benchmark[c]	Number of Modeled IRWs Exceeding Benchmark Value[d]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	10	10	10	9	9
Human health water and organism NRWQC	0	0	0	0	0
Human health organism only NRWQC	0	0	0	0	0
Drinking water MCL	1	1	1	1	1
Wildlife Results					
Sediment TEC	19	19	19	18	18
Fish ingestion NEHC for minks	15	15	15	14	14
Fish ingestion NEHC for eagles	15	15	15	14	14
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	9	9	9	8	8
T4 fish tissue concentration screening value (subsistence)	16	16	16	15	15
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	15	15	15	14	14
Oral RfD for child (subsistence)	17	17	17	16	16
Oral RfD for adult (recreational)	13	13	13	12	12

Table A-8. Modeled IRWs with Exceedances of Selenium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Selenium Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Oral RfD for adult (subsistence)	15	15	15	14	14
Human Health Results—Cancer					
LECR for child (recreational)	f	f	f	f	f
LECR for child (subsistence)	f	f	f	f	f
LECR for adult (recreational)	f	f	f	f	f
LECR for adult (subsistence)	f	f	f	f	f

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total selenium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved selenium.

f—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-9. Modeled IRWs with Exceedances of Thallium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Thallium Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	294	279	51.8	44.6	22.1
Evaluation Benchmark[c]	Number of Modeled IRWs Exceeding Benchmark Value[d]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater acute NRWQC	e	e	e	e	e
Freshwater chronic NRWQC	e	e	e	e	e
Human health water and organism NRWQC	3	3	2	1	1
Human health organism only NRWQC	3	3	2	1	1
Drinking water MCL	1	1	0	0	0
Wildlife Results					
Sediment TEC	e	e	e	e	e
Fish ingestion NEHC for minks	e	e	e	e	e
Fish ingestion NEHC for eagles	e	e	e	e	e
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	e	e	e	e	e

Table A-9. Modeled IRWs with Exceedances of Thallium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Thallium Loadings (lb/year)[a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
T4 fish tissue concentration screening value (subsistence)	e	e	e	e	e
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	13	13	12	11	11
Oral RfD for child (subsistence)	17	17	15	14	14
Oral RfD for adult (recreational)	6	6	6	4	4
Oral RfD for adult (subsistence)	14	14	13	12	12
Human Health Results—Cancer					
LECR for child (recreational)	e	e	e	e	e
LECR for child (subsistence)	e	e	e	e	e
LECR for adult (recreational)	e	e	e	e	e
LECR for adult (subsistence)	e	e	e	e	e

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total thallium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—A benchmark value is not yet established for this pollutant or was not included in EPA's analyses.

Table A-10. Modeled IRWs with Exceedances of Zinc Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Zinc Loadings (lb/year) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass loadings from all 92 steam electric power plants in pollutant loadings analysis[b]	4,990	1,110	646	430	378
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater acute NRWQC[e]	0	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0	0
Human health water and organism NRWQC	0	0	0	0	0
Human health organism only NRWQC	0	0	0	0	0
Drinking water MCL	0	0	0	0	0
Wildlife Results					
Sediment TEC	8	1	1	1	1
Fish ingestion NEHC for minks	0	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0	0
Human Health Results—Fish Consumption Advisories					
T4 fish tissue concentration screening value (recreational)	[f]	[f]	[f]	[f]	[f]
T4 fish tissue concentration screening value (subsistence)	[f]	[f]	[f]	[f]	[f]
Human Health Results—Non-Cancer					
Oral RfD for child (recreational)	0	0	0	0	0
Oral RfD for child (subsistence)	1	0	0	0	0
Oral RfD for adult (recreational)	0	0	0	0	0
Oral RfD for adult (subsistence)	0	0	0	0	0
Human Health Results—Cancer					
LECR for child (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2023f and 2023g.

Abbreviations: IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes 103 immediate receiving waters from 92 plants (some of which discharge to multiple receiving waters). Of these 103 immediate receiving waters, all 103 receive discharges of the evaluated wastestreams under baseline and Option 1, 97 do under Option 2, 77 do under Option 3, and 76 do under Option 4.

c—All benchmark values are based on total zinc concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

e—Benchmark value is based on dissolved zinc.

f—A benchmark value is not yet established for this pollutant or was not included in EPA’s analyses.

Table A-11. Modeled IRWs with Exceedances of Arsenic Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value is based on inorganic arsenic.

Table A-12. Modeled IRWs with Exceedances of Cadmium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	1	0	0	0	0
Child—subsistence	Non-Hispanic White	1	0	0	0	0
	Non-Hispanic Black	1	0	0	0	0
	Mexican-American	1	1	1	1	1
	Other Hispanic	1	1	1	1	1
	Other, including multiple races	1	1	1	1	1
Adult—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	1	0	0	0	0
Adult—subsistence	Non-Hispanic White	1	0	0	0	0
	Non-Hispanic Black	1	0	0	0	0
	Mexican-American	1	1	1	1	1
	Other Hispanic	1	1	1	1	1
	Other, including multiple races	1	1	1	1	1

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value is based on dissolved cadmium.

