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

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LIST OF ABBREVIATIONS

μg/g	Micrograms per gram
μg/L	Micrograms per liter
$\mu g/m^3$	Micrograms per cubic meter
μS/cm	MicroSiemens per centimeter
ADES	Advanced Emissions Solutions, Inc.
ADD	Average daily dose
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation factor
BAT	Best Available Technology Economically Achievable
BCA	Benefit and Cost Analysis
BCF	Bioconcentration factor
Br-DBP	Brominated disinfection byproduct
CCME	Canadian Council of Ministers of the Environment
CCR	Coal combustion residuals
CFR	Code of Federal Regulations
CUWA	California Urban Water Agencies
DBP	Disinfection by-product
DCN	Document control number
D-FATE	Downstream Fate and Transport Equations
DNA	Deoxyribonucleic acid
DWTP	Drinking water treatment plant
EA	Environmental assessment
ED	Exposure duration
EJ	Environmental justice
ELGs	Effluent limitations guidelines and standards
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERG	Eastern Research Group, Inc.
EROM	Extended Unit Runoff Method
FGD	Flue gas desulfurization
FGMC	Flue gas mercury control
FR	Federal Register
FW	Freshwater
g/kg	Grams per kilogram
GIS	Geographic information system
HAA5	Haloacetic acids
HH O	Human Health for the consumption of Organism Only
HH WO	Human Health for the consumption of Water and Organism
HQ	Hazard quotient
ICAC	Institute of Clean Air Companies
I-DBP	Iodinated disinfection byproduct
IQ	Intelligence quotient
IRW	Immediate receiving water
KDEP	Kentucky Department for Environmental Protection

LADD	Lifetime average daily dose
lb/yr	Pounds per year
L/kg	Liter per kilogram
LC_{50}	Median lethal concentration
LECR	Lifetime excess cancer risk
LOEC	Lowest observed effect concentration
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MRL	Minimal risk level
mg/day	Milligrams per day
mg/kg	Milligrams per kilogram
mg/kg-day	Milligrams per kilogram per day
mg/m^3	Milligram per cubic meter
mg/L	Milligrams per liter
mS/cm	MilliSiemens per centimeter
NCDC	National Climatic Data Center
NEHC	No effect hazard concentration
NHDES	New Hampshire Department of Environmental Services
NHDPlus	National Hydrography Dataset Plus
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council of the National Academies
NRWQC	National Recommended Water Quality Criteria
POTW	Publicly owned treatment works
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per thousand
PSES	Pretreatment Standards for Existing Sources
RfD	Reference dose
RIA	Regulatory impact analysis
STORET	EPA’s STOrage and RETrieval Data Warehouse
T3	Trophic level 3
T4	Trophic level 4
TDD	Technical Development Document
TDS	Total dissolved solids
TEC	Threshold effect concentration
TEL	Threshold effect level
TKN	Total Kjeldahl nitrogen
TSS	Total suspended solids
TTHM	Total trihalomethanes
USGS	United States Geological Survey
U.S. DOJ	United States Department of Justice
U.S. EPA	United States Environmental Protection Agency
UV	Ultraviolet
VIP	Voluntary incentive program
WHO	World Health Organization

SECTION 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.” In support of the development of the 2015 rule, the EPA conducted an environmental assessment (EA) to evaluate the environmental impact of pollutant loadings discharged by coal-fired power plants and assess the potential environmental improvement from pollutant loading changes under the rule. The 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 Final EA.” Following promulgation, the EPA received seven petitions for review of the 2015 rule, and the Administrator announced his decision to reconsider the 2015 rule in an April 12, 2017, letter. See the *Supplemental Technical Development Document for Proposed Revisions to the Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (Supplemental TDD) (U.S. EPA, 2019a) for additional background and information on rulemaking history. The EPA is now conducting a new rulemaking regarding the appropriate technology bases and associated limits for the best available technology economically achievable (BAT) effluent limitations and pretreatment standards for existing sources (PSES) applicable to flue gas desulfurization (FGD) wastewater and bottom ash transport water discharged from coal-fired power plants. To support the new rulemaking, the EPA conducted a Supplemental EA on the two wastestreams being evaluated.

The Clean Water Act does not require that the EPA assess the water-related environmental impacts, or the benefits, of its ELGs, and the Agency did not make its decision on the proposed rule based on the expected benefits of the rule. The EPA does, however, inform itself of the benefits of its rule, as required by Executive Order 12866. See the *Benefit and Cost Analysis for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report) (U.S. EPA, 2019b). The Supplemental EA evaluated the potential environmental impacts due to pollutant loadings under baseline discharge practices (i.e., following full implementation of the 2015 rule) and the changes in those impacts under varying regulatory options of this proposed rule.

1.1 BACKGROUND ON STEAM ELECTRIC WASTEWATER DISCHARGES

Based on demonstrated impacts documented in literature and modeled receiving water pollutant concentrations, discharges of coal-fired power plant wastewater can impact the water quality in receiving waters, impact the wildlife in the surrounding environments, and pose a human health risk to nearby communities. There is substantial evidence that pollutants (e.g., mercury and selenium) found in coal-fired power plant wastewater discharges propagate from the aquatic environment to terrestrial food webs, indicating a potential for broader impacts on ecological systems by diminishing population diversity and disrupting community dynamics in the areas surrounding coal-fired power plants. Ecosystem recovery from exposure to pollutants in power plant wastewater discharges can be extremely slow. Even short periods of exposure (e.g., less than a year) can cause observable ecological impacts that last for years (Benson and Birge, 1985;

Brandt et al., 2017; Cañedo-Argüelles et al., 2013; CCME, 2018; Coughlan and Velte, 1989; Evans and Frick, 2001; Evers et al., 2011; Garrett and Inman, 1984; Guthrie and Cherry, 1976; Hallock and Hallock, 1993; Javed et al., 2016; Kimmel and Argent, 2010; Lemly, 1985, 1993, 1997, 1999, and 2018; NPS, 1997; NRC, 2006; Rowe et al., 2001 and 2002; Ruhl et al., 2012; Sorensen, 1988; Specht et al., 1984; U.S. EPA, 2011a and 2015a; U.S. EPA Region 5, 2016; Velasco et al., 2018; Weber-Scannell and Duffy, 2007; WHO, 1992).

Coal-fired power plants often discharge wastewater into waterbodies used for recreation and as sources of drinking water. Numerous studies have raised concern regarding the toxicity of these wastestreams and their impacts on downstream drinking water treatment systems (Brandt et al., 2017; Cornwell et al., 2018; ERG, 2019a, 2019b, and 2019c; Good and VanBriesen, 2016 and 2017; Javed et al., 2016; Lemly, 2018; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013). These discharges can also elevate halogen levels in surface water, which may contribute to disinfection byproduct formation at downstream drinking water treatment plants.

1.2 Scope of the Analysis

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 utilizing 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. In this Supplemental EA, the EPA uses the term “coal-fired power plant wastewater” to represent all combustion-related wastewaters that contain pollutants covered by the steam electric ELGs.[1] As noted earlier, the Supplemental EA evaluated two wastestreams from coal-fired power plants whose limits would be revised under the new rulemaking (FGD wastewater and bottom ash transport water), as described in Table 1-1.

[1] The steam electric ELGs control the discharge of pollutants to surface waters and do not regulate “wastewater.” To allow for more concise discussion in this Supplemental EA, the EPA occasionally refers to “wastewater” discharges and impacts without referencing the pollutants in the wastewater discharges.

Table 1-1. Coal-Fired Power Plant Wastestreams Evaluated in the Supplemental 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 (including 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 Supplemental TDD for further details). In the 2015 rule, the EPA established numeric effluent limitations for mercury, arsenic, selenium, and nitrate/nitrite as nitrogen (N) in FGD wastewater, based on treatment using chemical precipitation followed by biological treatment.
Bottom ash transport water	Water used to convey the bottom ash particles collected at the bottom of the boiler. Bottom ash transport waters contain halogens, total dissolved solids (TDS), total suspended solids (TSS), metals, and other toxic and bioaccumulative pollutants, such as arsenic and selenium (see the Supplemental TDD for further 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. In the 2015 rule, the EPA established zero discharge limitations for bottom ash transport water based on one of two technologies: (1) dry handling or (2) closed-loop systems.

The goal of the Supplemental EA was to answer the following two questions regarding pollutant loadings from the two evaluated wastestreams:

- What are the environmental and human health concerns regarding the pollutants being discharged with the evaluated wastestreams?
- What are the potential changes to water quality, wildlife, and human health impacts under the regulatory options compared to baseline (i.e., the 2015 rule)?

The Supplemental EA evaluated environmental concerns and potential exposures (ecological and human) to pollutants commonly found in wastewater discharges from coal-fired power plants. The EPA completed both qualitative and quantitative analyses. Qualitative analyses included reviewing additional literature documenting site impacts; assessing the pollutant loadings to receiving waters—including those designated as impaired or with a fish consumption advisory—under baseline and the regulatory options; and reviewing the effects of pollutant exposure on ecological and human receptors. To quantify impacts associated with these discharges, the EPA used a computer model[2] 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. The EPA compared the values calculated by the model to

[2] See Section 3.4 of this report for an overview of the model.

benchmark values to assess the extent of the environmental impacts nationwide. The EPA only evaluated the impacts of FGD wastewater and bottom ash transport water discharges and the incremental impacts of only these two wastestreams from coal-fired power plants.

The EPA assessed environmental impacts under baseline and four regulatory options, as shown in Table VII-1 of the preamble to the proposed rule. The EPA also developed subcategories for both of the evaluated wastestreams, also shown in Table VII-1. In general, each succeeding regulatory option from Option 1 to 4 would achieve more reduction in FGD wastewater pollutant discharges.

The EPA evaluated 112 coal-fired power plants that discharge one or both of the evaluated wastestreams directly or indirectly to surface waters under baseline and/or the regulatory options, and performed the quantitative modeling on a subset of 105 of these plants. The analyses presented in this report account for publicly announced plans from the steam electric power generating industry to retire or modify coal-fired generating units at specific power plants by December 31, 2028. See Section 3.2 of this report for additional details on the scope of the Supplemental EA.

The assessments described in this Supplemental EA focus on environmental impacts caused by exposure to pollutants in the evaluated wastestreams through the surface water exposure pathway. However, the proposed rule may have other environmental impacts unrelated to exposure to pollutants in wastewater discharges. Examples include changes in ground water and surface water withdrawals by coal-fired power plants; changes in the amount of dredging activity necessary to maintain capacities in reservoirs downstream from coal-fired power 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 the EPA's *Benefit and Cost Analysis for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report).

The Supplemental EA does not evaluate impacts caused by migration of pollutants from surface impoundments into ground water. The preamble to the proposed rule discusses how the EPA's Coal Combustion Residual (CCR) Rule addresses this type of impact and how it relates to this proposed rulemaking.

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

- *Regulatory Impact Analysis for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA), Document No. EPA-821-R-19-012. 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.
- *Benefit and Cost Analysis for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report), Document No. EPA-821-R-19-011 (U.S. EPA, 2019b). This

report summarizes the monetary benefits and societal costs that result from implementation of the proposed rule.

- *Supplemental Technical Development Document for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (Supplemental TDD), Document No. EPA-821-R-19-009 (U.S. EPA, 2019a). This report includes background on the proposed rule; industry description; wastewater characterization and identification of pollutants of concern; treatment technologies and pollution prevention techniques; and documentation of EPA's engineering analyses to support the proposed rule, including cost estimates, pollutant loadings, and a non-water-quality environmental impact assessment.

These reports are available in the public record for the proposed rule and on the EPA's website at https://www.epa.gov/eg/steam-electric-power-generating-effluent-guidelines-2019-proposed-revisions.

The proposed rule is based on data generated or obtained in accordance with the EPA's Quality System and Information Quality Guidelines.[3] The EPA's quality assurance and quality control activities for this rulemaking include the development, approval, and implementation of Quality Assurance Project Plans for using environmental data generated or collected from all sampling and analyses, existing databases, and literature searches, and for developing any models that used environmental data. Unless otherwise stated within this document, the EPA evaluated the data used and associated data analyses as described in these quality assurance documents to ensure that they are of known and documented quality; meet the EPA's requirements for objectivity, integrity, and utility; and are appropriate for the intended use.

[3] See the following EPA websites for further details: https://www.epa.gov/quality/about-epas-quality-system and https://www.epa.gov/quality/epa-information-quality-guidelines

SECTION 2
ENVIRONMENTAL AND HUMAN HEALTH CONCERNS ASSOCIATED WITH THE EVALUATED WASTESTREAMS

Discharges of flue gas desulfurization (FGD) wastewater and bottom ash transport water (the evaluated wastestreams) from coal-fired power plants 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. Numerous studies document ecological impacts such as fish mortality, genotoxicity, and lower fish survival and reproduction rates resulting from exposure to pollutants in coal-fired power plant discharges.[4] Halogen compounds associated with coal-fired power plant discharges also raise ecological and human health concerns. Halogens present 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.

The EPA documented environmental and human health concerns from coal-fired power plant discharges in the 2015 Final EA (U.S. EPA, 2015a). For this Supplemental EA, the EPA conducted a supplemental literature review that consisted of identifying and evaluating peer-reviewed journal articles, along with other published materials, and focused on environmental, ecological, and human health impacts resulting from discharges of pollutants in FGD wastewater and bottom ash transport water. This section presents a summary of relevant findings. Some of the articles documented impacts of coal-fired power plant discharges but did not provide specific wastestream details. When such details were documented in reviewed articles, the EPA included details regarding applicable wastestreams. See the memorandum "Methodology and Results of a Targeted Literature Search of Environmental Impacts from Steam Electric Power Plants" for additional details (ERG, 2019a).

This section details environmental concerns associated with wastewater discharges from coal-fired power plants, including the contamination of surface water, toxic effects on fish and aquatic life, and human health concerns.

2.1 POLLUTANTS DISCHARGED IN THE EVALUATED WASTESTREAMS

The EPA evaluated the pollutants discharged in FGD wastewater and bottom ash transport water for this Supplemental EA. Once these pollutants are released into the environment, they can reside for a long time in the receiving waters, bioaccumulating and/or binding with sediments. The 2015 Final EA presented the potential environmental, ecological, and human health concerns associated with exposure to metals, toxic bioaccumulative pollutants, nutrients, and TDS.[5] This Supplemental EA focuses on the impacts of discharges of TDS (and the resulting

[4] See 2015 Final EA; Brandt et al., 2017; Javed et al., 2016; Lemly, 2018.
[5] The 2015 Final EA discussed chloride and bromide discharges as part of the TDS parameter.

salinity of the receiving water) and halogens. Additionally, Appendix A provides examples of potential adverse impacts to humans and wildlife 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 coal-fired power plant discharges of these pollutants and nutrients are discussed further in the 2015 Final EA.

2.1.1 Total Dissolved Solids (TDS) Concentrations and Salinity

The concentration of TDS in water is a direct indication of the water's salinity. The primary constituents of TDS are organic salts and dissolved metals; small amounts of organic material can also be present. Common inorganic salts found in TDS can include cations (positively charged ions) of calcium, magnesium, potassium, and sodium, and anions (negatively charged ions) such as carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS concentrations in the evaluated wastestreams include dissolved metals and halogens, which can cause negative impacts (described in Appendix A and the following sections).

TDS concentrations higher than 700 milligrams per liter (mg/L) can result in reduced growth, decreased survival rates, and altered behavior in macroinvertebrate communities (U.S. EPA, 2018a). Appendix B presents examples of adverse impacts associated with elevated TDS concentrations in receiving water.

Salinity represents the total concentration of dissolved salts (a subset of TDS) in the water. Salts in inland waters consist primarily of the following cations: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}); and the following anions: bicarbonate (HCO_3^{2-}), carbonate (CO_3^{2-}), sulfate (SO_4^{2-}), and chloride (Cl^{-}) (Wetzel, 1983). Salts can enter water naturally, through erosion of soils and geologic formations over time and introduction of their dominant ions to local freshwater systems (Olson and Hawkins, 2012; Hem, 1985; Pond, 2004; U.S. EPA, 2011d). For example, salinity in freshwater lakes typically falls within the 100 to 500 mg/L range and is predominantly driven by calcium carbonate (Evans and Frick, 2001).

Human activity can increase salt concentrations in surface and ground water. Direct anthropogenic sources of salts include mining activities, use of road salt for de-icing, and discharge of sewage and industrial wastewater (Cañedo-Argüelles, 2013). Land use decisions, such as construction activities, resource extraction, and irrigation activities, can indirectly increase salt concentrations by increasing erosion and the transport of ions to surface waters (Cañedo-Argüelles et al., 2018). Additionally, saltwater intrusion into freshwater systems has been well documented in coastal areas of the United States and can be caused by factors including groundwater extraction and road construction projects and culverts (Barlow and Reichard, 2010; Stewart et al., 2002). Once salinity has increased in freshwater systems, the effect can be persistent. In lentic waters such as lakes and ponds, even small increases in salts can result in long-term increases in salinity, lasting months or years (Evans and Frick, 2001).

Freshwater aquatic organisms are adapted to specific salinity ranges and can experience adverse effects on fitness and survival when salinity increases beyond their tolerance (Cañedo-Argüelles et al., 2018). Increases in aquatic salinity can 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). TDS toxicity in the aquatic environment depends on its ionic composition and the interaction between ions present in the TDS discharge and the receiving water (Mount et al., 1993 and 1997).

Researchers have documented consequences of elevated salinity for aquatic organisms and ecosystems. Velasco et al. (2018) performed a meta-analysis of studies that evaluated salinity impacts in aquatic environments and found that 43 percent of the studies reported negative impacts to aquatic organisms (e.g., decreased survival and growth, increased osmolyte concentration in body fluids, and changes to metabolic rates), while 20 percent of the studies found positive impacts, primarily on increased survival or tolerance to heat or cold stress. Benthic invertebrates, including caddisfly, mayfly, *Nais variabilis* (oligochaete), and mosquito larvae, exposed to sodium chloride (NaCl) concentrations ranging from 1,300 to 12,000 mg/L exhibit mortality and reduced survival (Evans and Frick, 2001). Fish mortality occurs at NaCl concentrations ranging from 5,500 to 12,000 mg/L for certain species of rainbow trout, Indian carp fry, minnows, and goldfish. At higher concentrations (14,000 to 50,000 mg/L), other fish species (e.g., bluegill sunfish, channel catfish, rainbow trout species, brook trout, and golden shiners) exhibit decreased survival and recovery (Evans and Frick, 2001). Increased salinity has been linked to adverse effects on freshwater ecosystems, 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).

Elevated levels of TDS in the source water can also negatively impact downstream drinking water treatment and distribution by accelerating corrosion of transport pipes and producing organoleptic effects (e.g., undesirable taste). The EPA has not set a primary maximum contaminant level (MCL) for TDS but has set a secondary MCL for TDS as a nuisance parameter at 500 mg/L. Above this level, drinking water can demonstrate hardness, deposits, color, staining, and a salty taste (U.S. EPA, 2017 and 2018a). Individual halides, such as bromide, chloride, and iodide, in source water can cause the formation of DBPs at downstream DWTPs, which can impact human health (Cornwell et al., 2018; Corsi et al., 2010; ERG, 2019c; Good and VanBriesen, 2016 and 2017; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013).

At coal-fired power plants, the average TDS concentration in untreated FGD wastewater is 33,300 mg/L. Untreated FGD wastewater has been reported to contain average concentrations of the following ions (U.S. EPA, 2015b):

- Calcium: 3,290 mg/L (total) and 2,050 mg/L (dissolved).
- Chloride: 7,180 mg/L.
- Magnesium: 3,250 mg/L (total) and 3,370 mg/L (dissolved).
- Sodium: 2,520 mg/L (total) and 276 mg/L (dissolved).
- Sulfate: 13,300 mg/L.

2.1.2 Bromide

Bromine is naturally present in coal. Some coal-fired power plants also add bromine to their combustion processes to enhance mercury emissions control or burn refined coal amended with bromide compounds (U.S. EPA, 2019a). After combustion, bromine partitions in part to FGD wastewater and bottom ash 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 mg/L (EPRI, 2009; Good, 2018; U.S. EPA, 2015c and 2019a). Average bromide levels of 5.1 mg/L have been documented in bottom ash transport wastewaters (U.S. EPA, 2019a). These levels are higher than the average levels of 0.014 mg/L to 0.2 mg/L reported for freshwater surface waters (Bowen, 1966 and 1979; 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 substantive source of bromide loadings from the plants (Cornwell et al., 2018; Good and VanBriesen, 2016, 2017, and 2019; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013; U.S. DOJ, 2015; U.S. EPA, 2015c).

Bromide is highly soluble and nonreactive in freshwater systems and is consequently used as a tracer for hydrology field studies (Brantley et al., 2014; Cowie et al., 2014; Cox et al., 2003; Flury and Papritz, 1993; Writer et al., 2011). Because of this stability, studies of bromide fate and transport in freshwater systems focus on downstream transport and dilution of mass loadings in surface water flow volume (Cornwell et al., 2018; Good and VanBriesen, 2016, 2017, and 2019; Harkness et al., 2015; Ruhl et al., 2012; States et al., 2013; Weaver et al., 2015; Wilson and VanBriesen, 2013).

Bromide's toxicity in freshwater aquatic environments is low relative to substances such as copper or cadmium cations. Reviews of freshwater aquatic organism toxicology studies cite effect concentrations 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). Bromide's toxicity for human beings through oral ingestion is also low relative to other substances. 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). As noted in Section 2.1.1, bromide also contributes to TDS levels, salinity levels, and potential associated effects in surface waters.

While bromide's direct toxicity is relatively low, toxicity associated with its contribution to DBP formation in drinking water treatment and distribution systems can be greater (Krasner, 2006; Krasner et al., 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, some of which 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). While multiple factors affect DBP formation[6],

[6] Additional factors influencing DBP formation include pH, temperature, disinfection process type and dosage level, organic material levels and type, and treatment and distribution system residence time (Brown et al., 2011; Hong et al., 2013; Obolensky and Singer, 2008).

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).

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 linkage 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 generally have higher toxicity than their chlorinated analogues (Cortés and Marco, 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., 2017a; Regli et al., 2015; Sawade et al., 2016; Wang et al., 2017; Yang et al., 2014).

Table 2-1 lists the Maximum Contaminant Level (MCL) limits that EPA has issued for select DBPs in disinfected drinking water. These limits are intended to serve as indicator metrics for control of total DBPs of which more than 600 individual species have been identified to date (Richardson and Postigo, 2011; U.S. EPA, 2006 and 2016a). The DBP MCLs aim to balance the need for adequate disinfection to control human health risks from microbial pathogens with the human health risks from DBPs (Li and Mitch, 2018; Plewa et al., 2017; U.S. EPA, 2016a). DWTPs must produce water of a quality that complies with MCLs. The Maximum Contaminant Level Goal (MCLG) limits listed in Table 2-1 reflect the level below which there is no known or expected risk to human health and are not treatment level requirements (U.S. EPA, 2009a).

DWTPs comply with DBP MCLs through a variety of techniques to adjust source water quality, disinfection processes, and/or DBP removal as needed (McGuire et al., 2014; U.S. EPA, 2016a). Source water quality control through direct bromide removal is infeasible in conventional treatment systems (States et al., 2013) and instead requires specialized treatment processes (Chen et al., 2008; CUWA, 2011; U.S. EPA, 2016a; Watson et al., 2012). In addition to cost and operational feasibility considerations, many compliance approaches have human health risk considerations because they modify, rather than eliminate, DBP mixtures and may not decrease total human health risk (Bond et al., 2011; Cadwallader and VanBriesen, 2019; Francis et al., 2010; Huang et al., 2017; Kolb et al., 2017b; Krasner, 2009; Li and Mitch, 2018; McGuire et al., 2014; Plewa et al., 2017; States et al., 2013; U.S. EPA, 2016a; Wagner and Plewa, 2017; Watson et al., 2014)

Table 2-1. Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for Drinking Water Disinfection Byproducts (DBPs)

Regulated DBPs	MCL	MCLG
Bromate (plants that use ozone)	0.010 mg/L	Zero
Chlorite (plants that use chlorine dioxide)	1.0 mg/L	0.8 mg/L
Haloacetic Acids-5 (HAA5)	0.060 mg/L	
Monochloroacetic acid		-
Dichloroacetic acid		Zero
Trichloroacetic acid		0.3 mg/L
Bromoacetic acid		-
Dibromoacetic acid		-
Total Trihalomethanes (TTHM)	0.080 mg/L	
Chloroform		-
Bromodichloromethane		Zero
Dibromochloromethane		0.06 mg/L
Bromoform		Zero

Source: U.S. EPA, 2009a.

Acronyms: DBP (disinfection byproduct); mg/L (milligrams per liter).

Several studies have identified elevated bromide levels at DWTP intakes downstream of FGD wastewater discharges from coal-fired power plants (McTigue et al., 2014; States et al., 2013; U.S. DOJ, 2015; U.S. EPA, 2015c). Studies have also identified changes in total DBP and Br-DBP levels at DWTPs corresponding to changes in upstream bromide discharges (Cadwallader and VanBriesen, 2019; Cornwell et al., 2018; Marusak, 2017; McTigue et al., 2014; States et al., 2013; U.S. DOJ, 2015; U.S. EPA, 2019c; Wang et al., 2017). The BCA Report (U.S. EPA, 2019b) describes the EPA's estimate of changes in bromides loadings from steam electric power plants under the regulatory options, and the effects of these changes on downstream DWTPs and associated human health risks.

In addition to their formation in DWTPs, Br-DBP formation has been documented in publicly owned treatment works (POTWs) and other wastewater treatment facilities that disinfect bromide-containing waters prior to discharge (Chen et al., 2009; Hladik et al., 2014; Krasner et al., 2009; Pignata et al., 2011). A subset of steam electric power plants discharges to POTWs (U.S. EPA, 2019a). Discharges from the treatment facilities to surface waters could contribute to elevated Br-DBP levels in downstream surface water drinking water sources and aquatic ecosystems. The toxicity of Br-DBPs to organisms has been documented in laboratory settings but has not been well characterized in natural aquatic environments (Butler et al., 2005; Chen et al., 2009; Environment Canada and Health Canada, 2010; Hanigan et al., 2017; Soltermann et al., 2016).

2.1.3 Iodine

Iodine is naturally present in coal.[7] Some coal-fired power plants also add iodine to their combustion processes to enhance mercury emissions control or burn refined coal amended with

[7] Native iodine levels in coal range from 0.15 to 12.9 ppm (Bettinelli et al., 2002; Good, 2018). One source states that many coals used by utility plants have iodine levels greater than 3 ppm (Sjostrom et al., 2016).

iodide compounds (ADES, 2016; Gadgil, 2016; ICAC, 2019; Sahu, 2017; Senior et al., 2016; Sjostrom et al., 2016; Sjostrom and Senior, 2019).[8] Iodine volatilizes during combustion and partitions to FGD wastewaters and, to a lesser extent, to bottom ash 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). Limited data on typical iodine concentrations in FGD wastewater and bottom ash transport waters are available, though methods have been proposed for maintaining iodine concentrations in FGD wastewater below approximately 100 mg/L to ensure normal FGD system operation and to recover iodine for reuse (Sjostrom et al., 2016).

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.[9] 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).

Available data on iodide's ecotoxicity in freshwater aquatic environments suggests that it is generally lower than that of substances such as copper or cadmium cations. Estimates of median lethal toxic concentrations (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 (Juhnke and Ludemann, 1978; Laverock et al., 1995). Toxicity to single-celled organisms is reported to be similar to that of bromide (Bringmann and Kühn, 1977, 1980, and 1981). 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). As noted in Section 2.1.1, iodide also contributes to TDS levels, salinity levels, and the potential associated effects in surface waters.

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, 2004). The MRL for acute and chronic oral exposure to iodide is 0.01 milligrams per kilogram-day (mg/kg-day) based on endocrine effects (ATSDR, 2019a).

While iodide's direct toxicity is relatively low, toxicity associated with iodine's contribution to DBP formation in drinking water treatment and distribution systems can be greater. DBPs are a broad class of compounds, some of which have toxic properties, that form as byproducts of drinking water disinfection. Iodine in source water becomes reactive during chlorine-, chlorine dioxide-, chloramine, or UV-based disinfection and combines 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; 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

[8] Addition rates are reported to range from 1-30 ppm and are typically less than 10 ppm (Gadgil, 2016; ICAC, 2019; Sjostrom et al., 2016).
[9] The highest measured levels reflect influence of irrigation water return flows in arid areas.

contribute to I-DBP formation during drinking water disinfection (Ackerson et al., 2018; Dong et al., 2019; Duirk et al., 2011; 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 generally been found to increase with 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).[10]

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; 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 Section 2.1.2), additional 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). I-DBPs can also affect drinking water aesthetics by creating medicinal flavors and odors that are detectable at low concentrations (Cancho et al., 2000 and 2001; Hansson et al., 1987).

The MCLs and MCLGs listed in Table 2-1 do not include limits for I-DBPs in drinking water. As noted in Section 2.1.2, the current limits address a subset of DBPs and are indicators for control of total DBPs, of which more than 600 individual species have been identified to date (Richardson and Postigo, 2011; U.S. EPA, 2006 and 2016a).

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., 2012), they have the potential to generate I-DBPs when their source waters contain iodine. DWTPs are not required to monitor I-DBP levels in treated water and may not be aware of the presence of I-DBPs in their systems (Tugulea et al., 2018). As DWTPs take steps to decrease concentrations of regulated DBPs, their actions may or may not reduce I-DBP levels, depending on the nature of the process change (Criquet et al., 2012; Dong et al., 2019; Gruchlik et al., 2015; Hua and Reckhow, 2007; Krasner, 2009; Li and Mitch, 2018; McGuire et al., 2014; Tugulea et al., 2018; U.S. EPA, 2016a).

In addition to their formation in DWTPs, I-DBP formation has been documented in POTWs and other wastewater treatment facilities that disinfect iodine-containing waters prior to discharge (Gong and Zhang 2015; Hladik et al., 2014 and 2016). A subset of coal-fired power plants discharges to POTWs (U.S. EPA, 2019a). Discharges from the treatment facilities to surface waters could contribute to elevated I-DBP levels in downstream surface waters, drinking water sources, and aquatic ecosystems. The toxicity of I-DBPs to organisms has been documented in

[10] Additional 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.

laboratory settings but has not yet been characterized in natural aquatic environments (Hanigan et al., 2017; Hladik et al., 2016).

There is limited information available on the presence of iodine in the waste streams addressed in this proposal, therefore it was not included in this analysis.

2.2 SUPPLEMENTAL LITERATURE REVIEW ON ENVIRONMENTAL IMPACTS OF OTHER POLLUTANTS IN DISCHARGES OF THE EVALUATED WASTESTREAMS

This section summarizes the new information identified in the supplemental literature review on environmental impacts caused by exposure to pollutants in discharges of the evaluated wastestreams other than TDS, bromine, and iodine (which are described in Section 2.1). According to the recently published peer-reviewed studies summarized below, discharges from coal-fired power plants have the potential to cause or contribute to ecological impacts including lethal impacts, such as fish kills, and sublethal impacts, such as teratogenic deformities, oxidative stress, deoxyribonucleic acid (DNA) damage, and genotoxicity (Brandt et al., 2017; Javed et al., 2016; Lemly, 2018). Additional information on ecological impacts, human health effects, and documented cases of water quality impacts from coal-fired power plants can be found in Section 3.3 of the 2015 Final EA. This section discusses the findings of three additional studies identified in the supplemental literature review.

Lemly (2018) investigated selenium pollution from the E.W. Brown Electric Generating Station in Herrington Lake, Kentucky, where coal ash wastewater discharged from ash disposal ponds led to elevated selenium concentrations in water, sediment, benthic macroinvertebrates, and fish tissue. The study found selenium levels two to nine times higher than the level that is toxic to fish reproduction and survival (i.e., toxic thresholds of 1.5 micrograms per liter (µg/L) in water, 2 micrograms per gram (µg/g) in sediment, and 3 µg/g in macroinvertebrates) (Hamilton, 2003; Lemly, 2002 and 2018; Peterson and Nebeker, 1992; U.S. EPA, 2016b). The study collected and examined juvenile largemouth bass (*Micropterus salmoides*) and found that 12.2 percent displayed teratogenic deformities, including spinal, craniofacial, and fin deformities. The abnormality rate is 25 times the background abnormality rate (0.5 percent). Background abnormalities consist of only minor fin deformities. The occurrences of morphological abnormalities and toxic levels of selenium in fish tissue confirm that coal ash discharges into Herrington Lake are contributing to unacceptable toxicity in fish tissue. The study findings were consistent with a previous study, conducted by the State of Kentucky in 2016 (KDEP, 2016), in which mature bluegill (*Lepomis macrochirus*) and mature largemouth bass were collected from Herrington Lake and analyzed for toxic effects. The KDEP (2016) study reported whole-body selenium concentrations that exceeded biological effects thresholds. Nine out of the ten sampled fish exceeded the EPA's national ambient water quality criterion of 8.5 milligrams of selenium per kilogram (mg/kg) of whole-body fish tissue (U.S. EPA, 2016c).

Brandt et al. (2017) examined the impacts of selenium on freshwater ecosystems associated with effluent discharges from coal-fired power plants. 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. The study evaluated selenium samples from six North Carolina lakes between 2010 and 2015. Three of the lakes received current or historical selenium discharges from coal-fired power plants and the other three lakes did not receive selenium discharges from coal-fired power plants (i.e., they were reference lakes[11] that corresponded to each of the impacted lakes). Sutton Lake, which received the highest selenium loading during the study period, had the highest level of selenium in aquatic organism tissues.[12] The study found that 85 percent of fish had muscle selenium concentrations exceeding the EPA's fish tissue-specific criterion of 11.3 mg/kg and 31 percent had ovary/egg selenium concentrations exceeding the criterion of 15.1 mg/kg. Fish tissue samples from Mayo Lake showed that 27 percent of fish had selenium concentrations exceeding the criterion and no ovary/egg concentrations exceeding the criterion. Fish tissue and ovary/egg selenium concentrations were significantly[13] elevated in fish from all three lakes receiving historical or current effluent discharges from coal-fired power plants relative to those from their corresponding reference lakes.

The literature also documented heavy metals originating from coal-fired power plant discharges as being responsible for oxidative stress and genotoxicity in receiving water fish species. Javed et al. (2016) collected the spotted snakehead (*Channa punctatus*) as a bioindicator species to evaluate the impact of metal discharges on aquatic species. Javed et al. (2016) noted in the study's introduction that before an increase in the power plant's capacity in the 1970s, the receiving water (a canal in Kasimpur, India) had a diverse fish population. Following an increase in effluent discharges, numerous species disappeared. The author did not identify any studies that examined whether the power plant was the cause of the species loss. Their study evaluated fish tissue samples for metal concentrations (chromium, cobalt, copper, iron, manganese, nickel, and zinc) and fish biomarkers.[14] Iron was highly bioavailable and accumulated in the liver, kidney, muscle, and integument of the fish. Biomarkers showed oxidative stress and DNA damage in fish tissues. The kidney was the most impacted organ, while muscle tissue was the least impacted. DNA damage was observed at statistically significant levels in the fishes' gill cells and liver. Evaluation of fish tissue appropriate for human consumption found that manganese fell above the WHO benchmark of 1 mg/kg (Javed et al., 2016).

[11] The reference lakes are control locations that represent "natural" selenium introduction into the environment.
[12] Collected aquatic organisms included largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), and redbreast sunfish (*Lepomis auritus*).
[13] The exception was two cases (both ovary/egg selenium concentrations comparisons) in which the count of fish collected was insufficient to establish a statistical difference.
[14] Biomarkers included lipid peroxidation (LPO), superoxide dismutase (SOD), catalase (CAT), glutathione S transferase (GST), reduced glutathione (GSH), and DNA damage (Javed et al., 2016).

SECTION 3
OVERVIEW OF METHODOLOGY FOR THE SUPPLEMENTAL QUANTITATIVE ENVIRONMENTAL ASSESSMENT

This section provides an overview of the EPA's methodology for quantitatively evaluating the environmental and human health effects of discharges of the evaluated wastestreams to surface waters.

3.1 IMPACT AREAS SELECTED FOR QUANTITATIVE ASSESSMENT

An exposure pathway is the route a pollutant takes from its source (e.g., an emission stack or wastewater outfall) to its endpoint (e.g., a surface water), and how receptors (e.g., wildlife or people) can come into contact with it. This Supplemental EA focused the quantitative analysis on the surface water exposure pathway and evaluated the pollutant loadings and impacts associated with two wastestreams: flue gas desulfurization (FGD) wastewater and bottom ash transport water.

The EPA focused its quantitative assessment on the following wildlife and human health impacts caused by discharges of the evaluated wastestreams to surface waters under baseline (i.e., following full implementation of the 2015 rule) and the potential changes in those impacts under each of the four 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) standard for the consumption of water and organisms and 2) 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, the 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

(LECR) 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 (ADD) of a pollutant exceeds the oral reference dose (RfD) for that pollutant.

The EPA performed this quantitative assessment using the Immediate Receiving Water (IRW) Model, described later in this section. Appendices C, D, and E of this report and Section 5 of the 2015 Final EA (U.S. EPA, 2015a) provide additional details on the IRW Model and the water quality, wildlife, and human health benchmark values selected for use in the evaluation of environmental effects.

The 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 changes in human bladder cancer risk resulting from consumption of treated drinking water with elevated levels of brominated disinfection byproducts. The methodology and results of these analyses are presented in the BCA Report (U.S. EPA, 2019b). All analyses compare changes from the proposed rule to changes from the 2015 rule.

3.2 Scope of Evaluated Plants and Immediate Receiving Waters

The EPA estimates that 550 coal-fired generating units operated at 284 power plants are subject to this proposed rule. This does not include generating units and plants that are expected to retire or convert to non-coal fuels by December 31, 2028. The EPA limited the scope of the Supplemental EA to the 112 coal-fired power plants that will discharge one or both of the evaluated wastestreams directly or indirectly to surface waters under baseline and/or the regulatory options.[15] The Supplemental TDD (U.S. EPA, 2019a) describes how the EPA updated the industry profile to reflect changes since the 2015 rule, including an assessment of impacts of other regulations affecting steam electric power plants, such as the Coal Combustion Residual (CCR) Rule.

The IRW Model, which excludes discharges to the Great Lakes and estuaries, encompasses 105 coal-fired power plants that discharge to 106 immediate receiving waters.[16] 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 3-1 presents the number of coal-fired power plants, generating units, and immediate receiving waters evaluated in this Supplemental EA. Figure 3-1 shows the locations of the immediate receiving waters evaluated in this Supplemental EA and indicates those that are included in the IRW modeling. See the memorandum "Receiving Waters Characteristics

[15] Of the 112 plants in the Supplemental EA, 108 plants discharge directly to surface water and four plants discharge indirectly to a publicly owned treatment works (POTW).

[16] Two of the 105 plants discharge to more than one immediate receiving water, while one modeled immediate receiving water receives discharges from multiple plants.

Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019d) for the list of immediate receiving waters and for details regarding the EPA's methodology for identifying the immediate receiving waters.

The number of evaluated coal-fired power plants and generating units, and the number of the associated immediate receiving waters, vary across baseline and the four regulatory options. 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 preamble for details). Table 3-2 presents the number of plants, generating units, and immediate receiving waters with nonzero pollutant loadings under baseline and each regulatory option.

3.3 Pollutant Loadings for the Evaluated Wastestreams

To support the quantitative evaluation of environmental impacts via the surface water exposure pathway, the EPA calculated plant-specific *baseline* and *post-compliance* pollutant loadings (in pounds per year) for FGD wastewater and bottom ash transport water being discharged to surface water or through publicly owned treatment works (POTWs) to surface water. The EPA estimated baseline pollutant loadings for these two wastestreams based on the requirements established in the 2015 rule (i.e., baseline assumes full compliance with the 2015 rule), whereas the post-compliance loadings represent full implementation of the regulatory options across all steam electric power plants subject to the requirements of the proposed rule. The Supplemental TDD describes how the EPA calculated estimates of the baseline and post-compliance pollutant loadings for each evaluated wastestream.

Four plants reported transferring wastewater to a POTW rather than discharging directly to surface water. For these plants, the EPA adjusted the baseline and post-compliance loadings to account for pollutant removals expected during treatment at the POTW for each analyte.

Section 4.1 of this report presents the industry-wide annual baseline pollutant loadings for FGD wastewater and bottom ash transport water, and the post-compliance pollutant changes (relative to baseline) for each of the four regulatory options. The plant-specific annual loadings were used throughout the analyses described in the remainder of this section. The Supplemental EA did not evaluate the impacts of any discharges other than the two evaluated wastestreams; therefore, the pollutant loadings and subsequent quantitative analyses do not represent a complete assessment of environmental impacts from coal-fired power plants.

Table 3-1. Plants, Generating Units, and Immediate Receiving Waters Evaluated in the Supplemental EA

Category	Number Evaluated in Pollutant Loadings Analysis, Downstream Analysis, and Proximity Analysis	Subset Also Evaluated in IRW Model
Coal-Fired Power Plants	112	105
Coal-Fired Generating Units	254	239
Immediate Receiving Waters		
River/Stream	88	88
Lake/Pond/Reservoir	18	18
Great Lakes	5	--
Estuary/Bay/Other	1	--
Total Immediate Receiving Waters	**112**	**106**

Source: ERG, 2019d and 2019e.

Table 3-2. Plants, Generating Units, and Immediate Receiving Waters with Pollutant Loadings under Baseline and Four Regulatory Options

Category	Baseline	Option 1	Option 2	Option 3	Option 4	Any Scenario
Pollutant Loadings, Downstream, and Proximity Analyses [a]						
Coal-Fired Power Plants	69	111	97	95	70	112
Coal-Fired Generating Units	164	250	219	220	159	254
Immediate Receiving Waters	69	111	96	94	69	112
Subset Also Evaluated in IRW Model [a,b]						
Coal-Fired Power Plants	66	104	90	88	65	105
Coal-Fired Generating Units	156	235	204	205	148	239
Immediate Receiving Waters	66	105	90	88	64	106

Source: ERG, 2019e.

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 – The EPA updated the pollutant loadings data set after the completion of the quantitative analyses in this Supplemental EA. The final industry loadings calculated using these revised data sets are presented in the Supplemental TDD and Section 4.1 of this report. However, the EPA did not rerun the proximity analyses and IRW Model to reflect the updated loadings data sets. See the memorandum "Pollutant Loadings Analysis and Supporting Documentation for the 2019 Steam Electric Environmental Assessment" (ERG, 2019e) for more information.

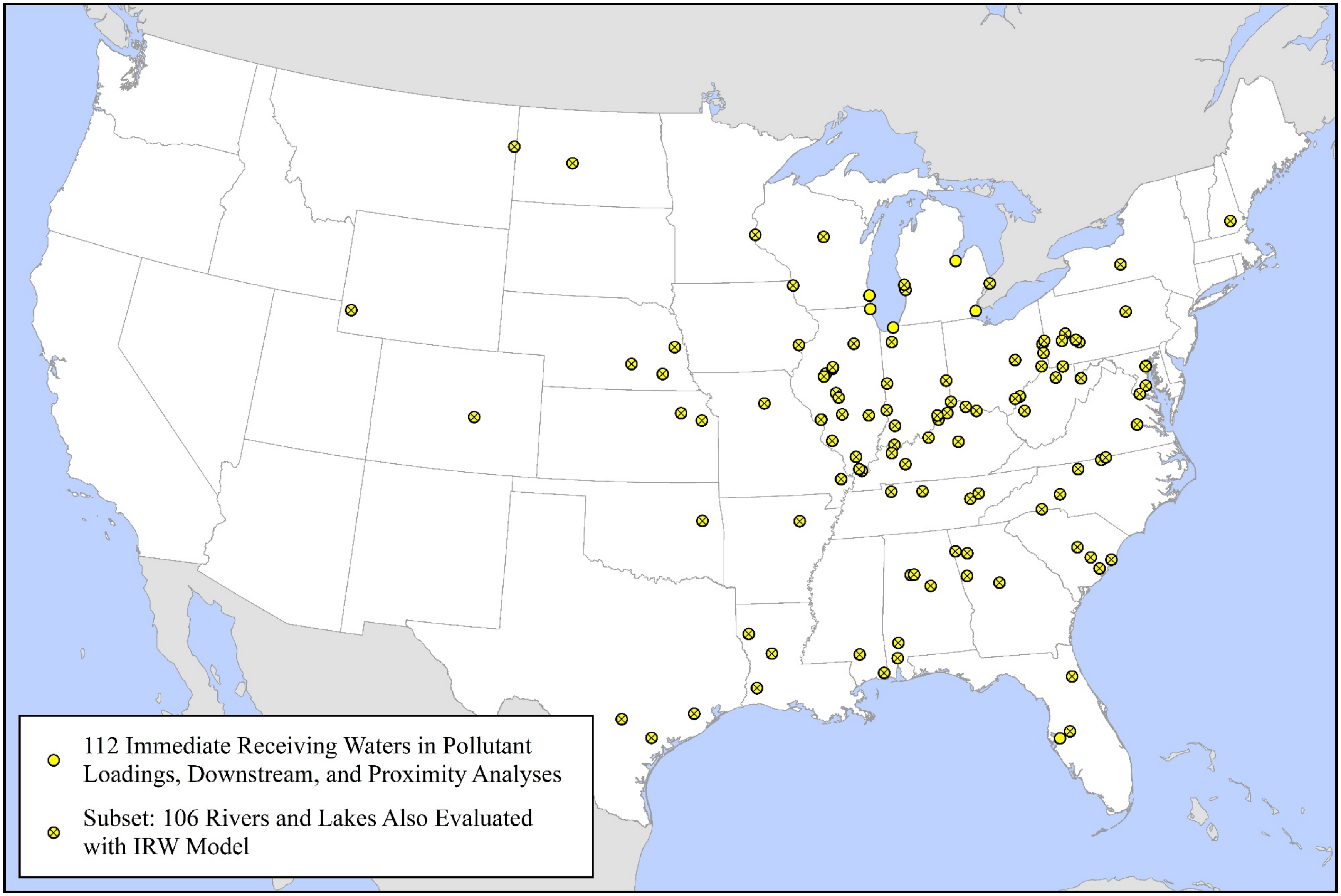

Figure 3-1. Locations of Immediate Receiving Waters Evaluated in the Supplemental EA

In addition to calculating estimated plant-specific baseline and post-compliance pollutant loadings, the EPA also calculated pollutant loadings to represent *current industry practices* conditions for FGD wastewater and bottom ash transport water. These loadings represent the continued use of the existing technologies at each plant, and do not assume compliance with the discharge limits promulgated in the 2015 rule. The memorandum "Pollutant Loadings Associated with Current Discharges of FGD Wastewater and Bottom Ash Transport Water" (ERG, 2019f) describes the EPA's methodology for calculating the current industry practices loadings for each evaluated wastestream. The EPA used these estimated loadings to assess the potential for continuing impacts that could occur due to factors including delayed compliance deadlines for selected regulatory options; discharges from generating units or plants that are subcategorized out of a regulatory option; and discharges from plants that elect to participate in the Voluntary Incentives Program (VIP).[17]

The memorandum "Pollutant Loadings Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" provides additional documentation of the Supplemental EA loadings analyses (ERG, 2019e).

3.4 OVERVIEW OF IMMEDIATE RECEIVING WATER (IRW) MODEL

The EPA used the IRW Model to complete the quantitative assessment of potential wildlife and human health impacts described in Section 3.1. The EPA used the same IRW Model described in the 2015 Final EA and incorporated updates to selected parameters and benchmark values, as documented in Appendices C, D, and E.

The IRW Model evaluates impacts within the immediate surface water[18] where discharges occur. Section 4.2 presents the results of the IRW Model analyses based on baseline and post-compliance pollutant loadings for the two evaluated wastestreams.

[17] As described in the preamble for the proposed rule, the EPA is proposing a VIP as part of each regulatory option except Option 4. The VIP establishes more stringent effluent limitations, based on membrane filtration, for FGD wastewater in exchange for additional time to comply with those limitations because the membrane technology is not currently available nationwide and therefore is not the BAT for this proposed rule. Plants electing to participate in the VIP would be granted additional time (until December 31, 2028) to meet these more stringent limitations. This time extension would allow the technology to become available on a nationwide basis and allow plants more time to conduct pilot testing, demonstrations, and further analyses associated with implementing a new technology.

[18] The length of the immediate receiving water, as defined in the National Hydrography Dataset Plus (NHDPlus) Version 2, generally ranges from approximately 1 to 5 miles; the longest immediate receiving water is 9.1 miles. The upstream and downstream boundaries are defined in NHDPlus Version 2, and each coal-fired power 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 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019g) for details on the immediate discharge zone and length of stream reach represented at each discharge location.