Table A-13. Modeled IRWs with Exceedances of Copper Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value based on total copper.

Table A-14. Modeled IRWs with Exceedances of Mercury (as Methylmercury) Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	23	15	15	13	13
	Non-Hispanic Black	23	16	16	14	14
	Mexican-American	23	17	16	14	14
	Other Hispanic	23	17	16	14	14
	Other, including multiple races	23	17	16	14	14
Child—subsistence	Non-Hispanic White	28	19	19	17	17
	Non-Hispanic Black	28	19	19	17	17
	Mexican-American	29	19	19	17	17
	Other Hispanic	29	19	19	17	17
	Other, including multiple races	32	23	23	21	21
Adult—recreational	Non-Hispanic White	23	15	15	13	13
	Non-Hispanic Black	23	16	16	14	14
	Mexican-American	23	17	16	14	14
	Other Hispanic	23	17	16	14	14
	Other, including multiple races	23	17	16	14	14
Adult—subsistence	Non-Hispanic White	28	19	19	17	17
	Non-Hispanic Black	28	19	19	17	17
	Mexican-American	29	19	19	17	17
	Other Hispanic	29	19	19	17	17
	Other, including multiple races	32	23	23	21	21

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

Table A-15. Modeled IRWs with Exceedances of Nickel Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value based on total nickel.

Table A-16. Modeled IRWs with Exceedances of Selenium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	13	13	13	12	12
	Non-Hispanic Black	13	13	13	12	12
	Mexican-American	14	14	14	13	13
	Other Hispanic	13	13	13	12	12
	Other, including multiple races	14	14	14	13	13
Child—subsistence	Non-Hispanic White	15	15	15	14	14
	Non-Hispanic Black	15	15	15	14	14
	Mexican-American	16	16	16	15	15
	Other Hispanic	16	16	16	15	15
	Other, including multiple races	16	16	16	15	15
Adult—recreational	Non-Hispanic White	13	13	13	12	12
	Non-Hispanic Black	13	13	13	12	12
	Mexican-American	14	14	14	13	13
	Other Hispanic	13	13	13	12	12
	Other, including multiple races	14	14	14	13	13
Adult—subsistence	Non-Hispanic White	15	15	15	14	14
	Non-Hispanic Black	15	15	15	14	14
	Mexican-American	16	16	16	15	15
	Other Hispanic	16	16	16	15	15
	Other, including multiple races	16	16	16	15	15

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value based on total selenium.

Table A-17. Modeled IRWs with Exceedances of Thallium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	6	6	6	4	4
	Non-Hispanic Black	9	9	9	7	7
	Mexican-American	10	10	9	8	8
	Other Hispanic	9	9	9	8	8
	Other, including multiple races	10	10	9	8	8
Child—subsistence	Non-Hispanic White	14	14	13	12	12
	Non-Hispanic Black	14	14	13	12	12
	Mexican-American	15	15	14	13	13
	Other Hispanic	15	15	14	13	13
	Other, including multiple races	17	17	15	14	14
Adult—recreational	Non-Hispanic White	6	6	6	4	4
	Non-Hispanic Black	9	9	9	7	7
	Mexican-American	10	10	9	8	8
	Other Hispanic	9	9	9	8	8
	Other, including multiple races	10	10	9	8	8
Adult—subsistence	Non-Hispanic White	14	14	13	12	12
	Non-Hispanic Black	14	14	13	12	12
	Mexican-American	15	15	14	13	13
	Other Hispanic	15	15	14	13	13
	Other, including multiple races	17	17	15	14	14

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value based on total thallium.

Table A-18. Modeled IRWs with Exceedances of Zinc Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.

b—Benchmark value based on total zinc.

Table A-19. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding LECR[a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child—recreational	Non-Hispanic White	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0
	Mexican-American	0	0	0	0	0
	Other Hispanic	0	0	0	0	0
	Other, including multiple races	0	0	0	0	0
Child—subsistence	Non-Hispanic White	1	0	0	0	0
	Non-Hispanic Black	1	0	0	0	0
	Mexican-American	1	0	0	0	0
	Other Hispanic	1	0	0	0	0
	Other, including multiple races	1	0	0	0	0
Adult—recreational	Non-Hispanic White	1	0	0	0	0
	Non-Hispanic Black	2	1	1	0	0
	Mexican-American	3	1	1	0	0
	Other Hispanic	2	1	1	0	0
	Other, including multiple races	3	1	1	0	0
Adult—subsistence	Non-Hispanic White	9	2	2	1	1
	Non-Hispanic Black	10	2	2	1	1
	Mexican-American	12	3	2	1	1
	Other Hispanic	12	3	2	1	1
	Other, including multiple races	13	3	2	1	1

Source: U.S. EPA, 2023g.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 98 total immediate receiving waters and loadings from 85 plants (some of which discharge to multiple receiving waters). Of these 98 immediate receiving waters, all 98 receive discharges of the evaluated wastestreams under baseline and Option 1, 93 do under Option 2, 74 do under Option 3, and 73 do under Option 4.