3.4.1 Structure of the IRW Model

The IRW Model has three interrelated modules: a Water Quality Module, a Wildlife Module, and a Human Health Module, which are described in further detail below. Figure 3-2 provides an overview of the IRW Model inputs and the connections among the three modules to support the EPA's modeling framework. Appendices C, D, and E 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 Final EA provides additional information on the IRW Model, including a detailed discussion of the equilibrium-partition modeling methodology used in the Water Quality Module.

- *Water Quality Module*. This module uses plant-specific input data (annual average pollutant loadings and cooling water flow rates) and surface water-specific characteristic 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 (NRWQCs and MCLs) as an indicator of potential impacts on aquatic life and human health. The EPA supplemented these annual average outputs by modeling the water column pollutant concentrations during best-case months (low loadings and high flow rates, resulting in greater dilution) and worst-case months (high loadings and low flow rates, resulting in less dilution) and comparing the results to the NRWQCs and MCLs.[19]
- *Wildlife Module*. This 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.[20] 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)[21] and piscivorous wildlife (NEHCs). The EPA selected minks and eagles as representative piscivorous wildlife that consume T3 and T4 fish, respectively.
- *Human Health Module*. This module uses the fish tissue concentrations from the Wildlife Module to calculate non-cancer and cancer risks to human populations from

[19] Data regarding actual monthly loadings were not available for this analysis. Therefore, the EPA estimated monthly loadings using monthly net electricity generation data at the coal-fired generating unit level as an indicator of monthly discharges of the evaluated wastestreams. Using monthly flow rate data for each immediate receiving water from NHDPlus Version 2, the EPA then identified the months that would produce the lowest (best-case) and highest (worst-case) ratios of pollutant loadings to flow rates for each immediate receiving water and performed water quality modeling for those selected months. See the memorandum "Monthly Water Quality Modeling Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019j) for further details.

[20] 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.

[21] 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.

consuming fish that are caught from contaminated receiving waters. The EPA performed this analysis using two sets of fish consumption rates:[22]

- 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 individuals who rely on self-caught fish for a larger share of their food intake as compared to recreational fishers.
- A data set with consumption rates for recreational and subsistence fishers in different race categories (Non-Hispanic White; Non-Hispanic Black; Mexican-American; Other Hispanic; and Other, including Multiple Races). The EPA used this data set in an Environmental Justice analysis to evaluate whether the post-compliance change in human health impacts (relative to baseline) will disproportionately impact minority groups.

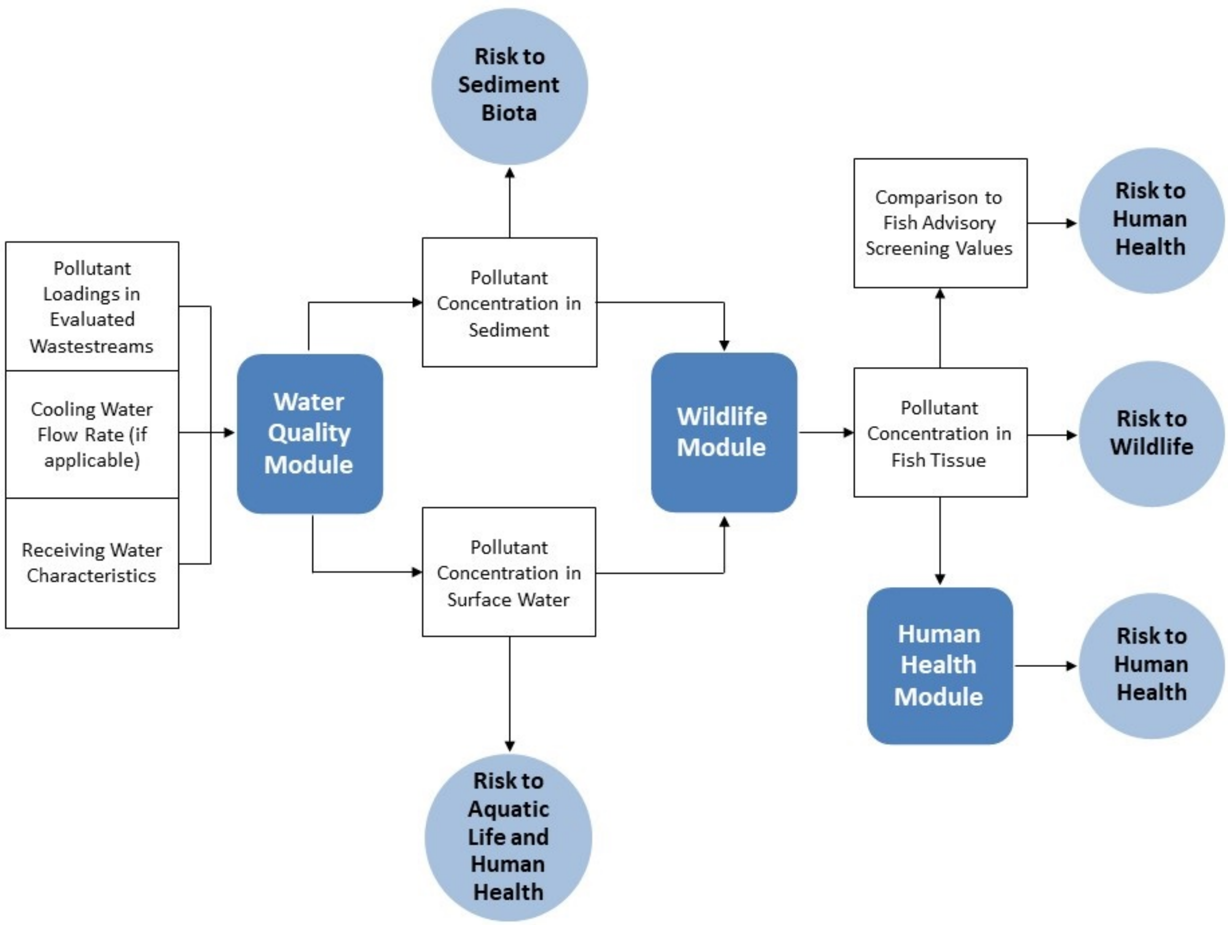

Figure 3-2. Overview of IRW Model

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

The EPA also assessed the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories, thereby posing a human health risk. The EPA compared the T4 fish tissue concentrations from the Wildlife Module to fish consumption advisory screening values. Screening values are defined as 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 these 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).[23]

3.4.2 Pollutants Evaluated by IRW Model

In the 2015 Final EA, the EPA focused the IRW Model quantitative analyses on 10 toxic pollutants, all of which can bioaccumulate in fish and impact wildlife and human receptors via fish consumption. These pollutants were arsenic, cadmium, hexavalent chromium (chromium VI), copper, lead, mercury, nickel, selenium, thallium, and zinc. Sections 4.1.2 and 5.1.1 of the 2015 Final EA provide additional discussion on the selection of these pollutants for evaluation using the IRW Model.

For the Supplemental EA, the EPA evaluated the same ten pollutants with the exception of chromium VI (the analytical data sets for the evaluated wastestreams do not include concentration data for chromium VI). The Supplemental TDD describes the EPA's methodology for estimating baseline and post-compliance pollutant loadings for each evaluated wastestream.

As was the case with the 2015 Final EA, the Supplemental EA did not use water quality modeling to assess the impacts associated with discharges of total dissolved solids (TDS), bromides, chlorides, or nutrients (total nitrogen and total phosphorus). These pollutants were excluded from the IRW Model analyses primarily because of the limited availability of national-level numeric water quality, wildlife, and human health benchmark values for comparison with the model outputs. The 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).

3.5 DOWNSTREAM ANALYSIS

As part of the economic benefits analysis, the 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 FGD wastewater or bottom ash transport water. See the BCA Report for a detailed discussion of the D-FATE model and the analysis, which uses annual average pollutant loadings and surface water flow rates.

For this Supplemental EA, the 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 post-compliance loadings. The EPA used this approach to estimate the extent (in river miles) of

[23] See the memorandum "IRW Model: Water Quality, Wildlife, and Human Health Analyses and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019k) for documentation of the fish advisory screening level analysis.

impacts in downstream surface waters under baseline and the changes in these impacts under the four regulatory options. Results are presented in Section 4.3 of this report. See the memorandum "Downstream Modeling Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019g) for details regarding the methodology for this analysis.

3.6 Proximity Analysis for Impaired Waters and Fish Consumption Advisory Waters

As was the case with the 2015 Final EA, the EPA performed a proximity analysis to identify:

- Immediate receiving waters that states, territories, and authorized tribes have identified, pursuant to Section 303(d) of the Clean Water Act, as impaired waterbodies that can no longer meet their designated uses (e.g., drinking, recreation, and aquatic habitat) due to pollutant concentrations that exceed water quality standards. These impaired waterbodies are also known as "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.

Section 4.4 of this report presents the results of the proximity analysis. See the memorandum "Proximity Analyses and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019h) for a description of the proximity analysis methodology.

The EPA also performed further spatial analyses to identify public drinking water supply intakes downstream from discharges of FGD wastewater and/or bottom ash transport water. See the BCA Report regarding the methodology and results of that analysis.

SECTION 4
RESULTS OF THE SUPPLEMENTAL QUANTITATIVE ENVIRONMENTAL ASSESSMENT

This section presents the estimated pollutant loadings in flue gas desulfurization (FGD) wastewater and bottom ash transport water discharges—the evaluated wastestreams—under baseline, the estimated pollutant loading changes associated with each of four regulatory option scenarios, and the results of the quantitative analyses described in Section 3, which include the following:

- Use of the 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; 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 those estimated concentrations and estimated exposure doses to various benchmark values as indicators of potential water quality, wildlife, and human health impacts (including Environmental Justice (EJ) concerns associated with differential fish consumption rates).
  - Evaluate the estimated changes in those impacts under the regulatory option scenarios.
  - Perform a supplemental "best-case" and "worst-case" monthly water quality analysis.
- 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 option scenarios.
- A proximity analysis to identify immediate receiving waters that are designated as Clean Water Act 303(d)-listed impaired waterbodies or have been issued fish consumption advisories.

The BCA Report (U.S. EPA, 2019b) discusses the EPA's evaluation of other impacts that were not quantified in this Supplemental EA.

4.1 ESTIMATED POLLUTANT LOADINGS FOR THE EVALUATED WASTESTREAMS

As discussed in the preamble for the proposed rule, the EPA evaluated four regulatory options for the proposed revisions to the 2015 rule. The controls of these four options differ in stringency and in their applicability to coal-fired power plants and generating units, based on each entity's wastestream, generation capacity, net power generation, and wet FGD scrubber flow. The EPA estimated the pollutant loadings for baseline (2015 rule conditions) and each regulatory option, as well as changes in pollutant loadings associated with coal-fired power plants to achieve compliance for each of the main regulatory options. This section discusses estimated annual pollutant loadings in the discharges of the evaluated wastestreams from coal-fired power plants under baseline and each regulatory option evaluated for the proposed revisions to the 2015 rule.

Under baseline, the EPA estimates that the coal-fired power plant industry annually discharges more than 1,670,000,000 pounds of pollutants in the evaluated wastestreams to surface waters, either directly or via publicly owned treatment works (POTWs). Under the proposed regulatory option (Option 2), the EPA estimates that, once all plants in scope have implemented the provisions of Option 2, this figure will decrease by 104,000,000 pounds (6.2 percent) relative to the 2015 rule baseline. Table 4-1 presents the estimated total industry pollutant loadings, in pounds per year, for baseline and estimated pollutant loadings changes for each regulatory option. The EPA estimated the changes in pollutant loadings by subtracting the baseline loadings from the post-compliance loadings. The memorandum "Pollutant Loadings Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019e) discusses the EPA's methodology for estimating total industry pollutant loadings for baseline and each regulatory option.

Table 4-1. Estimated Industry-Level Pollutant Loadings and Estimated Change in Loadings by Regulatory Option

Regulatory Option	Estimated Total Industry Pollutant Loading (lb/year)	Estimated Change in Total Industry Pollutant Loadings (lb/year) [a]
Baseline	1,670,000,000	--
1	1,680,000,000	13,400,000
2	1,560,000,000	-104,000,000
3	1,390,000,000	-276,000,000
4	342,000,000	-1,320,000,000

Source: ERG, 2019e.

Note: Pollutant loadings values are rounded to three significant figures.

a – Negative values represent an estimated decrease in loadings to surface waters compared to baseline. Positive values represent an estimated increase in loadings to surface waters compared to baseline.

The pollutants with the greatest estimated reductions in annual mass loadings under Option 2 are total dissolved solids (TDS) (105,000,000 lb/yr decrease relative to baseline), chloride (35,200,000 lb/yr decrease), magnesium (23,400,000 lb/yr decrease), bromide (13,400,000 lb/yr decrease), calcium (4,800,000 lb/yr decrease), and boron (1,450,000 lb/yr decrease). However, loadings for 27 out of 37 pollutants for which the EPA calculated loadings, including the bioaccumulative pollutants and metals (except thallium) modeled in the IRW Model, will have slightly higher loadings under Option 2 relative to baseline.[24]

[24] Under Option 2, the EPA estimates that some plants will decrease FGD wastewater pollutant loadings by recycling FGD wastewater (reducing total flow of FGD wastewater discharged), installing the Option 2 technology basis, or by participating in the VIP (installing membrane filtration). Other plants are estimated to have increases in total pollutant loadings, based on new proposed subcategories and the proposed purge option for bottom ash transport water.

This Supplemental EA and the 2015 Final EA (U.S. EPA, 2015a) focus on a subset of the pollutants for which the EPA calculated loadings. Table 4-2 presents estimated pollutant loadings under baseline and pollutant loadings changes for each of the regulatory options for this subset of pollutants. The memorandum "Pollutant Loadings Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019e) discusses the EPA's methodology for estimating pollutant loadings for each immediate receiving water and presents pollutant loadings under baseline and net change associated with each of the regulatory options for all 37 pollutants for which EPA calculated loadings.

Table 4-2. Estimated Annual Baseline Mass Pollutant Loadings and Estimated Change in Loadings Under Four Regulatory Options for the Evaluated Wastestreams (Supplemental EA Subset of Pollutants)

Pollutant	Estimated Baseline Pollutant Loadings (lb/yr)	Estimated Change in Pollutant Loadings Relative to Baseline (lb/yr) [a]			
		Option 1	Option 2	Option 3	Option 4
Aluminum	9,060	8,780	58,000	7,340	2,200
Arsenic	407	95.7	599	25.7	-225
Boron	15,500,000	54,600	-1,450,000	-2,650,000	-12,400,000
Bromide	32,200,000	52,500	-13,400,000	-15,000,000	-29,200,000
Cadmium	302	7.41	15.8	-43.1	-223
Chloride	492,000,000	3,300,000	-35,200,000	-82,200,000	-392,000,000
Chromium	447	52.2	299	-25.1	-302
Copper	264	40.6	242	-4.78	-167
Iron	8,290	6,950	46,400	5,620	839
Lead	240	107	693	66.3	-79.2
Magnesium	233,000,000	573,000	-23,400,000	-40,000,000	-187,000,000
Manganese	870,000	1,570	-90,500	-149,000	-688,000
Mercury	4.50	6.55	8.30	1.63	-0.543
Nickel	554	355	1,220	142	-130
Nitrogen, Total [b]	530,000	5,970,000	1,900,000	1,220,000	897,000
Phosphorus, Total	22,200	2,280	12,900	-1,560	-15,400
Selenium	547	57,900	18,400	12,500	12,200
TDS	1,660,000,000	13,200,000	-105,000,000	-276,000,000	-1,320,000,000
Thallium	675	11.7	-0.561	-106	-529
Vanadium	880	104	607	-47.5	-596
Zinc	1,560	347	2,180	108	-749
Total [c]	**775,000,000**	**10,000,000**	**-71,600,000**	**-139,000,000**	**-620,000,000**

Source: ERG, 2019e.

Acronyms: lb/yr (pounds per year); TDS (total dissolved solids).

Note: Pollutant loadings values are rounded to three significant figures.

a – Negative values represent an estimated decrease in loadings to surface waters compared to baseline. Positive values represent an estimated increase in loadings to surface waters compared to baseline.

b – Total nitrogen loadings are the sum of ammonia and total Kjeldahl nitrogen (TKN) for FGD wastewater and the sum of nitrate-nitrite (as N) and TKN for bottom ash transport water.

c – Represents the summed loadings for the subset of pollutants focused on in the Supplemental EA, excluding TDS. Pollutant loadings exclude TDS to avoid double-counting mass.

Table 4-2 presents estimated changes in pollutant loadings that would be achieved after industry-wide implementation of the control technologies needed to comply with any applicable effluent limitations at each plant. Implementation timing for each plant varies by regulatory option, wastestream, subcategorization, and the plant's permit renewal schedule. Plants would implement bottom ash transport water control technologies no later than December 31, 2023. Plants would implement FGD control technologies by December 31, 2023 under Option 1; by December 31, 2025 under Options 2 and 3; and by December 31, 2028 under Option 4. Under Options 1, 2, and 3, plants participating in the Voluntary Incentives Program (VIP) may implement FGD wastewater controls by December 31, 2028.[25] See the preamble for further discussion of the regulatory options and associated compliance deadlines.

Due to the differing compliance timelines for individual wastestreams and plants, the net change in pollutant loadings and corresponding environmental changes will be staggered over time as the plants implement control technologies. The Supplemental EA estimates post-compliance environmental changes associated with each regulatory option using steady-state annual average pollutant loadings reflecting full implementation of the effluent limitations. Therefore, the results of the Supplemental EA may underestimate short-term environmental impacts for the period prior to full implementation of the regulatory options during which plants transition from current discharges to discharges associated with full implementation.

4.2 KEY IMPACTS IDENTIFIED BY 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 coal-fired power plants.[26] See Section 3 of this document and Appendices C, D, and E for detailed discussions of the IRW Model's structure.

The following sections present the results from each module. The results identify modeled exceedances of water quality, wildlife, and human health benchmark values under baseline and the net changes in those exceedances under each regulatory option.[27] Appendix F includes additional IRW Model outputs.

4.2.1 Water Quality Module

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

[25] The EPA estimates that 18 of 70 coal-fired power plants discharging FGD wastewater (26 percent) may conclude that the VIP for FGD wastewater under Option 2 is the least costly option. The Supplemental TDD describes how the EPA estimated which technology would be the least costly for each plant.
[26] The Supplemental EA encompasses a total of 112 immediate receiving waters and loadings from 112 coal-fired power plants (some of which discharge to multiple receiving waters). The IRW Model, which excludes the Great Lakes and estuaries, analyzes a total of 106 immediate receiving waters and loadings from 105 coal-fired power plants.
[27] The net change represents the change in benchmark value exceedances under each regulatory option relative to baseline. Under Regulatory Options 2, 3, and 4, there are scenarios where some receiving waters no longer have exceedances observed at baseline, and other immediate receiving waters have "new" exceedances. For example, under Regulatory Option 4, increased discharges of bottom ash transport water result in a net increase in exceedances despite the incorporation of membrane treatment for FGD wastewater.

to the National Recommended Water Quality Criteria (NRWQC) and drinking water maximum contaminant levels (MCLs) under baseline and each regulatory option. 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. Table 4-3 summarizes the Water Quality Module results.

Table 4-3. Modeled IRWs with Exceedances of NRWQCs and MCLs under Baseline and Four Regulatory Options

Water Quality Evaluation Benchmark	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Freshwater Acute NRWQC	0	2 (+2)	0 (0)	0 (0)	0 (0)
Freshwater Chronic NRWQC	0	10 (+10)	3 (+3)	2 (+2)	2 (+2)
Human Health Water and Organism NRWQC	9	20 (+11)	17 (+8)	16 (+7)	13 (+4)
Human Health Organism Only NRWQC	4	9 (+5)	8 (+4)	7 (+3)	7 (+3)
Drinking Water MCL	1	3 (+2)	3 (+2)	2 (+1)	1 (0)
Total Number of Unique Immediate Receiving Waters [b]	**9**	**21 (+12)**	**17 (+8)**	**16 (+7)**	**13 (+4)**

Source: ERG, 2019i.

Acronyms: 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 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

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

Table 4-4 presents the number of immediate receiving waters with exceedances of any NRWQC or MCL by pollutant.

Table 4-4. Modeled IRWs with Exceedances of Any NRWQC or MCL, by Pollutant under Baseline and Four Regulatory Options

Pollutant	Modeled Number of IRWs Exceeding NRWQC or MCL (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Arsenic	9	20 (+11)	17 (+8)	16 (+7)	13 (+4)
Cadmium	0	0 (0)	1 (+1)	0 (0)	0 (0)
Copper	0	0 (0)	1 (+1)	0 (0)	0 (0)
Lead	0	1 (+1)	2 (+2)	1 (+1)	1 (+1)
Mercury	0	0 (0)	0 (0)	0 (0)	0 (0)
Nickel	0	0 (0)	1 (+1)	0 (0)	0 (0)
Selenium	0	10 (+10)	3 (+3)	2 (+2)	2 (+2)
Thallium	4	5 (+1)	4 (0)	3 (-1)	1 (-3)
Zinc	0	0 (0)	0 (0)	0 (0)	0 (0)
Any Pollutant [b]	**9**	**21 (+12)**	**17 (+8)**	**16 (+7)**	**13 (+4)**

Source: ERG, 2019i.

Acronyms: 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 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

b – Total may not equal the sum of the individual values because some immediate receiving waters have exceedances for multiple pollutants.

The Water Quality Module results described above are based on estimated annual average loadings and flow rates. As described in Section 3.4, the EPA also performed a water quality analysis using estimated monthly pollutant loadings (of the same nine pollutants evaluated in the Water Quality Module) and monthly surface water flow rates to assess the significance of monthly variability in the modeled water quality impacts. Table 4-5 presents the number of immediate receiving waters with modeled exceedances of each water quality benchmark for the best-case analysis and exceedances of Freshwater Acute and Chronic NRWQCs for the worst-case analysis.[28]

[28] The EPA did not consider the Human Health Water and Organism NRWQC, Human Health Organism Only NRWQC, and Drinking Water MCL when evaluating worst-case monthly outputs because these benchmark values are based on longer-term (i.e., lifetime) exposure.

Table 4-5. Modeled IRWs with Exceedances of NRWQCs and MCLs under Baseline and Four Regulatory Options: Best- and Worst-Case Monthly Scenarios

Water Quality Evaluation Benchmark	Modeled Number of IRWs Exceeding NRWQC or MCL (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Best-Case Monthly Scenario (Lowest Ratio of Loadings to Flow Rate)					
Freshwater Acute NRWQC	0	0 (0)	0 (0)	0 (0)	0 (0)
Freshwater Chronic NRWQC	0	4 (+4)	1 (+1)	0 (0)	0 (0)
Human Health Water and Organism NRWQC	4	8 (+4)	6 (+2)	6 (+2)	6 (+2)
Human Health Organism Only NRWQC	2	4 (+2)	5 (+3)	4 (+2)	2 (0)
Drinking Water MCL	0	0 (0)	0 (0)	0 (0)	0 (0)
Any Water Quality Evaluation Benchmark [b]	**4**	**8 (+4)**	**6 (+2)**	**6 (+2)**	**6 (+2)**
Worst-Case Monthly Scenario (Highest Ratio of Loadings to Flow Rate)					
Freshwater Acute NRWQC	0	3 (+3)	1 (+1)	0 (0)	0 (0)
Freshwater Chronic NRWQC	2	17 (+15)	8 (+6)	6 (+4)	5 (+3)
Any Water Quality Evaluation Benchmark [b]	**2**	**17 (+15)**	**8 (+6)**	**6 (+4)**	**5 (+3)**

Source: ERG, 2019j.

Acronyms: 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 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

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

The results of the monthly analysis demonstrate some similarities with the results of the annual average analysis:

- Under the worst-case monthly analysis, the total number of immediate receiving waters with exceedances of the Freshwater Chronic NRWQC increases under all options (relative to baseline).
- Total arsenic (for the Human Health Water and Organism NRWQC in the best-case analysis) and total selenium (for the Freshwater Chronic NRWQC in both analyses) remain the primary drivers of the water quality exceedances (ERG, 2019j).

The monthly analysis also provides information beyond that provided by the annual average analysis:

- Most worst-case months occur during the summer, whereas most best-case months occur during the winter and early spring.

- Under the best-case monthly analysis, approximately one-third to one-half of immediate receiving waters with exceedances in the annual average analysis continue to have exceedances of at least one water quality benchmark value.
- Under the worst-case monthly analysis, many receiving waters (more than were identified in the annual average analysis) experience exceedances of the Freshwater Chronic NRWQC. This suggests the potential for impacts on aquatic life during certain periods characterized by low flows, high loadings, or a combination of the two.

These results suggest that seasonal water quality impacts from discharges of the evaluated wastestreams, and their increase under the regulatory options, may be more prevalent than indicated by the annual average analysis (ERG, 2019j).

The EPA evaluated whether there are geographic clusters of immediate receiving waters whose worst-case months occur during the same time of year, indicating the potential for seasonal cumulative effects in the affected watersheds. Figure 4-1 illustrates the worst-case month identified for each immediate receiving water in the supplemental monthly analysis. This shows the following geographic patterns:

- Nearly the entire length of the Ohio River has clusters of immediate receiving waters with worst-case months during July, August, and September.
- The Illinois River has a cluster of immediate receiving waters with worst-case months in September, October, and November.
- Several other parts of the country have smaller clusters of immediate receiving waters with worst-case months during the same season. Examples include the Mobile River watershed in southern Alabama (August); the Wabash River watershed in southwest Indiana (October); and the Santee River watershed in South Carolina (July-September).

The watersheds referenced above are examples of areas that could potentially experience adverse seasonal cumulative effects due to concurrent, or nearly concurrent, discharges of evaluated wastestreams from multiple plants. This dynamic could be particularly pronounced during summer and early autumn. Swimming, fishing, and boating in local waterways are generally more common during these seasons, potentially increasing opportunities for exposure to degraded water quality conditions in the immediate receiving waters.

Additionally, 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. For example, the Northern madtom (*Noturus stigmosus*), a small catfish, lives in tributaries along the Ohio River, including the lower Ohio watershed; it spawns in June and July and is currently listed as endangered in Ohio. Since the Northern madtom spawns during worst-case conditions in the Ohio River watershed, it could experience reduced fecundity and its population could be further compromised by seasonal fluctuations in pollutant loadings from coal-fired power plants.

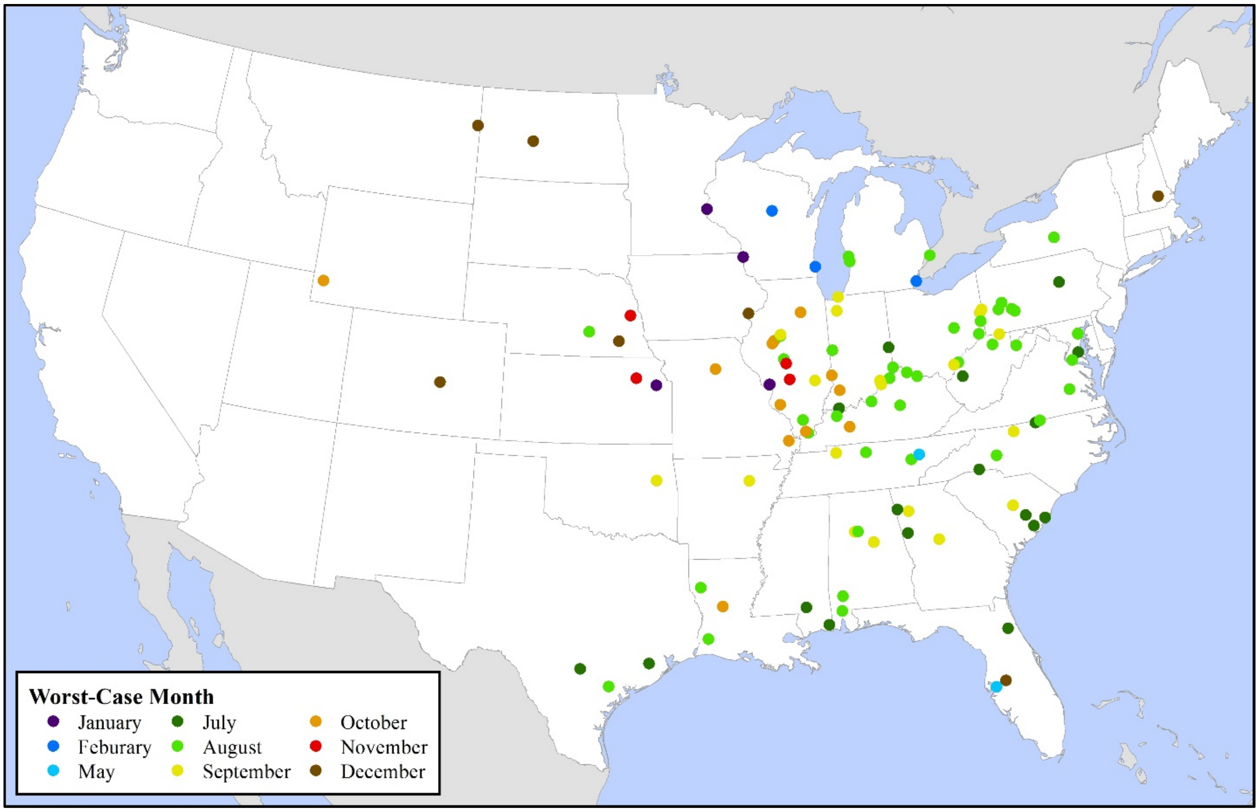

Figure 4-1. Worst-Case Months for Water Quality Conditions in Immediate Receiving Waters

Data regarding actual monthly loadings were not available for this analysis. This analysis is intended only to illustrate that seasonal impacts resulting from discharges of the evaluated wastestreams, and the increase in those impacts under Option 2, may be more extensive than shown in the annual average analysis, and that some watersheds (not necessarily the examples noted in this discussion) could experience increased seasonal impacts depending on the seasonal discharge patterns of coal-fired power plants in those watersheds.

4.2.2 Wildlife Module

The IRW Wildlife Module compares sediment pollutant concentrations to threshold effect concentrations (TECs) for sediment biota; calculates the bioaccumulation of pollutants in trophic level 3 (T3) and trophic level 4 (T4) fish tissue; and compares these tissue concentrations to no effect hazard concentrations (NEHCs) for minks and eagles. This analysis expands on the evaluation of potential wildlife impacts based on the Freshwater Chronic and Acute NRWQCs in the Water Quality Module.

Table 4-6 presents the number of immediate receiving waters with modeled exceedances of the TECs and NEHCs under baseline and changes in those exceedances under the regulatory options. Results are presented for all pollutants in aggregate and individually for selenium and mercury, which cause most of the exceedances.

Table 4-6. Modeled IRWs with Exceedances of TECs and NEHCs under Baseline and Four Regulatory Options

Wildlife Evaluation Benchmark	Pollutant [a]	Modeled Number of IRWs Exceeding TEC or NEHC (Difference Relative to Baseline) [b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Sediment TEC	Any Pollutant	2	20 (+18)	10 (+8)	7 (+5)	6 (+4)
	Nickel	0	3 (+3)	4 (+4)	3 (+3)	2 (+2)
	Selenium	2	20 (+18)	10 (+8)	7 (+5)	6 (+4)
	Mercury	0	5 (+5)	4 (+4)	3 (+3)	2 (+2)
Fish Ingestion NEHC for Minks	Any Pollutant	0	10 (+10)	4 (+4)	2 (+2)	2 (+2)
	Selenium	0	9 (+9)	3 (+3)	1 (+1)	1 (+1)
	Mercury	0	3 (+3)	3 (+3)	2 (+2)	2 (+2)
Fish Ingestion NEHC for Eagles	Any Pollutant	1	11 (+10)	7 (+6)	5 (+4)	3 (+2)
	Selenium	0	9 (+9)	3 (+3)	1 (+1)	1 (+1)
	Mercury	1	6 (+5)	6 (+5)	5 (+4)	3 (+2)
Any Wildlife Pollutant Benchmark for Any Pollutant [b]		**2**	**20 (+18)**	**10 (+8)**	**7 (+5)**	**6 (+4)**

Source: ERG, 2019i.

Acronyms: IRW (immediate receiving water); TEC (Threshold Effect Concentration); NEHC (No Effect Hazard Concentration).

a – Appendix F presents results for all individual modeled pollutants.

b – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

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

4.2.3 Human Health Module

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 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}. This analysis expands on the evaluation of potential human health impacts based on the NRWQCs and MCLs in the Water Quality Module.

Under baseline, the EPA estimates the average daily doses (for one or more pollutants) among subsistence fishers exceed the oral RfDs (non-cancer) in 6 to 8 percent of immediate receiving waters, depending on the age group evaluated. Average daily doses among recreational fishers exceed oral RfDs in 4 to 6 percent of immediate receiving waters. The exceedances are primarily driven by thallium and mercury (as methylmercury). 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 non-cancer health effects on surrounding fisher populations.

The EPA estimates that the number of immediate receiving waters contributing to oral RfD (non-cancer) exceedances increases for all standard cohorts (i.e., cohorts that are not split into different race categories) under all regulatory options. Under Option 2, the EPA estimates that pollutant concentrations in fish tissue increase for all modeled pollutants relative to baseline concentrations. The pollutants that cause increased potential for non-cancer health effects based on oral RfDs are mercury (as methylmercury), selenium, thallium, and, to a lesser degree, cadmium and zinc. For example, the number of immediate receiving waters with methylmercury concentrations that pose a non-cancer risk to humans increases from 3 to 6 percent (under baseline) to 7 to 16 percent (under Option 2), with the specific increase depending on the cohort. Table 4-7 presents the number of immediate receiving waters where the average daily dose of the modeled pollutants exceeds the corresponding oral RfD.

Although the Supplemental EA did not directly assess the potential non-cancer health effects posed by lead,[29] Option 2 increases the annual loadings of lead to the environment by 693 pounds compared to baseline. The monetized human health effects associated with changes in lead discharges are discussed in the BCA Report.

Under baseline, the EPA estimates that none of the immediate receiving waters would contain fish contaminated with inorganic arsenic that present cancer risks greater than the LECR benchmark value of one in one million for the most sensitive, standard cohort. The EPA calculates that all of the regulatory options increase the number of immediate receiving waters containing fish with inorganic arsenic levels that exceed the selected LECR threshold for adult recreational and subsistence fishers. Option 2 also increases the number of exceedances for the child recreational and subsistence fisher cohort. Table 4-8 presents the number of immediate receiving waters where the LECR for inorganic arsenic exceeds one-in-a-million. The BCA Report further discusses the EPA's assessment of potential cancer impacts for human populations.

[29] The EPA has not developed an RfD for lead because adverse health effects "may occur at blood lead levels so low as to be essentially without a threshold" (U.S. EPA, 2004).

Table 4-7. Modeled IRWs with Exceedances of Oral RfD (Non-Cancer Human Health Effects) under Baseline and Four Regulatory Options

Age and Type of Fish Consumption Cohort	Pollutant [a]	Modeled Number of IRWs Exceeding Oral RfD (Difference Relative to Baseline) [b]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Child – Recreational	Any Pollutant	6	15 (+9)	12 (+6)	10 (+4)	8 (+2)
	Mercury (as methylmercury)	5	11 (+6)	10 (+5)	9 (+4)	8 (+3)
	Selenium	0	9 (+9)	3 (+3)	1 (+1)	1 (+1)
	Thallium [c]	6	9 (+3)	8 (+2)	7 (+1)	4 (-2)
Child – Subsistence	Any Pollutant	9	23 (+14)	19 (+10)	14 (+5)	11 (+2)
	Mercury (as methylmercury)	6	19 (+13)	17 (+11)	14 (+8)	11 (+5)
	Selenium	2	16 (+14)	9 (+7)	5 (+3)	3 (+1)
	Thallium [c]	9	14 (+5)	11 (+2)	10 (+1)	7 (-2)
Adult – Recreational	Any Pollutant	4	10 (+6)	7 (+3)	7 (+3)	7 (+3)
	Mercury (as methylmercury)	3	10 (+7)	7 (+4)	7 (+4)	7 (+4)
	Selenium	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
	Thallium [c]	4	6 (+2)	5 (+1)	4 (0)	2 (-2)
Adult – Subsistence	Any Pollutant	6	16 (+10)	12 (+6)	10 (+4)	8 (+2)
	Mercury (as methylmercury)	6	14 (+8)	12 (+6)	10 (+4)	8 (+2)
	Selenium	0	10 (+10)	4 (+4)	2 (+2)	1 (+1)
	Thallium [c]	6	10 (+4)	8 (+2)	8 (+2)	6 (0)
Any Pollutant and Age/Consumption Cohort [d]		**9**	**23 (+14)**	**19 (+10)**	**14 (+5)**	**11 (+2)**

Source: ERG, 2019i.

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

a – Appendix F presents results for each individual modeled pollutant.

b – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

c – The EPA used the chronic oral exposure value cited in U.S. EPA, 2010a for thallium chloride as the RfD.

d – Total may not equal the sum of the individual values because some immediate receiving waters have exceedances for multiple pollutants and/or cohorts.

Table 4-8. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) under Baseline and Four Regulatory Options

Age and Type of Fish Consumption Cohort	Modeled Number of 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)	1 (+1)	0 (0)	0 (0)
Child – Subsistence	0	0 (0)	1 (+1)	0 (0)	0 (0)
Adult – Recreational	0	1 (+1)	2 (+2)	1 (+1)	1 (+1)
Adult – Subsistence	0	1 (+1)	2 (+2)	1 (+1)	1 (+1)
Total Number of Unique Immediate Receiving Waters [b]	**0**	**1 (+1)**	**2 (+2)**	**1 (+1)**	**1 (+1)**

Source: ERG, 2019i.

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

a – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

b – Total may not equal the sum of the individual values because some immediate receiving waters have exceedances for multiple cohorts.

The EPA also performed an Environmental Justice (EJ) analysis, using fish consumption rates for recreational and subsistence fishers in different race categories, to assess whether the post-compliance change in human health impacts (relative to baseline) will disproportionately impact minority groups. Table 4-9 presents the number of immediate receiving waters in which the modeled average daily dose of mercury, selenium, or thallium exceeds the oral RfD. Results are presented by cohort (recreational and subsistence fisher) and race category.

This analysis suggests that the increase in non-cancer human health impacts under all regulatory options may disproportionately affect minority race categories due to their higher fish consumption rates.

Appendix E describes the Human Health Module and Appendix F presents the non-cancer and cancer risk results for each age group (for both standard and EJ cohorts).

Table 4-9. Modeled IRWs with Exceedances of Oral RfD (Non-Cancer Human Health Effects), by Race Category, under Baseline and Four Regulatory Options

Age and Type of Fish Consumption Cohort	Race Category	Modeled Number of IRWs Exceeding Oral RfD (Difference Relative to Baseline) [a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Mercury (as methylmercury)						
Recreational (All age cohorts)	Non-Hispanic White	3	10 (+7)	7 (+4)	7 (+4)	7 (+4)
	Non-Hispanic Black	3	10 (+7)	7 (+4)	7 (+4)	7 (+4)
	Mexican-American	3	11 (+8)	8 (+5)	8 (+5)	8 (+5)
	Other Hispanic	3	10 (+7)	7 (+4)	7 (+4)	7 (+4)
	Other, Including Multiple Races	3	11 (+8)	8 (+5)	8 (+5)	8 (+5)
Subsistence (All age cohorts)	Non-Hispanic White	5	14 (+9)	11 (+6)	10 (+5)	8 (+3)
	Non-Hispanic Black	6	14 (+8)	12 (+6)	10 (+4)	8 (+2)
	Mexican-American	6	16 (+10)	14 (+8)	11 (+5)	9 (+3)
	Other Hispanic	6	16 (+10)	14 (+8)	11 (+5)	9 (+3)
	Other, Including Multiple Races	6	17 (+11)	15 (+9)	12 (+6)	10 (+4)
Selenium						
Recreational (All age cohorts)	Non-Hispanic White	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
	Non-Hispanic Black	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
	Mexican-American	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
	Other Hispanic	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
	Other, Including Multiple Races	0	6 (+6)	2 (+2)	1 (+1)	1 (+1)
Subsistence (All age cohorts)	Non-Hispanic White	0	10 (+10)	4 (+4)	2 (+2)	1 (+1)
	Non-Hispanic Black	0	10 (+10)	4 (+4)	2 (+2)	1 (+1)
	Mexican-American	0	12 (+12)	6 (+6)	4 (+4)	2 (+2)
	Other Hispanic	0	12 (+12)	6 (+6)	4 (+4)	2 (+2)
	Other, Including Multiple Races	1	12 (+11)	6 (+5)	4 (+3)	2 (+1)

Table 4-9. Modeled IRWs with Exceedances of Oral RfD (Non-Cancer Human Health Effects), by Race Category, under Baseline and Four Regulatory Options

Age and Type of Fish Consumption Cohort	Race Category	Modeled Number of IRWs Exceeding Oral RfD (Difference Relative to Baseline) [a]				
		Baseline	Option 1	Option 2	Option 3	Option 4
Thallium						
Recreational (All age cohorts)	Non-Hispanic White	4	6 (+2)	5 (+1)	4 (0)	2 (-2)
	Non-Hispanic Black	4	6 (+2)	5 (+1)	4 (0)	2 (-2)
	Mexican-American	5	7 (+2)	6 (+1)	5 (0)	2 (-3)
	Other Hispanic	4	6 (+2)	5 (+1)	4 (0)	2 (-2)
	Other, Including Multiple Races	5	7 (+2)	6 (+1)	5 (0)	2 (-3)
Subsistence (All age cohorts)	Non-Hispanic White	6	10 (+4)	8 (+2)	8 (+2)	5 (-1)
	Non-Hispanic Black	6	10 (+4)	8 (+2)	8 (+2)	6 (0)
	Mexican-American	6	11 (+5)	9 (+3)	9 (+3)	7 (+1)
	Other Hispanic	6	11 (+5)	9 (+3)	9 (+3)	7 (+1)
	Other, Including Multiple Races	8	14 (+6)	10 (+2)	10 (+2)	7 (-1)

Source: ERG, 2019i.

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

A – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

The EPA also compared 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.[30] Based on the modeling results, up to 6 percent of the evaluated immediate receiving waters may contain fish with contamination levels that could trigger advisories for recreational and/or subsistence fishers under baseline; this increases to approximately 13 percent under Option 2. Mercury and selenium are the pollutants most likely to exceed screening values. Table 4-10 presents the number and percentage of immediate receiving waters where the modeled T4 fish tissue concentrations exceed screening values used for fish advisories.[31]

Table 4-10. Comparison of Modeled T4 Fish Tissue Concentrations to Fish Advisory Screening Values under Baseline and Four 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)	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	2	7 (+5)	7 (+5)	6 (+4)	5 (+3)
Selenium	20	0	5 (+5)	2 (+2)	1 (+1)	1 (+1)
Total for Any Pollutant in Evaluated Wastestreams [b]		**2**	**8 (+6)**	**7 (+5)**	**6 (+4)**	**5 (+3)**
Subsistence Fishers						
Arsenic	0.00327	0	0 (0)	0 (0)	0 (0)	0 (0)
Cadmium	0.491	0	0 (0)	1 (+1)	0 (0)	0 (0)
Mercury (as methylmercury)	0.049	6	16 (+10)	14 (+8)	11 (+5)	9 (+3)
Selenium	2.457	0	12 (+12)	6 (+6)	4 (+4)	2 (+2)
Total for Any Pollutant in Evaluated Wastestreams [b]		**6**	**18 (+12)**	**14 (+8)**	**11 (+5)**	**9 (+3)**

Sources: ERG, 2019i.

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

A – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

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

[30] For this analysis, the 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).

[31] As described in Section 4.4.2, none of the immediate receiving waters are under fish consumption advisories for arsenic, cadmium, or selenium; each advisory screening value exceedance shown in Table 4-10 for these pollutants therefore indicates a "new" receiving water of concern that may warrant additional monitoring and/or evaluation of human health risk. Similarly, for mercury under Option 2, 9 of the 14 immediate receiving waters with modeled exceedances of the advisory screening value are "new" receiving waters of concern that are not under fish consumption advisories for mercury.

4.3 IMPACTS IN DOWNSTREAM SURFACE WATERS

The 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 for a description of the model) to assess potential water quality, wildlife, and human health impacts in approximately 10,400 river miles of downstream surface waters. The methodology, which uses estimated annual average pollutant loadings and surface water flow rates, is summarized in Section 3.5 of this report and presented in further detail in the memorandum "Downstream Modeling Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019g).

Table 4-11 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[32] and indicates the total length of downstream surface waters for which the EPA calculated an exceedance of a benchmark value for at least one of the modeled pollutants.

For each benchmark value with modeled exceedances under baseline, the analysis shows that the total length of downstream surface waters with exceedances increases under Option 2. For example, the length of downstream surface waters with at least one exceedance of the Human Health Water and Organism NRWQC increases from 64.6 miles (baseline) to 187 miles (Option 2), and exceedances of the oral RfD increase from 101 miles (baseline) to 198 miles (Option 2) for the child subsistence fisher cohort. Option 2 also results in downstream exceedances of some benchmark values that do not have modeled exceedances under baseline (e.g., the Freshwater Acute and Chronic NRWQCs and the LECR).

[32] 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 4-11. Modeled Downstream River Miles with Exceedances of Any Pollutant Evaluation Benchmark Value under Baseline and Four Regulatory Options

Evaluation Benchmark	Modeled Number of Downstream River Miles Exceeding Benchmark Value (Difference Relative to Baseline)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Water Quality Results					
Freshwater Acute NRWQC	0.0	4.66 (+4.66)	0.372 (+0.372)	0.0 (0)	0.0 (0)
Freshwater Chronic NRWQC	0.0	26.1 (+26.1)	6.59 (+6.59)	2.51 (+2.51)	2.51 (+2.51)
Human Health Water and Organism NRWQC	64.6	143 (+78.5)	187 (+122)	127 (+62.2)	77.2 (+12.6)
Human Health Organism Only NRWQC	19.4	43.4 (+23.9)	68.2 (+48.8)	36.4 (+16.9)	30.8 (+11.4)
Drinking Water MCL	2.56	7.84 (+5.28)	4.62 (+2.06)	2.19 (-0.372)	0.0 (-2.56)
Wildlife Results					
Fish Ingestion NEHC for Minks	0.372	49.1 (+48.8)	20.3 (+19.9)	8.42 (+8.04)	5.62 (+5.25)
Fish Ingestion NEHC for Eagles	15.9	69.0 (+53.1)	42.8 (+26.8)	32.4 (+16.5)	27.9 (+11.9)
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	42.6	90.4 (+47.8)	125 (+82.4)	63.2 (+20.6)	47.2 (+4.57)
Oral RfD for Adult (Recreational)	28.5	53.8 (+25.3)	77.3 (+48.8)	45.4 (+16.9)	39.9 (+11.4)
Oral RfD for Child (Subsistence)	101	179 (+77.8)	198 (+96.9)	127 (+26.3)	77.0 (-23.9)
Oral RfD for Adult (Subsistence)	50.1	110 (+60.3)	143 (+92.9)	68.2 (+18.1)	47.2 (-2.99)
Human Health Results – Cancer					
LECR for Child (Recreational)	0.0	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
LECR for Adult (Recreational)	0.0	0.0 (0)	2.06 (+2.06)	0.0 (0)	0.0 (0)
LECR for Child (Subsistence)	0.0	0.0 (0)	2.06 (+2.06)	0.0 (0)	0.0 (0)
LECR for Adult (Subsistence)	0.0	2.51 (+2.51)	4.56 (+4.56)	2.51 (+2.51)	2.51 (+2.51)

Source: ERG, 2019g.

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

Note: River miles are rounded to three significant figures. As part of this analysis, the EPA evaluated approximately 10,400 river miles of surface waters downstream of immediate receiving waters.

4.4 DISCHARGES TO IMPAIRED WATERS AND FISH CONSUMPTION ADVISORY WATERS

Discharges of the evaluated wastestreams to Clean Water Act 303(d) impaired waters and fish consumption advisory waters[33] may contribute to water quality impairments, increased health risk associated with consuming fish, and a reduction in the extent of viable downstream fisheries. Table 4-12 summarizes the number of immediate receiving waters that are classified as either a 303(d) impaired water or a fish consumption advisory water under baseline and each regulatory option. Sections 4.4.1 and 4.4.2 present the results of the EPA's assessment of immediate receiving waters that are 303(d) impaired waters or fish consumption advisory waters, respectively.[34]

Table 4-12. IRWs Identified as Clean Water Act 303(d) Impaired Waters or Fish Consumption Advisory Waters under Baseline and Four Regulatory Options

Category	Number of IRWs (Difference Relative to Baseline)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Impaired water	39	59 (+20)	53 (+14)	51 (+12)	37 (-2)
Subset impaired for one or more pollutants associated with the evaluated wastestreams.	26	42 (+16)	35 (+9)	35 (+9)	24 (-2)
Fish consumption advisory water	50	67 (+17)	55 (+5)	54 (+4)	32 (-18)
Subset with a fish consumption advisory for one or more pollutants associated with the evaluated wastestreams.	37	46 (+9)	35 (-2)	35 (-2)	18 (-19)

Source: ERG, 2019h.

4.4.1 Impaired Waters

The EPA determined that more than half (60 of 112) of the immediate receiving waters analyzed in the Supplemental EA are 303(d) impaired waters.[35] As shown in Table 4-13, 26 of the immediate receiving waters under baseline (23 percent) and 35 of the immediate receiving waters under Option 2 (31 percent) are impaired for a pollutant present in the evaluated wastestreams. Figure 4-2, Figure 4-3, and Figure 4-4 present the locations of immediate receiving waters that are classified as impaired by high concentrations of mercury, metals (other than mercury), and nutrients, respectively.

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[33] 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.

[34] See the memorandum "Proximity Analyses and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019h) for a description of the methodology used to evaluate the proximity of coal-fired power plants to 303(d) impaired waters, fish consumption advisory waters, and other sensitive environments.

[35] See the memorandum "Proximity Analyses and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019h) for a complete list of the impairment categories identified in the EPA's 303(d) waters proximity analysis.

Table 4-13. IRWs Listed as 303(d) Impaired for Pollutants Present in the Evaluated Wastestreams under Baseline and Four Regulatory Options

Pollutant Causing Impairment	Number of IRWs Listed as 303(d) Impaired Waters (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mercury	12	22 (+10)	18 (+6)	18 (+6)	14 (+2)
Metals, other than mercury [b]	9	14 (+5)	12 (+3)	12 (+3)	8 (-1)
Nutrients	8	12 (+4)	11 (+3)	11 (+3)	7 (-1)
TDS, including chlorides	1	2 (+1)	2 (+1)	2 (+1)	2 (+1)
Total for Any Pollutant in Evaluated Wastestreams [c]	26	42 (+16)	35 (+9)	35 (+9)	24 (-2)

Source: ERG, 2019h.

Acronyms: IRW (immediate receiving water); TDS (total dissolved solids).

a – For this proximity analysis, the EPA evaluated 112 immediate receiving waters that receive discharges of the evaluated wastestreams under any scenario, either directly or indirectly via a POTW. Of these 112 immediate receiving waters, 69 receive discharges of the evaluated wastestreams under baseline, 111 under Option 1, 96 under Option 2, 94 under Option 3, and 69 under Option 4.

b – Of the 14 immediate receiving waters classified as impaired for "metal, other than mercury" under baseline or any regulatory option, 11 immediate receiving waters are specifically listed as impaired for one or more of the following individual pollutants evaluated in the Supplemental EA: cadmium (1), chromium (1), copper (2), iron (6), lead (3), manganese (1), selenium (1), and zinc (1).

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

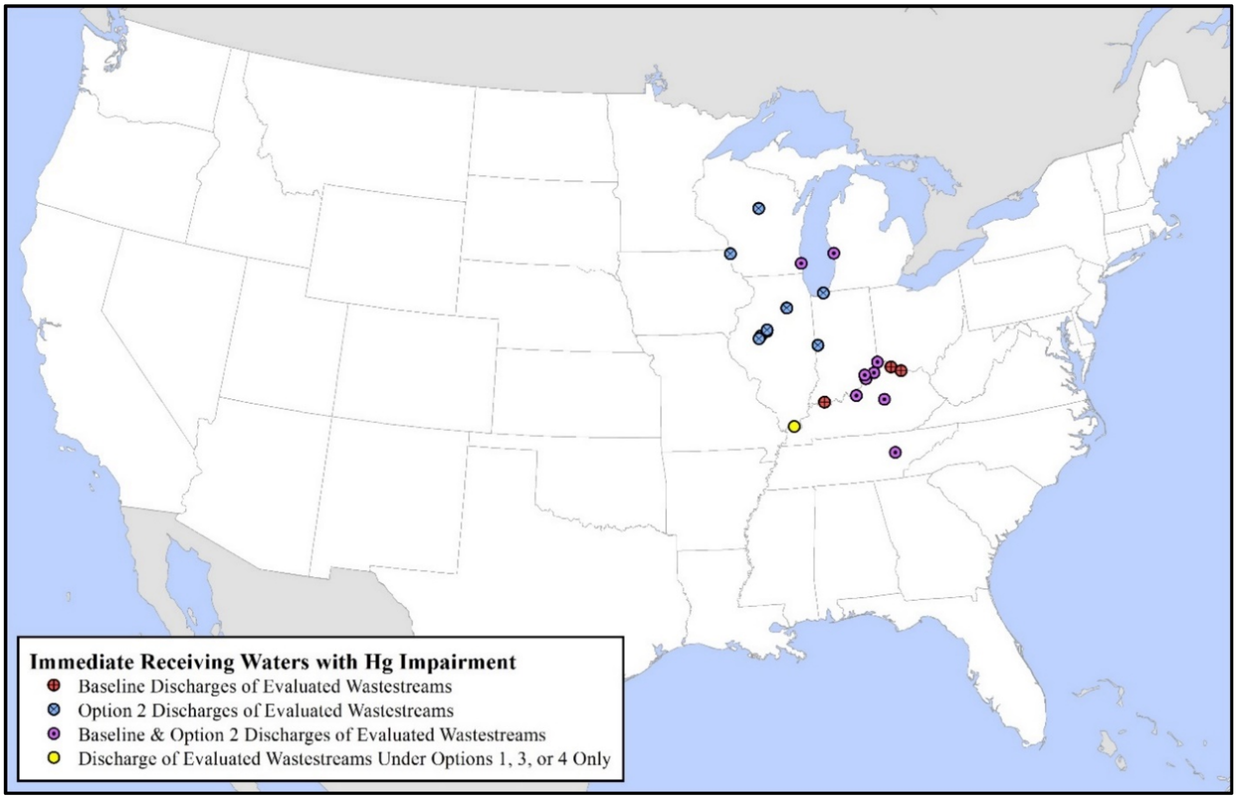

Figure 4-2. Immediate Receiving Waters Impaired by Mercury

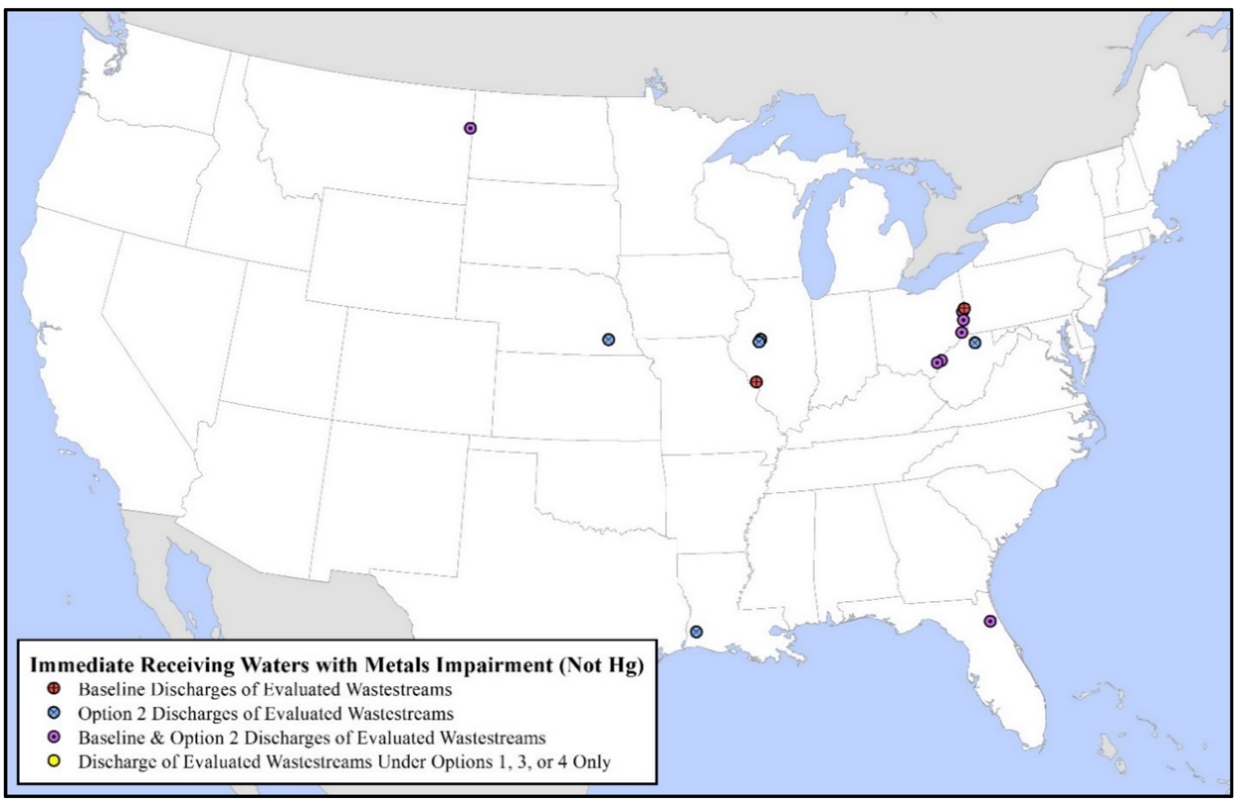

Figure 4-3. Immediate Receiving Waters Impaired by Metals, Other Than Mercury

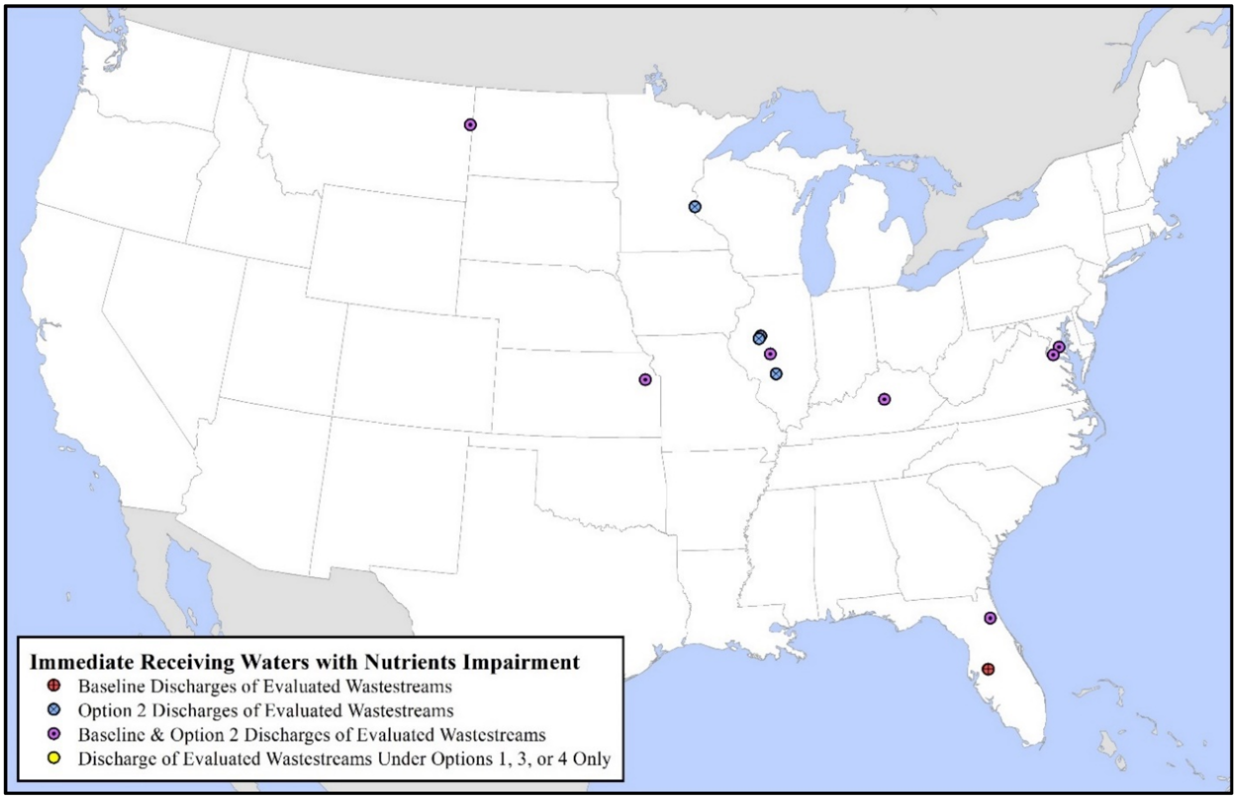

Figure 4-4. Immediate Receiving Waters Impaired by Nutrients

Option 2 has a mixed effect on the loadings of pollutants to waters that are already impaired for those pollutants, increasing estimated loadings for some pollutants and decreasing them for others. Once requirements under Option 2 have been met at all plants (i.e., by December 31, 2028), the EPA estimates the following net changes relative to baseline in pollutant loadings to impaired waters:

- Nitrogen increase of 23,000 lb/yr and phosphorus increases of 151 lb/yr to nutrient-impaired waters.
- Phosphorus increase of 116 lb/yr to phosphorus-impaired waters.
- Mercury increase of 1.6 lb/yr to mercury-impaired waters.
- Net changes in loadings to receiving waters impaired for a metal (except mercury):
  - Aluminum increase of 1,220 lb/yr.
  - Arsenic decrease of 5.15 lb/yr.
  - Barium decrease of 359 lb/yr.
  - Beryllium decrease of 5.45 lb/yr.
  - Cadmium decrease of 15.7 lb/yr.
  - Calcium decrease of 7,520,000 lb/yr.
  - Chromium decrease of 16.1 lb/yr.
  - Cobalt decrease of 19.5 lb/yr.

- Copper decrease of 7.50 lb/yr.
- Iron increase of 902 lb/yr.
- Lead increase of 7.00 lb/yr.
- Magnesium decrease of 13,600,000 lb/yr.
- Manganese decrease of 50,600 lb/yr.
- Molybdenum decrease of 453 lb/yr.
- Nickel increase of 9.21 lb/yr.
- Potassium increase of 39,100 lb/yr.
- Selenium increase of 1.18 lb/yr.
- Silicon increase of 16,300 lb/yr.
- Sodium decrease of 885,000 lb/yr.
- Strontium increase of 2,860 lb/yr.
- Thallium decrease of 37.7 lb/yr.
- Titanium increase of 33.8 lb/yr.
- Vanadium decrease of 31.2 lb/yr.
- Zinc decrease of 13.8 lb/yr.

4.4.2 Fish Consumption Advisories

The EPA determined that 50 of the immediate receiving waters under baseline (45 percent) and 55 of the immediate receiving waters under Option 2 (49 percent) are under fish consumption advisories.[36] As shown in Table 4-14, 37 of the 50 immediate receiving waters (under baseline) and 35 of the 55 immediate receiving waters (under Option 2) are under an advisory for a pollutant associated with the evaluated wastestreams. All of these immediate receiving waters are under fish consumption advisories for mercury. The EPA also reviewed fish consumption advisories for arsenic, cadmium, chromium, copper, lead, selenium, zinc, and unspecified metals, but did not identify any immediate receiving waters receiving discharges under baseline or the regulatory options. Under Option 2, the EPA estimates a 2.52 lb increase in annual mercury loadings to immediate receiving waters with fish consumption advisories for mercury. Figure 4-5 illustrates the locations of immediate receiving waters with fish consumption advisories for mercury.

[36] See the memorandum "Proximity Analyses and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019h) for a complete list of the types of advisories identified in the EPA's fish consumption advisories proximity analysis, including advisories due to pollutants that are not associated with the evaluated wastestreams.

Table 4-14. IRWs with Fish Consumption Advisories for Pollutants Present in the Evaluated Wastestreams under Baseline and Four Regulatory Options

Pollutant Causing Fish Consumption Advisory	Number of IRWs with Fish Consumption Advisory (Difference Relative to Baseline) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mercury	37	46 (+9)	35 (-2)	35 (-2)	18 (-19)
Total for Any Pollutant in Evaluated Wastestreams	**37**	**46 (+9)**	**35 (-2)**	**35 (-2)**	**18 (-19)**

Source: ERG, 2019h.

Acronyms: IRW (immediate receiving water).

a – For this proximity analysis, the EPA evaluated 112 immediate receiving waters that receive discharges of the evaluated wastestreams under any scenario, either directly or indirectly via a POTW. Of these 112 immediate receiving waters, 69 receive discharges of the evaluated wastestreams under baseline, 111 under Option 1, 96 under Option 2, 94 under Option 3, and 69 under Option 4.

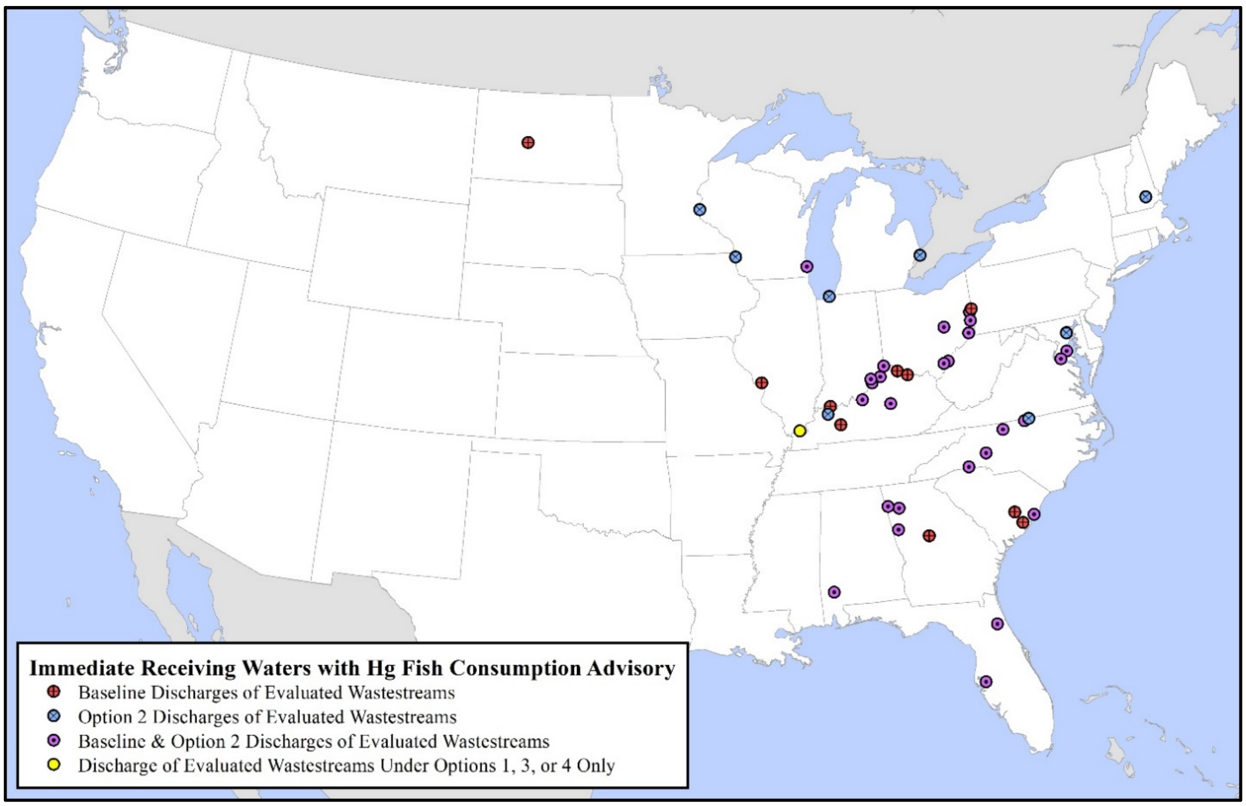

Figure 4-5. Immediate Receiving Waters with Fish Consumption Advisory for Mercury

SECTION 5
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APPENDIX A
ADVERSE IMPACTS FROM EXPOSURE TO METALS AND TOXIC AND BIOACCUMULATIVE POLLUTANTS

Table A-1 presents example adverse impacts from exposure to elevated concentrations of metals and toxic and bioaccumulative pollutants, which are present in discharges of the evaluated wastestreams (flue gas desulfurization (FGD) wastewater and bottom ash transport water) from coal-fired power plants. The table is not an exhaustive list of adverse impacts but provides context for an assessment of environmental, ecological, and human health impacts from exposure to these pollutants. Additional information is available in *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (2015 Final EA) (U.S. EPA, 2015a).

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Aluminum	Minimal risk level (MRL) for intermediate and chronic oral exposure is 1.0 milligrams per kilograms per day (mg/kg/day).	Neurological impacts	Elevated levels of aluminum can adversely impact some species' ability to regulate ions and can inhibit respiratory functions (U.S. EPA, 2018b). Oral exposures to aluminum in animal studies show that the nervous system is a sensitive target (ATSDR, 2008a). High levels of aluminum can also cause brain disease in children with kidney disease and bone disease in children with kidney disease, and in children taking some medicines containing aluminum (ATSDR, 2008a).
Arsenic [b]	MRL for acute oral exposure is 0.005 mg/kg/day.	Gastrointestinal impacts	Arsenic tends to bioaccumulate in aquatic communities and potentially impacts higher-trophic-level organisms. Elevated arsenic tissue concentrations are associated with liver poisoning, developmental abnormalities, behavioral impairments, metabolic failure, reduced growth, and appetite loss in aquatic organisms (NRC, 2006; Rowe et al., 2002; U.S. EPA, 2011a). In humans, arsenic contamination is associated with an increased risk of bladder, lung, and skin cancer, particularly in inorganic forms. Arsenic is also a potential endocrine disruptor. Non-cancer impacts from long-term exposure include dermal impacts, developmental effects, diabetes, cardiovascular disease, and pulmonary disease. Chronic exposure via drinking water has been associated with excess incidence of miscarriages, stillbirths, preterm births, and low birth weights (Diamanti-Kandarakis et al., 2009; WHO, 2018).
	MRL for chronic oral exposure is 0.0003 mg/kg/day.	Dermal impacts	
Boron	MRL for acute and intermediate oral exposure is 0.2 mg/kg/day.	Developmental impacts	Boron can be toxic to vegetation and to wildlife at certain water concentrations and dietary levels. Toxicity in fish can occur at levels of 10 to 300 milligrams per liter (mg/L) and mallard duckling growth can be impacted at dietary levels of 30 to 300 mg/kg. Boron does not magnify through the food chain but does accumulate in aquatic and terrestrial plants (WHO, 1998). In animals, acute excessive amounts of boron can cause lethargy, rapid respiration, eye inflammation, and dermal impacts (U.S. EPA, 2008a). In humans, exposure via ingestion of large quantities over a short time period can adversely impact the stomach, intestines, liver, kidney, and brain. Human exposure to high concentrations of boron (85 mg/kg) can cause nausea, vomiting, diarrhea, and redness of the skin (ATSDR, 2010a; U.S. EPA, 2008a).

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Cadmium	MRL for intermediate oral exposure is 0.0005 mg/kg/day.	Musculoskeletal impacts	Cadmium can readily bioaccumulate in aquatic organisms, especially mollusks, soil invertebrates, and microorganisms. Cadmium contamination can lead to skeletal malformations in fish (WHO, 1992).
	MRL for chronic oral exposure is 0.0001 mg/kg/day.	Renal impacts	Cadmium is a probable human carcinogen. Human exposure to high concentrations of cadmium in drinking water and food can irritate the stomach, leading to vomiting and diarrhea, and sometimes death. Chronic oral exposure via diet or drinking water to lower concentrations can lead to kidney damage and weakened bones (ATSDR, 2008b; ATSDR, 2012a).
Chromium (III)	MRL for intermediate inhalation exposure (soluble particulates) is 0.0001 milligrams per cubic meter (mg/m^3).	Respiratory impacts	The toxicity of chromium (III) to aquatic organisms is impacted by water hardness, being more toxic in soft water (U.S. EPA, 1980a). Fawad et al. (2016) studied chromium (III) accumulation in goldfish (*Carassius auratus*) and found highest accumulation in the gills, followed by the intestines, and then the skin. When chromium (III) levels exceed recommended limits, more of the metal accumulates in the fish organs such as the liver, muscle, and gills and raises the mortality rate. Chromium can cause physiological and behavioral changes (e.g., loss of appetite and reduced growth) (Fawad et al., 2016). Potential risks to humans from chromium exposure include respiratory and immunological damage (ATSDR, 2012b).
Copper	MRL for acute and intermediate oral exposure is 0.01 mg/kg/day.	Gastrointestinal impacts	Copper can be lethal to freshwater fish at concentrations ranging from 10 ppb – 20 ppb in soft water (in hard water, the cations reduce the bioavailability of the dissolved copper). Adverse impacts to fish include impaired neurological function, reduced reproduction, and damage to gills, olfactory receptors, and lateral line cilia. Other freshwater aquatic organism impacts include inhibiting photosynthesis of algae, reduced growth and reproduction of zooplankton (due to impacts to algae food supply), and impaired growth and survival of mussels (Woody and O'Neal, 2012). Human exposure to high concentrations of copper can cause gastrointestinal distress (i.e., nausea, vomiting, and/or abdominal pain), liver and kidney damage, anemia, immunotoxicity, and developmental toxicity (U.S. EPA, 1980b).

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Iron	*No MRL*	--	Iron contamination can cause sublethal impacts to aquatic organisms, including reduced growth, reduced development, and reduced reproduction. Iron also increases turbidity, reduces primary production, and reduces interstitial spaces in benthic sediment, which can smother invertebrates, periphyton, and eggs. Iron precipitates can clog and damage the gills of fish resulting in respiratory impacts (Cadmus et al., 2018). In humans, individuals with iron overload disorders can experience oxidative damage and organ dysfunction, impacting metabolism (i.e., diabetes mellitus), the liver (i.e., cirrhosis), the heart (i.e., cardiomyopathy), and endocrine glands (Dev and Babitt, 2017).
Lead	*No MRL*	--	Lead contamination can delay embryonic development, suppress reproduction, and inhibit growth in fish, crab, and several other aquatic organisms (U.S. EPA, 1984; U.S. EPA, 2011a). Human exposure to high concentrations of lead in drinking water (and other exposure pathways) can result in adverse impacts to almost every organ and body system. Lead impacts include neurological effects, with long-term exposure resulting in children (e.g., decreased cognitive function, IQ loss, altered behavior and mood, and weakness in fingers, wrists, or ankles), renal damage and reduced renal function, cardiovascular impacts (e.g., increased blood pressure), reproductive impacts, and developmental impacts. Developmental impacts include premature births and decreased child growth (ATSDR, 2019b).
Magnesium	*No MRL*	--	Magnesium generally does not pose a risk to aquatic life unless associated with other anions, such as chloride or sulfate. Such compounds can contribute to salinity stress and impact species diversity in sensitive aquatic communities (NHDES, 2019). In humans, increased intake of magnesium salts may cause a change in bowel habits (diarrhea). Drinking water in which both magnesium and sulfate concentrations are present in high concentrations (approximately 250 mg/L each) can have a laxative effect (Sengupta, 2013).

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Manganese	MRL for chronic inhalation exposure is 0.03 micrograms per cubic meter ($\mu g/m^3$).	Neurological impacts	Manganese primarily accumulates in organisms lower in the food chain, such as phytoplankton, algae, mollusks, and some fish (ATSDR, 2008c). Although high levels can be toxic to humans, manganese is not generally considered toxic when ingested (WHO, 2011). The most common impacts due to human exposure to high concentrations of manganese involve the nervous system (ATSDR, 2008c).
Mercury [c]	MRL for chronic oral exposure to methylmercury is 0.0003 mg/kg/day.	Developmental impacts	Once in the environment, mercury can convert into methylmercury, increasing the potential for bioaccumulation. Methylmercury contamination can reduce growth and reproductive success in fish and invertebrates. Adverse impacts on wildlife include behavioral and reproductive effects (Evers et al., 2011). In humans, high exposure to inorganic mercury may result in damage to the gastrointestinal tract, the nervous system, and the kidneys. Exposure at levels above the drinking water maximum contaminant level (MCL), 0.002 mg/L, can result in kidney damage (U.S. EPA, 2019d). Fetuses, infants, and children are particularly susceptible to impaired neurological development from methylmercury exposure (ATSDR, 1999; Evers et al., 2011).
Nickel	MRL for intermediate inhalation exposure is 0.0002 mg/m^3.	Respiratory impacts	Nickel can inhibit the growth of microorganisms (i.e., bacteria and protozoans) and algae. Nickel toxicity in fish and aquatic invertebrates varies among species and can reduce fish growth and adversely impact the immune system, muscles, gills, and liver. Nickel does not biomagnify in the aquatic food web (ATSDR, 2005a; Eisler, 1998; Min et al., 2015; U.S. EPA, 1986). Human exposure via drinking water at high concentrations of nickel (e.g., 250 parts per million (ppm)), can cause gastrointestinal effects (stomachache) and adverse effects to the blood and kidney (ATSDR, 2005a).
	MRL for intermediate inhalation exposure is 0.00009 mg/m^3.	Respiratory impacts	

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Selenium	MRL for chronic oral exposure is 0.005 mg/kg/day.	Dermal impacts	Selenium readily bioaccumulates. The bioaccumulation of selenium is of particular concern due to its potential to impact higher trophic levels through biomagnification (Coughlan and Velte, 1989). Elevated concentrations have caused fish kills and numerous sublethal effects (e.g., organ damage, decreased growth rates, reproductive failure) to aquatic and terrestrial organisms (NPS, 1997). In humans, acute exposure via food or water adversely impacts the liver, respiratory system (i.e., pulmonary edema and lesions of the lung), cardiovascular system (e.g., tachycardia), gastrointestinal system (nausea, vomiting, et. al.), and neurological system (e.g., aches, irritability, chills, and tremors). Chronic exposure via food or water can cause skin and tooth discoloration, loss of hair and nails, excess tooth decay, and neurological impacts (i.e., lack of mental alertness and listlessness) (U.S. EPA, 2000b, 2016b, and 2016c).
Thallium	Reference dose for chronic oral exposure (thallium chloride): 1.00 x 10^{-5} mg/kg/day (U.S. EPA, 2010a).	Hair follicle atrophy (U.S. EPA, 2010a)	Thallium can bioaccumulate in fish and vegetation in fresh and marine waters, as well as in marine invertebrates, which suggests that thallium may be a potential risk to higher order organisms in vulnerable ecosystems (U.S. EPA, 2011b). In humans, short-term exposure to thallium can lead to neurological symptoms (e.g., weakness, sleep disorders, muscular problems), alopecia, gastrointestinal effects, and reproductive and developmental damage. Long-term exposures at levels above the MCL (0.002 mg/L) change blood chemistry and damage liver, kidney, and intestinal and testicular tissues (U.S. EPA, 2009a; U.S. EPA, 2009b).
Vanadium	MRL for intermediate oral exposure is 0.01 mg/kg/day.	Hematological impacts	Vanadium contamination can increase blood pressure, decrease blood cell count, and cause mild neurological effects in animals (ATSDR, 2012c). There are very few reported cases of oral exposure to vanadium in humans; however, a few reported incidences documented nausea, diarrhea, and stomach cramps (ATSDR, 2012c).

Table A-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of Metals and Toxic and Bioaccumulative Pollutants

Pollutant	Benchmark Value [a]	Benchmark Value Endpoint [a]	Potential Adverse Impacts
Zinc	MRL for intermediate and chronic oral exposure is 0.3 mg/kg/day.	Hematological impacts	Elevated zinc levels adversely impact aquatic plant and animal growth, survival, and reproduction. At higher concentrations, zinc is lethal to aquatic organisms by causing irreversible destruction of the gill epithelium. Zinc contamination changes behavior, reduces oxygen supply, interferes with gill uptake of calcium, and impairs reproduction in fish. High zinc levels in birds can cause mortality, reduce growth, or damage the pancreas (CCME, 2018; U.S. EPA Region 5, 2016). In humans, short-term exposure to levels 10-15 times the recommended daily allowance (11 mg/day for men and 8 mg/day for women) can cause nausea, vomiting, and stomach cramps. Long-term exposure at high levels can cause anemia and damage the pancreas (ATSDR, 2005b).

Acronyms: mg/day (milligrams per day); mg/kg (milligrams per kilograms); mg/kg/day (milligram per kilogram-day); mg/L (milligrams per liter); milligrams per cubic meter (mg/m^3); MRL (minimal risk level); ppb (parts per billion); ppm (parts per million).
a – Reference is ATSDR, 2019a unless otherwise listed.
b – The EPA based its quantitative human health assessments on the estimated concentration of inorganic arsenic in fish tissue (see Section 4).
c – The EPA based its quantitative wildlife and human health assessments on the estimated concentration of methylmercury in fish tissue (see Section 4).

APPENDIX B
ADVERSE IMPACTS FROM EXPOSURE TO TOTAL DISSOLVED SOLIDS

Table B-1 presents example adverse impacts from exposure to elevated concentrations of total dissolved solids (TDS), which is present in discharges of the evaluated wastestreams (flue gas desulfurization (FGD) wastewater and bottom ash transport water) from coal-fired power plants. The table is not an exhaustive list of adverse impacts but provides context for an assessment of environmental and ecological impacts from exposure to TDS and the corresponding increase in salinity of the receiving water.

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Invertebrates	*Salinity*: >8.2 ppt	Oxygen consumption decreases significantly among invertebrates due to physiological stress.	--	Silva and Davies, 1999 (as cited in Cañedo-Argüelles et al., 2013)
Ephemeroptera (mayfly), Plecoptera (stonefly), and Pulmonate (molluscs)	*Salinity*: >3 mS/cm (milliSiemens per centimeter)	Salinity at which the organisms are rarely registered. 48- and 72-hour LC50 is approximately 5 to 20 mS/cm.	48- and 72-hour exposure.	Williams et al., 2003; Hassell et al., 2006; Echols et al., 2010; Kefford et al., 2012 (as cited in Cañedo-Argüelles et al., 2013)
Chironomids (*Chironomus tentans*)	Chironomids exhibited toxic effects at >1,100 mg/L.	Researchers synthesized Red Dog Mine effluent and exposed larval chironomids to a TDS concentration of 2,089 mg/L. Their dry weight (a growth indicator for these organisms) was reduced by 45 percent. The researchers also observed reduced survival among larval chironomids exposed to synthetic Kensington Mine effluent at TDS concentrations of 1,750 and 2,240 mg/L.	Researchers maintained larval chironomids in test containers and exposed them to synthetic effluent (based on discharge from one of two local mines in Alaska) for 10 days. They measured mortality and dry weight at the end of the incubation.	Chapman et al., 2000
Coontail (*Ceratophyllus demersum*) and cattail (*Typha* sp.)	1,170 mg/L (Estimated)	In a 1988 study of plant communities near irrigation drains in Stillwater Marsh, researchers found that coontails and cattails growing in the marsh had nearly been eliminated. TDS concentrations were modeled to have increased from 270 mg/L (historical values from 1845 to 1860) to 1,170 mg/L (projected values for 1992 and beyond, as estimated in 1988).	Reported TDS concentration data at the wetland inlet flow at Stillwater Marsh, Nevada, were estimated for 1992 and beyond. Reductions in coontail and cattail in Stillwater Marsh were based on comparisons of observed populations in 1988 to populations recorded in a 1959 survey by the U.S. Fish and Wildlife Service.	Hallock and Hallock, 1993

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Vascular aquatic plants, fish	20,000 mg/L	After Carson Sink was inundated and TDS concentrations rose to 20,000 mg/L, vascular aquatic plants died. Fish did well initially, but they started dying after about a year when water evaporated and the TDS concentration increased.	Historical TDS concentrations in Carson Sink, Nevada, likely varied dramatically based on inundation. The plant species that were reported to be present in a 1929 survey could withstand TDS concentrations between 650 and 16,800 mg/L during normal conditions. TDS concentrations when the wetland is filled have been recorded at 3,100 mg/L (1983) and 20,000 mg/L (1987).	Hallock and Hallock, 1993
American coot (*Fulica americana*)	1,170 mg/L (Estimated)	Coots had reduced field nest success and low fecundity due to vegetation loss and subsequent nest exposure. Nesting success decreased from 43 to 52 percent (1968 to 1970) to 25 percent (1988). The researchers attributed vegetation loss to drought, increased TDS, and increased predation.	Nesting success for the study was measured during an annual assessment in May 1988. Those values were compared to nesting surveys conducted in the Stillwater Wildlife Management Area in 1968-1970, 1983, and 1987-1988.	Hallock and Hallock, 1993
Atlantic salmon (*Salmo salar*), rainbow trout (*Salmo gairdneri*), and brook trout (*Salvelinus fontinalis*)	>522 mg/L calcium sulfate ($CaSO_4$). Calcium in the experimental water ranged between 34-544 mg/L.	Researchers found low survival rates (~33 percent) when eggs were incubated in very hard water with calcium sulfate concentrations >522 mg/L during water hardening (the process by which the shells of newly shed eggs absorb water and become firm over the course of a few hours). High concentrations of chloride, sulfate, and sodium ions did not affect egg survival.	Eggs were incubated to eye-up (the point at which eyes develop on the embryo). Eggs were exposed to treatment water for 1.5 or 3.5 hours of hardening, depending on the experiment. Egg survival rates were not significantly affected by water chemistry after hardening.	Ketola et al., 1988

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Fish communities	2,000 – 2,300 mg/L	Researchers documented notably lower species richness and density at two sampling locations immediately downstream of the coal mining wastewater discharges. Fish community metrics declined notably at three sampling stations among 17 stations compared to the reference station. However, one of these three sites may have been impacted by factors other than TDS concentrations (i.e., toxicity from untreated coal plant runoff and sewage). Based on TDS data collected at all sampling sites, researchers identified 2,000 to 2,300 mg/L as the limit before fish communities experience adverse effects.	Researchers sampled fish populations and measured water quality parameters at 17 locations along the South Fork of Tenmile Creek in southwestern Pennsylvania during the summers of 2007 and 2008. Researchers collected 10,940 fish representing seven families and 42 species/hybrids during the survey.	Kimmel and Argent, 2010
Walleye (*Stizostdion vitreum*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), white sucker (*Catostomus commersoni*), and common carp (*Cyprinus carpio*)	1,750-6,700 mg/L (Concentrations at which eggs were incubated) ≥2,400 mg/L (Concentration at which adverse impacts were observed)	Fish egg hatching success significantly decreased at TDS concentrations above 2,400 mg/L for all species studied except common carp. Embryo survival decreased at TDS concentrations above 2,400 mg/L for walleye and northern pike. Survival to hatching was less than 2 percent for all species except common carp at TDS concentrations above 2,400 mg/L.	Researchers collected fish eggs during spawning runs between mid-April and May 1992 in Devils Lake, North Dakota, and Many Point Lake, Minnesota. They incubated the fertilized eggs overnight, and assessed fertilization success after one or three days, depending on species. Live embryos were incubated and counted every one to three days until hatching.	Koel and Peterka, 1995

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Water flea (*Ceriodaphnia dubia*)	Variable ion concentrations: Na = 15,000 mg/L, K = 450 mg/L, Ca =1,800 mg/L, Mg = 320 mg/L, Cl = 26,000 mg/L (highest reported concentration)	Concentrations for the four (of six total) samples that were acutely toxic to *C. dubia*.	Grab samples were collected from the Black Warrior Basin, Alabama. Twenty-four- and 48-hour survival for two species of water flea (*C. dubia* and *Daphnia magna*) and flathead minnows (*Pimephales promelas*) were ascertained. Within 36 hours of collection, all samples were tested for acute toxicity. Exposure began with the organisms that were less than 24 hours old and lasted 48 hours.	Mount et al., 1993
Daphnids (*Daphnia magna*)	Elevated concentration of major ions (conductivity up to 30,300 µS/cm). Variable ion concentration in leachate: Na = 7,700 mg/L, K = 270 mg/L, Ca = 379 mg/L, Mg = 758 mg/L, Cl = 11,200 mg/L (Highest reported concentration)	Concentrations for two (of the five total) samples showed acute toxicity to *D. magna.*	Water samples were taken from irrigation drain waters from the Stillwater Wildlife Management Area in southwestern Nevada. 24-and 48-hour survival for two species of water flea (*C. dubia* and *Daphnia magna*) and flathead minnows (*Pimephales promelas*). Acute toxicity tests with *Daphnia magna* were conducted on both ambient samples as well as reconstituted waters.	Mount et al., 1993
Daphnids (*Ceriodaphnia dubia* and *Daphnia magna*), fathead minnows (*Pimephales promelas*)	10,000 mg/L [a]	No clear information on adverse impacts were provided. However, marginal plots of the regression equations from the ion toxicity model showed that *C. dubia* are, in general, the most sensitive of the three species to major ion toxicity, while fathead minnows are the least sensitive.	All organisms were obtained from in-house culture. Daphnids were less than 24 hours old at test initiation while fathead minnows were 1 to 7 days old. Researchers followed general EPA guideline for conducting acute whole effluent toxicity tests. Exposure periods were 48 hours for *C. dubia* and *D. magna* and 96 hours for fathead minnows, with daily observations of mortality. Tests were conducted under a 16-hour:8-hour light:dark photoperiod.	Mount et al., 1997

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Coho salmon (*Oncorhynchus kisutch*)	>1,250 ppm	Coho salmon eggs from two broodyears experienced decreased fertilization success when exposed to high TDS concentrations. For both broodyears, fertilization success decreased as the TDS concentration during fertilization increased. For one broodyear, eggs experienced higher mortality between eye-up and the alevin stage when maintained at high TDS concentrations after fertilization. Adverse impacts were observed beginning at TDS concentrations of 1,250 ppm.	Researchers incubated fertilized coho salmon embryos from broodyears 1999 and 2000 for 96 hours.	Stekoll et al., 2003
Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), king salmon (*O. tschawytscha*), pink salmon (*O. gorbuscha*), steelhead salmon (*O. mykiss*), and arctic char (*Salvelinus alpinus*)	For the continuous exposure study: LOEC: 750 ppm for chum and steelhead salmon. LOEC: 250 ppm for king, pink, and coho salmon. LOEC: 1875 ppm for arctic char. For the fertilization exposure study, every species had a different LOEC ranging from 250 to 1875 ppm.	The number of unfertilized eggs increased with TDS concentrations for all species except arctic char. The most sensitive species (coho salmon) exhibited adverse effects at TDS concentrations of 250 ppm. Steelhead salmon were the only species that exhibited a significant effect in the post-fertilization exposure experiment, with a reported LOEC of 1875 ppm.	Researchers incubated fertilized eggs to the 4- or 8-cell stage, which lasted from 18 to 43 hours. These bioassays were conducted for broodyears 2000 and 2001. TDS concentrations in the test solution ranged from 0 to 2,500 ppm.	Stekoll et al., 2003

Table B-1. Examples of Adverse Impacts from Exposure to Elevated Concentrations of TDS

Aquatic Organism	TDS Concentration	Adverse Impacts	Literature Details	Source
Coho salmon (*Oncorhynchus kisutch*)	>2,500 ppm	No consistent adverse impacts related to TDS were documented at the TDS concentrations tested. Researchers exposed coho salmon eggs to differing chronic TDS concentrations as they developed. Higher TDS concentrations during fertilization were found to result in higher pre-hatch mortality, and higher TDS concentrations at hatching were related to higher post-hatch mortality. Fish exposed to higher TDS concentrations generally had shorter lengths and lower weights at button-up (stage at which fish have no visible yolk sac).	Researchers incubated the fish eggs for at least six months. TDS ranged from 125 to 2,500 ppm in test solutions.	Stekoll et al., 2003

Acronyms: Ca (calcium); Cl (chlorine); K (potassium); LC50 (lethal concentration required to kill 50 percent of the population); LOEC (lowest observed effects concentration); Mg (magnesium); mg/L (milligrams per liter); mS/cm (milliSiemens per centimeter); µS/cm (microSiemens per centimeter); Na (sodium); ppm (parts per million); ppt (parts per thousand); TDS (total dissolved solids).

a – The test solutions were prepared in a lab by dissolving individual 10,000 mg/L of ion salts with moderately hard reconstituted water (MHRW). For tests evaluating only one salt (one cation and one anion), test solutions were prepared by serially diluting the 10,000-mg/L stock solutions with MHRW to develop a series of test concentrations.

APPENDIX C
WATER QUALITY MODULE METHODOLOGY

This appendix presents the model equations, input variables and constants, pollutant benchmark values, and methodology limitations/assumptions for the Water Quality Module of the Immediate Receiving Water (IRW) Model. This supplemental environmental assessment (Supplemental EA) analyzes only the proposed changes to the 2015 rule regarding best available technology economically achievable (BAT) effluent limitations and pretreatment standards for existing sources (PSES) for the evaluated wastestreams—specifically, flue gas desulfurization (FGD) wastewater and bottom ash transport water.

The Water Quality Module equations are organized by the methodology for nonvolatile pollutants (arsenic, cadmium, copper, lead, nickel, selenium, thallium, and zinc) and volatile pollutants (mercury). The EPA used the equations to calculate total and dissolved pollutant concentrations in receiving waters and total pollutant concentrations in sediment within the immediate discharge zone. The following tables describe the input requirements and data sources used in the Water Quality Module:

- Table C-1. Input Variables with Values from Site-Specific Data Sources.
- Table C-2. Input Variables and Constants with Globally Assigned Values.
- Table C-3. Input Variables with Values from Regional Data Sources.
- Table C-4. Partition Coefficients.
- Table C-5. Total Suspended Solids (TSS) Concentrations in Surface Waters.
- Table C-6. Regional Surface Water Temperatures.
- Table C-7. National Recommended Water Quality Criteria (NRWQC) and Drinking Water Maximum Contaminant Levels (MCLs).

The EPA calculated effluent pollutant loadings associated with the discharge of the evaluated wastestreams as part of its engineering analysis—see the *Supplemental Technical Development Document for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (Supplemental TDD), Document No. EPA-821-R-19-009 (U.S. EPA, 2019a). The Water Quality Module performs calculations on a per-immediate-receiving-water basis. For coal-fired power plants that discharge to multiple receiving waters, the EPA divided the plant-specific pollutant loadings accordingly among the receiving waters based on water diagrams provided in response to the *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (Steam Electric Survey) (U.S. EPA, 2010c). The EPA used the IRW Model to evaluate the environmental impacts from 105 coal-fired power plants in the receiving water quantitative analysis (106 unique immediate receiving waters).

While the Water Quality Module is not designed to account for pollutant speciation, the EPA did include assumptions of pollutant speciation for arsenic and mercury as appropriate in the subsequent Wildlife and Human Health Modules (see Appendix D and Appendix E, respectively). The EPA used total selenium loadings in the Water Quality Module; however, due to the partition coefficients available, the EPA assumed the dominant form of selenium in the receiving water was selenate (i.e., selenium (VI)). The EPA selected the selenate partition coefficient because, per the Steam Electric Survey, the significant majority of coal-fired power plants (113 of 150, or 75 percent) operating wet FGD systems use forced oxidation systems (U.S. EPA, 2010c). According to Maher et al. (2010), the majority of selenium discharged from these types of scrubbers is in the form of selenate.

Methodology Updates Subsequent to the 2015 Final EA

Since the completion of the 2015 Final EA, the EPA incorporated the following updates to the equations, data sets, and parameter values used in the Water Quality Module:

- ***NHDPlus Version 2.*** The EPA used the most recent version of the National Hydrography Dataset Plus (NHDPlus). NHDPlus Version 2 has been updated by its developers to incorporate higher resolution data sets and revised watershed boundaries and elevation data, among other improvements.
- ***Lake depth.*** For the 2015 Final EA, the EPA obtained site-specific mean and maximum lake depth values by researching external sources. NHDPlus Version 2 now includes modeled estimates of mean lake depth. For the Supplemental EA, the EPA continued to use the site-specific mean depth values used in the 2015 Final EA, where available. However, for those receiving waters where the EPA had previously identified only a maximum lake depth value (instead of the mean depth, which is preferred), the EPA used the modeled mean depth values provided by the Lake Morphometry layer in NHDPlus Version 2.
- ***Lake surface area.*** For the 2015 Final EA, the EPA obtained site-specific lake surface area values by researching external sources. The Lake Morphometry layer in NHDPlus Version 2 now includes surface area data. For the Supplemental EA, the EPA used surface area data from the Lake Morphometry layer, where available; otherwise, the EPA used external sources for surface area.
- ***Average annual streamflow.*** For the 2015 Final EA, the EPA selected the average annual streamflow data calculated using the Vogel method in NHDPlus. For the Supplemental EA, the EPA used the updated flow values in NHDPlus Version 2 that were calculated using the Extended Unit Runoff Method (EROM). The EPA determined that EROM was a more up-to-date and robust method for calculating streamflow than the Vogel method due to its use of more recent data in its calculations and availability of estimated monthly flow rates in addition to average annual flow rates.
- ***Freshwater NRWQC.*** The EPA incorporated the updated NRWQCs for cadmium and selenium.
  - ***Cadmium***. The EPA has updated the acute and chronic NRWQCs to match updates finalized in 2016.
  - ***Selenium.*** The EPA has updated the acute and chronic NRWQCs to reflect updates finalized in 2016. Selenium acute and chronic NRWQCs were changed to include discrete values for lotic and lentic systems. This was intended to reflect

differences in selenium bioaccumulation documented in lotic and lentic environments.

IRW Model: Water Quality Module Equations

The EPA calculated the nonvolatile pollutant concentrations for the following compartments within the receiving water:

- Total pollutant concentration in water column (C_{wc}).
- Dissolved pollutant concentration in water column (C_{dw}).
- Total pollutant concentration in sediment (C_{bs}).

The EPA used the equations presented below to calculate receiving water concentrations for arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc.

Equation C-1

$$Cw_{Tot,\ Rivers} = \frac{L_{total}}{(Q_{cool} + Q_{river}) \times f_{water} + K_{wt} \times V_{river}}$$

Where:

$Cw_{Tot,Rivers}$	=	Total pollutant concentration in the waterbody (water and sediment) in rivers and streams from pollutant loading (grams per cubic meter (g/m^3) or milligrams per liter (mg/L))	Output from Equation C-1
L_{total}	=	Average pollutant loading from evaluated wastestreams (grams per day (g/day))	Site-specific value from engineering analysis, based on annual average (see Table C-1)
Q_{cool}	=	Total cooling water effluent flow (cubic meters per day (m^3/day))	Site-specific value from engineering analysis (see Table C-1)
Q_{river}	=	Receiving water average annual flow (m^3/day)	Site-specific value from NHDPlus Version 2 (see Table C-1)
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
K_{wt}	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-10
V_{river}	=	Flow independent mixing volume for rivers and streams (m^3)	Output from Equation C-11

Equation C-2

$$Cw_{Tot,\ Lake} = \frac{L_{total}}{(Q_{cool} + Q_{lake}) \times f_{water} + K_{wt} \times V_{lake}}$$

Where:

$Cw_{Tot,\ Lake}$	=	Total pollutant concentration in the waterbody (water and sediment) in lakes, ponds, and reservoirs from pollutant loading (g/m^3 or mg/L)	Output from Equation C-2
L_{total}	=	Average pollutant loading from evaluated wastestreams (g/day)	Site-specific value from engineering analysis, based on annual average (see Table C-1)
Q_{cool}	=	Total cooling water effluent flow (m^3/day)	Site-specific value from engineering analysis (see Table C-1)
Q_{lake}	=	Average annual flow exiting the lake, pond, or reservoir (m^3/day)	Site-specific value from NHDPlus Version 2 (see Table C-1)
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
K_{wt}	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-10
V_{lake}	=	Flow independent mixing volume for lakes, ponds, and reservoirs (m^3)	Output from Equation C-12

Equation C-3

$$C_{wc} = f_{water} \times Cw_{tot\ (Rivers\ or\ Lakes)} \times \frac{d_z}{d_w}$$

Where:

C_{wc}	=	Total pollutant concentration in water column (mg/L)	Output from Equation C-3
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
Cw_{Tot} (Rivers or Lakes)	=	Total pollutant concentration in the waterbody (water and sediment) from pollutant loading (g/m^3 or mg/L)	Output from Equation C-1 or Equation C-2

d_z (Rivers or Lakes)	=	Depth of the waterbody (meters (m))	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

Equation C-4

$$C_{dw} = C_{wc}\left(\frac{1}{1 + Kd_{sw} \times TSS \times 0.000001}\right)$$

Where:

C_{dw}	=	Dissolved pollutant concentration in water (mg/L)	Output from Equation C-4
C_{wc}	=	Total pollutant concentration in water column (mg/L)	Output from Equation C-3
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (milliliters per gram (mL/g))	Globally assigned value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Regionally assigned value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor

Equation C-5

$$C_{bs} = f_{Benth} \times Cw_{tot\ (Rivers\ or\ Lakes)} \times \frac{d_z}{d_b}$$

Where:

C_{bs}	=	Total pollutant concentration in sediment (mg/L)	Output from Equation C-5
f_{Benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15

Cw_{Tot} (Rivers or Lakes)	=	Total pollutant concentration in the waterbody (water and sediment) from pollutant loading (g/m^3 or mg/L)	Output from Equation C-1 or Equation C-2
d_z (Rivers or Lakes)	=	Depth of the waterbody (m)	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_b (Rivers or Lakes)	=	Depth of upper benthic sediment layer (m)	Globally assigned value of 0.03 m (see Table C-2)

Equation C-6

$$f_{water} = \frac{[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}}{\left[[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right] + \left[(bsp + Kd_{bs} \times bsd) \times \frac{d_b}{d_z}\right]}$$

Where:

f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Globally assigned value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Regionally assigned value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_z (Rivers or Lakes)	=	Depth of the waterbody (m)	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
bsp	=	Bed sediment porosity (cubic centimeter per cubic centimeter (cm^3/cm^3))	Globally assigned value of 0.6 cm^3/cm^3 (see Table C-2)

Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Globally assigned value (see Table C-2 and Table C-4)
bsd	=	Bed sediment bulk density (gram per cubic centimeter (g/cm^3)) or (kilogram per liter (kg/L))	Globally assigned value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic layer (m)	Globally assigned value of 0.03 m (see Table C-2)

Equation C-7

$$d_w = \frac{Q_{river}}{v \times Width}$$

Where:

$d_{w,\,river}$	=	Depth of water column (m)	Output from Equation C-7
Q_{river}	=	Receiving water average annual flow (m^3/s)	Site-specific value from NHDPlus Version 2 (see Table C-1)
v	=	Receiving water velocity (m/s)	Site-specific value from NHDPlus Version 2 (see Table C-1)
$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8

Equation C-8

$$Width_{river} = 5.1867 \times Q_{river}^{0.4559}$$

Where:

$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8
Q_{river}	=	Receiving water average annual flow (m^3/s)	Site-specific value from NHDPlus Version 2 (see Table C-1)

Equation C-9

$$d_{z,\,river} = d_b + d_{w,\,river}$$

Where:

$d_{z,\,river}$	=	Depth of the waterbody (m)	Output from Equation C-9
d_b	=	Depth of upper benthic sediment layer (m)	Globally assigned value 0.03 m (see Table C-2)
$d_{w,\,river}$	=	Depth of water column (m)	Output from Equation C-7

Equation C-10

$$K_{wt} = (f_{water} \times k_{sw}) + (f_{benth} \times k_{sed}) + (f_{water} \times k_{vol}) + (f_{benth} \times K_b)$$

Where:

K_{wt}	=	Water concentration dissipation rate constant (1/day) for nonvolatile pollutants (see Equation C-16 for volatile pollutants)	Output from Equation C-10
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
k_{sw}	=	Degradation rate for water column (1/day)	Globally assigned value of 0/day (see Table C-2)
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
k_{sed}	=	Degradation rate for sediment (1/day)	Globally assigned value of 0/day (see Table C-2)
k_{vol}	=	Water column volatilization loss rate constant (1/day)	Globally assigned value of 0/day (see Table C-2)
K_b	=	Benthic burial rate (1/day)	Output from Equation C-14

Equation C-11

$$V_{river} = Width_{river} \times Len \times d_{z,river}$$

Where:

V_{river}	=	Flow independent mixing volume for rivers and streams (m^3)	Output from Equation C-11
$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8
Len	=	Length of stream reach (m)	Site-specific value from NHDPlus Version 2 (see Table C-1)
$d_{z, river}$	=	Depth of the waterbody (m)	Output from Equation C-9

Equation C-12

$$V_{lake} = Area \times d_{z,lake}$$

Where:

V_{lake}	=	Flow independent mixing volume for lakes, ponds, and reservoirs (m^3)	Output from Equation C-12
Area	=	Surface area of the lake (m^2)	Site-specific value from NHDPlus Version 2 (see Table C-1)
$d_{z,lake}$	=	Depth of the lake (m)	Site-specific value from NHDPlus Version 2 or other data source (see Table C-1)

Equation C-13

$$f_d = \frac{1}{1 + Kd_{sw} \times TSS \times 0.000001}$$

Where:

f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Globally assigned value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Regionally assigned value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor

Equation C-14

$$K_b = f_{benth} \times \frac{WB}{d_b}$$

Where:

K_b	=	Benthic burial rate (1/day)	Output from Equation C-14
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
WB	=	Rate of burial (m/day)	Globally assigned value of 0 m/day (see Table C-2)
d_b	=	Depth of upper benthic sediment layer (m)	Globally assigned value of 0.03 m (see Table C-2)

Equation C-15

$$f_{Benth} = \frac{(bsp + Kd_{bs} \times bsd) \times \frac{d_b}{d_z}}{\left[[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right] + \left[(bsp + Kd_{bs} \times bsd) \times \frac{d_b}{d_z}\right]}$$

Where:

f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
bsp	=	Bed sediment porosity (cm^3/cm^3)	Globally assigned value of 0.6 cm^3/cm^3 (see Table C-2)
Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Globally assigned value (see Table C-2 and Table C-4)
bsd	=	Bed sediment bulk density (g/cm^3) or (kg/L)	Globally assigned value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic sediment layer (m)	Globally assigned value of 0.03 m (see Table C-2)
d_z	=	Depth of the waterbody (m)	Output from Equation C-9
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Globally assigned value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Regionally assigned value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

The EPA calculated the volatile pollutant concentrations in each of the three compartments within the receiving water by building off the equations used to calculate nonvolatile pollutant concentrations. The water concentration dissipation rate constant, K_{wt}, in Equation C-10 was replaced with a $K_{wt,volatile}$ factor (see Equation C-16) that takes into account volatilization loss (k_{vol}). The EPA used the equations presented below in combination with the preceding equations to calculate receiving water concentrations for mercury only.

Equation C-16

$$K_{wt,\ volatile} = (f_{water} \times k_{sw}) + (f_{benth} \times k_{sed}) + (f_{water} \times f_d \times k_{vol}) + (f_{benth} \times K_b)$$

Where:

$K_{wt,\ volatile}$	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-16
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
k_{sw}	=	Degradation rate for water column (1/day)	Globally assigned value of 0/day (see Table C-2)
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
k_{sed}	=	Degradation rate for sediment (1/day)	Globally assigned value of 0/day (see Table C-2)
f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13
k_{vol}	=	Water column volatilization loss rate constant (1/day)	Output from Equation C-17
K_b	=	Benthic burial rate (1/day)	Output from Equation C-14

Equation C-17

$$k_{vol} = \frac{K_v \times f_d}{d_w}$$

Where:

k_{vol}	=	Water column volatilization loss rate constant (1/day)	Output from Equation C-17
K_v	=	Diffusion transfer rate (m/day)	Output from Equation C-18
f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

Equation C-18

$$K_v = \frac{1}{\left(\frac{1}{K_L}\right) + \left(\frac{1}{K_g \times \left(\frac{HLC}{R \times T_w}\right)}\right)} \theta_{water}^{(T_w - T_{hic})}$$

Where:

K_v	=	Diffusion transfer rate (m/day)	Output from Equation C-18
Θ_{water}	=	Temperature correction (unitless)	Globally assigned value of 1.026 (see Table C-2)
T_w	=	Temperature of the waterbody (Kelvin (K))	River or stream: regionally assigned value (see Table C-3 and Table C-6) Lake, pond, or reservoir: globally assigned value (see Table C-3 and Table C-6)
T_{hlc}	=	Temperature of Henry's Law Constant (HLC) (K)	Globally assigned value of 298 K (see Table C-2)
K_L (Rivers or Lakes)	=	Liquid-phase transfer coefficient (m/day)	River or stream: output from Equation C-19 Lake, pond, or reservoir: output from Equation C-21
K_g (Rivers or Lakes)	=	Gas-phase transfer coefficient (m/day)	River or stream: globally assigned value of 100 m/day (see Table C-2) Lake, pond, or reservoir: output from Equation C-23
HLC	=	Henry's Law Constant (atm-m^3/mole) [1]	Globally assigned value of 0.0113 atm-m^3/mol (see Table C-2)
R	=	Universal gas constant (atm-m^3/K-mole)	Globally assigned value of 0.00008205 atm-m^3/K-mole (see Table C-2)

[1] Units for Henry's Law Constant are atmospheres of absolute pressure (atm) per cubic meter (m^3) per mole (mol).

Equation C-19

$$K_{L(Rivers)} = \sqrt{\frac{10^{-4} \times D_w \times v}{d_z}} \times 86{,}400$$

Where:

$K_{L(Rivers)}$	=	Liquid-phase transfer coefficient (m/day)	Output from Equation C-19
D_w	=	Diffusivity of the pollutant in water (square centimeter per second (cm^2/s))	Output from Equation C-20
v	=	Receiving water velocity (m/s)	Site-specific value from NHDPlus Version 2 (see Table C-1)
$d_{z,river}$	=	Depth of waterbody (m)	Output from Equation C-9
86,400	=	Conversion factor (s/day)	Conversion factor

Equation C-20

$$D_w = \frac{22 \times 10^{-5}}{MW^{2/3}}$$

Where:

D_w	=	Diffusivity of the pollutant in water (cm^2/s)	Output from Equation C-20
MW	=	Molecular weight (grams per mole (g/mol))	Globally assigned value of 200.59 g/mol for mercury (see Table C-2)

Equation C-21

$$K_{L(Lakes)} = \sqrt{C_d} \times w_{10} \times \sqrt{\frac{\rho_a}{\rho_w}} \times \left(\frac{k^{0.33}}{\lambda_2}\right) \times Sc_w^{-0.67} \times 86{,}400$$

Where:

$K_{L(Lakes)}$	=	Liquid-phase transfer coefficient (m/day)	Output from Equation C-21
C_d	=	Drag coefficient (unitless)	Globally assigned value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Regionally assigned value (see Table C-3)
ρ_a	=	Density of air corresponding to water temperature (g/cm^3)	Globally assigned value of 0.0012 g/cm^3 (see Table C-2)

ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Globally assigned value of 1 g/cm^3 (see Table C-2)
k	=	Von Karman's constant (unitless)	Globally assigned value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Globally assigned value of 4 (see Table C-2)
Sc_w	=	Water Schmidt number (dimensionless)	Output from Equation C-22
86,400	=	Conversion factor (s/day)	Conversion factor

Equation C-22

$$Sc_w = \frac{\mu_w}{\rho_w \times D_w}$$

Where:

Sc_w	=	Water Schmidt number (dimensionless)	Output from Equation C-22
μ_w	=	Viscosity of water corresponding to water temperature (g/cm-s)	Globally assigned value of 0.0169 g/cm-s (see Table C-2)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Globally assigned value of 1 g/cm^3 (see Table C-2)
D_w	=	Diffusivity of the pollutant in water (cm^2/s)	Output from Equation C-20

Equation C-23

$$K_{g(Lakes)} = \sqrt{C_d} \times W_{10} \times \left(\frac{k^{0.33}}{\lambda_2}\right) \times Sc_a^{-0.67} \times 86{,}400$$

Where:

$K_{g(lakes)}$	=	Gas-phase transfer coefficient (m/day)	Output from Equation C-23
C_d	=	Drag coefficient (unitless)	Globally assigned value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Regionally assigned value (see Table C-3)
k	=	Von Karman's constant (unitless)	Globally assigned value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Globally assigned value of 4 (see Table C-2)
Sc_a	=	Air Schmidt number (dimensionless)	Output from Equation C-24
86,400	=	Conversion factor (s/day)	Conversion factor

Equation C-24

$$Sc_a = \frac{(1.32 + 0.009T_a) \times 10^5}{\frac{1.9}{MW^{2/3}}}$$

Where:

Sc_a	=	Air Schmidt number (dimensionless)	Output from Equation C-24
T_a	=	Air temperature (K)	Regionally assigned value (see Table C-3)
MW	=	Molecular weight (g/mol)	Globally assigned value of 200.59 g/mol for mercury (see Table C-2)

The EPA calculated the potential water quality impacts to aquatic life and humans by comparing the pollutant concentration in the water column (C_{wc} or C_{dw}, depending on the benchmark) to the water quality benchmark values presented in Table C-7.

IRW Model: Water Quality Module Inputs

Table C-1. Input Variables with Values from Site-Specific Data Sources

Input Variable	Input Category and Description	Site-Specific Data Source
L_{total}	Plant-specific effluent characteristic. Total waterbody loading.	The EPA estimated the pollutant discharge loadings using the methodology presented in the Supplemental TDD.
Q_{cool}	Plant-specific effluent characteristic. Total cooling water effluent flow by receiving water.	The EPA determined the estimated cooling water flow for each plant by outfall based an assessment of industry survey results using the methodology outlined in the memorandum "Receiving Water Characteristics Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (the Receiving Water Characteristics memorandum) (ERG, 2019d).
Q_{river}	Receiving water characteristic for rivers and streams. Waterbody annual flow.	The EPA extracted average annual flow values from the NHDPlus Version 2 data set using the methodology outlined in the Receiving Water Characteristics memorandum (ERG, 2019d). ERG used the average annual flow values calculated using the Enhanced Runoff Method (EROM). See the memorandum "Monthly Water Quality Modeling Analysis and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (the Monthly Water Quality Modeling memorandum) (ERG, 2019j) regarding the flow values used in the supplemental monthly analysis.

Table C-1. Input Variables with Values from Site-Specific Data Sources

Input Variable	Input Category and Description	Site-Specific Data Source
v	Receiving water characteristic for rivers and streams. Receiving water velocity.	The EPA extracted average annual velocity values from the NHDPlus Version 2 data set using the methodology outlined in the Receiving Water Characteristics memorandum (ERG, 2019g). The NHDPlus Version 2 data set includes estimated mean annual velocity values for each stream reach within the network using the Jobson Method (Jobson, 1996) and the estimated mean annual flow values.
Len	Receiving water characteristic for rivers and streams. Length of stream reach.	The EPA estimated the stream reach length based on outfall locations using the methodology described in the Receiving Water Characteristics memorandum (ERG, 2019d).
Q_{lake}	Receiving water characteristic for lakes, ponds, and reservoirs. Average discharge flow exiting the lake/pond system.	The EPA extracted average annual flow values from the NHDPlus Version 2 data set using the methodology outlined in the Receiving Water Characteristics memorandum (ERG, 2019d). ERG used the average annual flow values calculated using EROM.
Area	Receiving water characteristic for lakes, ponds, and reservoirs. Surface area of the lake, pond, or reservoir.	The EPA estimated the surface area of the lake, pond, or reservoir based on the surface area field from the NHDPlus Version 2 Lake Morphometry data layer, or site-specific data as described in the Receiving Water Characteristics memorandum (ERG, 2019d).
$d_{z,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs. Depth of the lake, pond, or reservoir.	The EPA estimated the depth of the lake, pond, or reservoir based on the mean depth field from the NHDPlus Version 2 Lake Morphometry data layer, or site-specific data as described in the Receiving Water Characteristics memorandum (ERG, 2019d).
$d_{w,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs. Depth of the water column.	The EPA estimated the depth of the lake, pond, or reservoir based on the mean depth field from the NHDPlus Version 2 Lake Morphometry data layer, or site-specific data as described in the Receiving Water Characteristics memorandum (ERG, 2019d).

Table C-2. Input Variables and Constants with Globally Assigned Values

Input Variable or Constant	Description	Assigned Value	Rationale/Data Source
bsp	Bed sediment porosity.	0.6 cm^3/cm^3	Bed sediment porosity is the volume of water per volume of benthic space with typical values ranging between 0.4 and 0.8 (U.S. EPA, 1998). The EPA selected an average value to use for this input variable.
bsd	Bed sediment bulk density.	1 g/cm^3	Bed sediment bulk densities typically range between 0.5 to 1.5 g/cm^3 (U.S. EPA, 1998). The EPA selected an average value to use for this input variable.
d_b	Depth of upper benthic layer.	0.03 m	The upper benthic layer variable represents the portion of the bed in equilibrium with the water column. Typical values can range from 0.01 to 0.05 m (U.S. EPA, 1998). The EPA selected an average value to use for this input variable.
k_{sw}	Degradation rate for water column.	0/day	The EPA assumed no loss from pollutant degradation in the water column, as an environmentally conservative assumption.
k_{vol}	Water column volatilization loss rate constant.	0/day	The EPA selected a volatilization rate of 0 for nonvolatile pollutants (i.e., all pollutants except mercury).
k_{sed}	Degradation rate for sediment.	0/day	The EPA assumed no loss from pollutant degradation in the sediment, as an environmentally conservative assumption.
WB	Rate of burial.	0/day	The EPA assumed no pollutant loss from burial within the waterbody sediments, as an environmentally conservative assumption.
Θ_{water}	Temperature correction.	1.026 (unitless)	The EPA selected the temperature correction factor based on the value provided in U.S. EPA (1998).
$K_{g(Rivers)}$	Gas phase transfer coefficient for rivers or streams.	36,500 m/yr (100 m/day)	The EPA selected the gas phase transfer coefficient for rivers and streams based on the value provided in U.S. EPA (1998).
R	Ideal gas constant.	0.00008205 atm-m^3/ K-mole	The ideal gas constant is a known chemical constant.
C_d	Drag coefficient.	0.0011 (unitless)	The EPA selected the drag coefficient based on the value provided in U.S. EPA (1998).
ρ_a	Density of air corresponding to water temperature.	0.0012 g/cm^3	The EPA selected the density of air corresponding to water temperature based on the value provided in U.S. EPA (2005a).
ρ_w	Density of water corresponding to water temperature.	1 g/cm^3	The EPA selected the density of water corresponding to water temperature based on the value provided in U.S. EPA (2005a).
k	Von Karman's constant.	0.4 (unitless)	The von Karman constant is a known dimensionless constant used to describe the velocity profile of a turbulent fluid flow near a boundary.

Table C-2. Input Variables and Constants with Globally Assigned Values

Input Variable or Constant	Description	Assigned Value	Rationale/Data Source
Kd_{sw}	Suspended sediment-surface water partition coefficient.	See Table C-4	The suspended sediment partition coefficient describes the partitioning of a pollutant between sorbing material, in this case suspended sediment and surface water. The EPA identified U.S. EPA (2005a) as the primary source for the pollutant-specific suspended sediment partition coefficients.
Kd_{bs}	Bottom sediment-pore water partition coefficient.	See Table C-4	The bottom sediment partition coefficient describes the partitioning of a pollutant between sorbing material, in this case bottom sediment and pore water. The EPA identified U.S. EPA (2005a) as the primary source for the pollutant-specific bottom sediment partition coefficients.
λ_2	Dimensionless viscous sublayer thickness.	4 (unitless)	The EPA selected the viscous sublayer thickness value based on the value provided in U.S. EPA (2005a).
μ_w	Viscosity of water corresponding to water temperature.	0.0169 g/cm-s	The EPA selected the viscosity of water value based on the value provided in U.S. EPA (2005a).
HLC	Henry's Law Constant.	0.0113 atm-m^3/mol	Henry's Law Constant is used in Equation C-18 to estimate the receiving water concentration for volatile pollutants. Mercury is the only volatile pollutant included in the IRW Model. Therefore, the assumed model default value is set to Henry's Law Constant for mercury at 298 K.
T_{hlc}	Temperature of Henry's Law Constant.	298 K	The value 298 K is the standard temperature value provided for Henry's Law Constant.
MW	Molecular weight.	200.59 g/mol	Molecular weight is used in Equation C-20 and Equation C-24 to estimate the receiving water concentration for volatile pollutants. Mercury is the only volatile pollutant included in the IRW Model. Therefore, the assumed model default value is set to the molecular weight for mercury.

Table C-3. Input Variables with Values from Regional Data Sources

Input Variable	Description	Assigned Value	Regional Data Source
TSS	Total suspended solids.	See Table C-5	The EPA used the geometric mean of the regional and national TSS concentrations determined as part of the *Human and Ecological Risk Assessment of Coal Combustion Residuals* (U.S. EPA, 2014).
W_{10}	Wind velocity 10 m above the water surface.	See Figure C-1	National Climatic Data Center national mean annual wind speed GIS coverage, downloaded on May 12, 2011 (NCDC, 2011). The EPA selected, as an environmentally conservative estimate, the lower of the wind speed range values for the analysis.
T_a	Air temperature.	See Figure C-2	National Climatic Data Center national mean annual temperature GIS coverage, downloaded on May 12, 2011 (NCDC, 2011). The EPA selected, as an environmentally conservative estimate, the lower of the air temperature range values for the analysis.
T_w	Temperature of the surface water.	See Table C-6	The EPA used the regional surface temperatures determined as part of the *Human and Ecological Risk Assessment of Coal Combustion Residuals* (U.S. EPA, 2014).

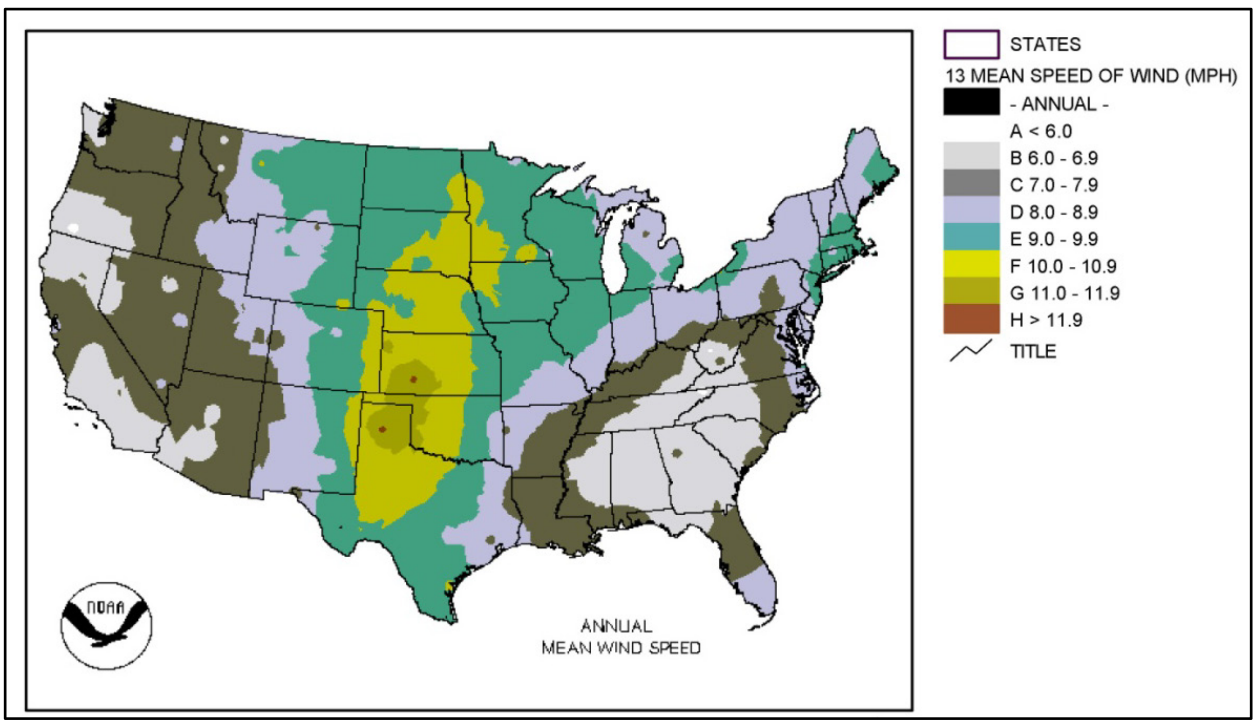

Figure C-1. National Climatic Data Center National Mean Annual Wind Speeds

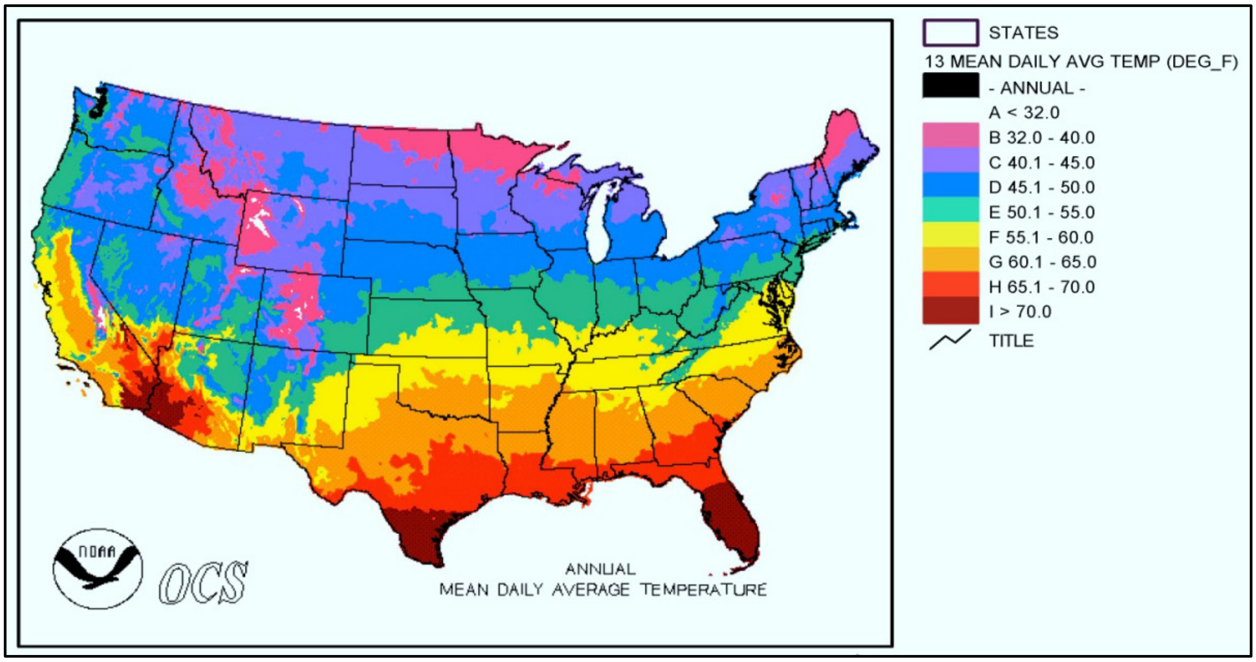

Figure C-2. National Climatic Data Center National Mean Annual Temperatures

Table C-4. Partition Coefficients

Pollutant	Suspended Sediment-Water Partition Coefficient (Kd_{sw}) (mL/g)	Bottom Sediment-Pore Water Partition Coefficient (Kd_{bs}) (mL/g)
Arsenic	7,900	250
Cadmium	79,000	2,000
Copper	50,000	3,200
Lead	500,000	40,000
Mercury (II)	200,000	79,000
Nickel	20,000	7,900
Selenium (IV)	25,000	4,000
Thallium	13,000	20
Zinc	100,000	13,000

Source: U.S. EPA, 2005a.

Table C-5. TSS Concentrations in Surface Waters

Hydrologic Region [a]	Number of Measurements	Number of Annual Medians	Annual Median TSS (mg/L) (log triangular distribution)		
			Min	Max	Weighted Geometric Mean
1	9,007	33	3.2	40	8
2	47,202	38	10	316	32
3	43,395	36	6.3	79	25
4	29,577	37	6.3	794	25
5	39,900	38	4	100	25
6	4,137	28	5	316	16
7	34,494	37	32	1,585	63
8	46,231	38	50	316	158
9	3,254	35	13	3,162	32
10	62,791	38	10	398	126
11	48,969	38	25	794	200
12	7,280	35	40	1,995	79
13	13,974	37	32	79,433	200
14	26,699	38	16	5,012	158
15	9,162	37	20	19,953	200
16	19,965	33	4	2,512	16
17	173,136	37	2	316	6
Lakes (national)	4,360	99	1	398	25

Source: U.S. EPA, 2014; Legacy STORET database.

a – For rivers and streams, the EPA used the weighted geometric mean TSS concentration for the corresponding hydrogeologic region. For lakes, ponds, and reservoirs, the EPA used a weighted national geometric mean.

Table C-6. Regional Surface Water Temperatures

Hydrologic Region	Climate	Surface Water Temperature (°C)	Surface Water Temperature (K)
1	North	14	287
2	North	16	289
3	South	21	294
4	North	14	287
5	North	17	290
6	South	18	291
7	North	15	288
8	South	20	293
9	North	10	283
10	North	13	286
11	South	17	290
12	South	21	294
13	South	16	289
14	South	9	282
15	South	17	290
16	South	9	282
17	North	11	284

Source: U.S. EPA, 2014; Legacy STORET database.

Table C-7. NRWQC and MCLs

Pollutant	FW Acute NRWQC [a,b] (mg/L)	FW Chronic NRWQC [a,b] (mg/L)	HH WO NRWQC [a,b] (mg/L)	HH O NRWQC [a,b] (mg/L)	MCL [a,c] (mg/L)
Arsenic	0.34 [d]	0.15 [d]	0.000018 [e]	0.00014 [e]	0.01
Cadmium	0.0018 [d,f]	0.00072 [d,f]	--	--	0.005
Copper	0.013 [d,g]	0.009 [d,g]	1.3	--	1.3 (Action Level); 1.0 [h]
Lead	0.065 [d]	0.0025 [d]	--	--	0.015 (Action Level)
Mercury	0.0014 [d]	0.00077 [d]	--	--	0.002 [e]
Nickel	0.47 [d]	0.052 [d]	0.61	4.6	--
Selenium	Lentic: 0.045 [i] Lotic: 0.094 [i]	Lentic: 0.0015 [j] Lotic: 0.0031 [j]	0.17	4.2	0.05
Thallium	--	--	0.00024	0.00047	0.002
Zinc	0.12 [d]	0.12 [d]	7.4	26	5 [h]

Acronyms: MCL (Maximum Contaminant Level); mg/L (milligrams per liter); NRWQC (National Recommended Water Quality Criteria).

Source: U.S. EPA, 2009a, 2009c, 2016c, and 2016d.

a – "--" designates instances where a benchmark value does not exist for the pollutant, or the benchmark value is a secondary standard.

b – Unless otherwise noted, pollutant concentrations were compared to the freshwater (FW) acute and chronic NRWQC and the human health (HH) water and organisms (WO) and organisms only (O) NRWQC from the EPA's *National Recommended Water Quality Criteria* (U.S. EPA, 2009c).

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

d – Benchmark value is expressed in terms of the dissolved pollutant in the water column.

e – Benchmark value is for inorganic form of pollutant.

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

g – The 2009 NRWQC for copper are calculated using the biotic ligand model; therefore, there is no national value. For this analysis, the EPA used the 2002 NRWQC values (U.S. EPA, 2002).

h – The 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. The results presented in Section 4 of the report and Appendix F are based on the number of immediate receiving waters with exceedances of the lower secondary drinking water standard (1.0 mg/L).

i – The selenium benchmark values are based on the NRWQC from the EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium – Freshwater 2016* (U.S. EPA, 2016c). The selenium acute NRWQC, as calculated here, assumes a background selenium concentration of zero and an intermittent exposure duration of 1 day, which is the shortest exposure period to be used when applying the criterion.

j – The selenium benchmark values are based on the NRWQC from the EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium – Freshwater 2016* (U.S. EPA, 2016c). 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.

IRW Model: Water Quality Module Methodology Limitations and Assumptions

The limitations and assumptions of the Water Quality Module include the following:

- The module is based on annual-average pollutant loadings from the two evaluated wastestreams at coal-fired power plants and annual-average flow rates within the immediate receiving waters. The module does not consider temporal variability (e.g., seasonal differences, storm flows, low-flow events, catastrophic events) and does not consider the potential for pollutants to accumulate in the environment over extended discharge periods covering multiple years. The effect of this limitation on the Water Quality Module outputs is undetermined, but it is likely to underestimate the long-term accumulation of pollutants within lakes, ponds, and reservoirs; this may subsequently underestimate the wildlife and human health impacts resulting from exposure to pollutants in these systems. To illustrate potential short-term temporal variability, the EPA also performed Water Quality Module runs using average monthly pollutant loadings and receiving water flow rates. This analysis is documented in the Monthly Water Quality Modeling memorandum (ERG, 2019j) and the results are discussed in Section 4.4 of the report.
- The module represents only the waterbody concentration within the immediate discharge zone (i.e., approximately 1 to 5 miles from the outfall) and does not calculate pollutant concentrations in downstream waters. This limitation results in a potential underestimate of the extent of surface waters with environmental and human health impacts under baseline, as well as changes under the regulatory options. However, the EPA performed a downstream analysis using the outputs from a separate pollutant fate and transport model. This analysis is documented in the memorandum "Downstream EA Modeling Methodology and Supporting Documentation for the 2019 Steam Electric Supplemental Environmental Assessment" (ERG, 2019g), and the results are discussed in Section 4.5 of the report.
- The module does not take into consideration pollutant speciation within the receiving stream. This limitation is particularly relevant to the wildlife impact analysis, as many of the ecological impacts are tied to a specific pollutant species. For example, inorganic arsenic is typically more toxic to aquatic life than organic arsenic. This limitation results in a potential overestimation of the number of immediate receiving waters with exceedances of water quality benchmark values for inorganic forms of the pollutant (e.g., the human health NRWQCs for arsenic).
- The module assumes that equilibrium is quickly attained within the waterbody following discharge and is consistently maintained between the water column and surficial bottom sediments. This assumption is especially significant regarding pollutant equilibrium within lakes, ponds, and reservoirs. The module equations presented in Appendix C do not take into consideration the effects of currents, inversion, or temperature variations within the water column, but assume that the entire mass of the lake, pond, or reservoir is at equilibrium. As a result, the module outputs do not reflect the potential spatial and temporal variability of pollutant concentrations within the immediate receiving water, and potentially underestimate the existence of isolated "hot spots" of elevated pollutant concentrations.

- The module assumes that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a partition coefficient. The EPA used a single partition coefficient to characterize the pollutant in the immediate receiving waters. The partition coefficient in a specific waterbody will be influenced by geochemical parameters (e.g., pH and presence of particulate organic matter and other sorbing material). The EPA used a mean or median value for the partition coefficients (central tendency of K_d values) based on data gathered from published sources, statistical analysis of retrieved data, geochemical modeling, and expert judgment (U.S. EPA, 2005a). The result of this assumption on the Water Quality Module outputs is undetermined due to site-specific factors.
- The module assumes that pollutants sorbed to bottom sediments are considered a net loss from the water column. This assumes that bottom sediments are not resuspended and deposited further downstream but remain within the immediate discharge zone and do not further contribute to the dissolved or suspended sediment concentrations within the water column. This assumption results in a potential overestimation of pollutant concentrations within the bottom sediments and a potential underestimation of pollutant concentrations within the water column and downstream reaches.
- The module assumes a pollutant burial rate of zero within bottom sediment. This is an environmentally protective assumption that might overestimate impacts to sediment receptors to some degree. The burial rate constant is a function of the deposition of sediments from the water column to the upper bed and accounts for the soil eroding into a waterbody becoming bottom sediment rather than suspended sediment. The rate of burial used for each segment of a waterbody may be difficult to obtain (U.S. EPA, 1998). The EPA had neither measured values nor the data to determine burial rates for each immediate receiving water. This assumption results in a potential overestimation of impacts in the bottom sediment.
- The module does not take into account ambient background pollutant concentrations or contributions from other point and nonpoint sources. Also, the pollutant loadings included in the module are not representative of the total pollutant loadings from coal-fired power plants, as there are several wastestreams that are not included in the analysis (e.g., fly ash transport water, leachate, stormwater runoff, metal cleaning wastes, and coal pile runoff). Because of this approach, the module likely underestimates the number and magnitude of benchmark value exceedances at baseline and under the regulatory options, which contributes to uncertainty in the number of environmental and human health improvements or impacts under the regulatory options relative to baseline.

APPENDIX D
WILDLIFE MODULE METHODOLOGY

This appendix presents the model equations, input variables and constants, pollutant benchmark values, and methodology limitations/assumptions for the Wildlife Module of the Immediate Receiving Water (IRW) Model, which quantifies impacts to the following ecological receptors:

- Aquatic and sediment organisms (amphibians, fish, invertebrates) in direct contact with receiving water and/or sediment in the immediate discharge zone of coal-fired power plants.
- Wildlife (minks and eagles)[2] that consume fish from receiving waters in the immediate discharge zone of coal-fired power plants.

For the supplemental environmental assessment (Supplemental EA), the EPA estimated pollutant concentrations in the immediate receiving water and sediment using the Water Quality Module (see Appendix C). The Wildlife Module uses these concentrations as inputs.

The following tables describe the input requirements and data sources used in the Wildlife Module:

- Table D-1. Threshold Effect Concentrations (TECs) for Sediment Biota.
- Table D-2. Bioconcentration Factors (BCFs) and Bioaccumulation Factors (BAFs) for Trophic Level 3 (T3) and Trophic Level 4 (T4) Fish.
- Table D-3. No Effect Hazard Concentrations (NEHCs) for Minks and Bald Eagles.

Methodology Updates Subsequent to the 2015 Final EA

Since the completion of the 2015 Final EA, the EPA incorporated the following updates to the equations, data sets, and parameter values used in the Wildlife Module:

- **Sediment threshold effect concentrations:** For the 2015 Final EA, the EPA used threshold effect levels (TELs) referenced in a single study (NOAA, 2008) as the benchmark values for impacts to sediment biota. For the Supplemental EA, the EPA replaced the TELs with threshold effect concentrations (TECs) developed through a consensus-based process (MacDonald et al., 2000). MacDonald et al. (2000) used six sets of sediment quality guidelines to develop the TECs.
- **Sediment benchmark value for selenium:** For the 2015 Final EA, the EPA did not identify a sediment benchmark value for selenium. For the Supplemental EA, the EPA identified and used a sediment benchmark value for selenium developed by Lemly (2002) using a long-term selenium concentration data set collected from 1970 through 1996 at Belews Lake, NC. Lemly recommended 2 micrograms selenium per gram of sediment (µg/g, equivalent to g/kg) as a toxicity benchmark value that would

[2] The EPA selected minks and eagles to represent national-scale impacts from coal-fired power plants because their habitats cover the entire United States (i.e., can be used for a national assessment).

be protective of reproductive success in fish and aquatic birds that bioaccumulate selenium through consumption of benthic organisms.

- **Revised Equation D-1:** The TELs used in the 2015 Final EA were expressed based on a wet weight basis, while the TECs used in the Supplemental EA are expressed on a dry weight basis. To accommodate this change, the EPA revised Equation D-1 to convert the pollutant concentration in sediment (C_{bs}) from a volume basis (mg/L) to a dry weight basis (mg/kg) using the assumed values in the Water Quality Module for bed sediment bulk density and porosity.
- **Cadmium bioconcentration factor:** In the 2015 Final EA, the EPA used a cadmium bioconcentration factor (BCF) of 270 liters per kilogram (L/kg), derived from Kumada et al. (1972), and applied this BCF to both trophic level 3 (T3) and trophic level 4 (T4) fish. For the Supplemental EA, the EPA calculated an updated cadmium BCF using the bioaccumulation data sets available in Appendix G of the U.S. EPA's *Aquatic Life Ambient Water Quality Criteria for Cadmium – 2016* (U.S. EPA, 2016d), which presents a set of "Acceptable Bioaccumulation Data" that were reviewed during development of the revised criteria. The EPA's calculations, which resulted in an updated cadmium BCF of 113 L/kg for both trophic levels, are documented in the Cadmium BCF Calculation spreadsheet (ERG, 2019k).

IRW Model: Wildlife Module Equations, Input Variables, and Impact Analysis

Impact to Aquatic Life Receptors from Direct Contact with Sediment. The EPA determined the potential negative impact to aquatic organisms from direct contact with the sediment in immediate receiving waters by comparing the pollutant concentration in the sediment (C_{bs} from the Water Quality Module) to the consensus-based TECs for sediment biota listed in Table D-1. The Wildlife Module expresses this comparison as a hazard quotient (HQ). An HQ of higher than one (i.e., pollutant concentration exceeds the TEC) indicates a potential impact to the exposed organism. The EPA used Equation D-1 to calculate the HQ for sediment biota.

EQUATION D-1

$$HQ_{sed} = \frac{\left(\frac{C_{bs}}{bsd}\right) \times \left(\frac{1}{1 - bsp}\right)}{TEC_{sed}}$$

Where:

HQ_{sed}	=	Hazard quotient for contact with sediment	Output from Equation D-1
C_{bs}	=	Total pollutant concentration in sediment (milligrams per liter (mg/L))	Water Quality Module output from Equation C-5
bsd	=	Bed sediment bulk density (gram per cubic centimeter (g/cm^3)) or (kilogram per liter (kg/L))	Globally assigned value of 1 g/cm^3 (see Table C-2)
bsp	=	Bed sediment porosity (cubic centimeter per cubic centimeter (cm^3/cm^3))	Globally assigned value of 0.6 cm^3/cm^3 (see Table C-2)

TEC_{sed}	=	Threshold effect concentration for sediment (milligrams per kilograms (mg/kg), dry weight basis)	Receptor-specific value (see Table D-1)

Adverse Effects to Piscivorous Wildlife. The EPA determined the potential negative impact to piscivorous wildlife (i.e., wildlife that consume fish) from the ingestion of contaminated fish by calculating fish tissue concentrations and comparing these concentrations to NEHCs as the selected ecological benchmark values. Equation D-2 calculates pollutant concentrations in fish for the evaluated pollutants, except for mercury. Because the more toxic form of mercury is methylmercury, the EPA used Equation D-3 for this pollutant (U.S. EPA, 2005b). Equation D-3 estimates the concentration of methylmercury in fish tissue, as opposed to total mercury.

The EPA compared the calculated T3 fish tissue concentration to the NEHC for minks and the calculated T4 fish tissue concentration to the NEHC for eagles (see Table D-3). The Wildlife Module expresses this comparison as an HQ. The EPA used Equation D-4 to calculate HQ values for arsenic, cadmium, copper, lead, mercury (as methylmercury), nickel, selenium, thallium, and zinc.

Equation D-2

$$C_{fishT} = C_{wc} \times BCF_T$$

Equation D-3

$$C_{fishT} = (0.15 \times C_{dw}) \times BCF_T$$

Where:

C_{fishT}	=	Pollutant concentration in fish (wet weight), where T represents trophic level T3 or T4 (mg/kg)	Output from Equation D-2 or Equation D-3
C_{wc}	=	Total pollutant concentration in water (mg/L)	Water Quality Module output from Equation C-3
C_{dw}	=	Dissolved pollutant concentration in water (mg/L)	Water Quality Module output from Equation C-4
0.15	=	Fraction of dissolved total mercury as dissolved methylmercury (unitless)	Globally assigned value (U.S. EPA, 2005b)
BCF_T	=	Bioconcentration factor or bioaccumulation factor for specified trophic level (liters per kilogram (L/kg))	Pollutant-specific value (see Table D-2)

Equation D-4

$$HQ_I = \frac{C_{fishT}}{NEHC}$$

Where:

HQ_I	=	Hazard quotient for ingestion of fish	Output from Equation D-4
C_{fishT}	=	Pollutant concentration in fish (wet weight), where T represents trophic level T3 or T4 (mg/kg)	Output from Equation D-2 or Equation D-3
NEHC	=	No effect hazard concentration (µg/g)	Receptor- and pollutant-specific (see Table D-3)

Table D-1. TECs for Sediment Biota

Pollutant in Wildlife Impact Assessment	TEC (mg/kg)	Notes/Source
Arsenic	9.79	MacDonald et al., 2000.
Cadmium	0.99	MacDonald et al., 2000.
Copper	31.6	MacDonald et al., 2000.
Lead	35.8	MacDonald et al., 2000.
Mercury	0.18	MacDonald et al., 2000.
Nickel	22.7	MacDonald et al., 2000.
Selenium	2	Lemly, 2002.
Thallium	None identified	The EPA could not complete the analysis for this pollutant – no TEC available for comparison.
Zinc	121	MacDonald et al., 2000.

Acronyms: mg/kg (milligrams per kilogram); TEC (Threshold Effect Concentration).

Table D-2. BCFs and BAFs for T3 and T4 Fish

Pollutant	BCF or BAF	Factor for T3 Fish (L/kg)	Factor for T4 Fish (L/kg)	Source
Arsenic	BCF	4	4	Barrows et al., 1980.
Cadmium	BCF	113	113	ERG, 2019k.
Copper [a]	BCF	36	36	U.S. EPA, 1980b.
Lead	BAF	46	46	Stephan, 1993.
Methylmercury	BAF	1.6×10^6	6.8×10^6	U.S. EPA, 1997a.
Nickel [b]	BCF	0.8	0.8	Calamari et al., 1982.
Selenium	BAF	490	1,700	Lemly, 1985.
Thallium	BCF	34	130	Barrows et al., 1980 and Stephan, 1993.
Zinc	BCF	350	350	Murphy et al., 1978.

Acronyms: BAF (bioaccumulation factor); BCF (bioconcentration factor); L/kg (liters per kilogram); T3 (trophic level 3); T4 (trophic level 4).

a – BCF not specific to a particular trophic level; applies to fish consumed by humans.

b – Nickel (soluble salts).

Table D-3. NEHCs for Minks and Bald Eagles

Pollutant in Wildlife Impact Assessment	NEHC for Mink (T3 Fish) (µg/g)	NEHC for Eagle (T4 Fish) (µg/g)	Notes
Arsenic	7.65	22.4	
Cadmium	5.66	14.7	
Copper	41.2	40.5	
Lead	34.6	16.3	
Methylmercury	0.37	0.5	No NEHC for methylmercury. The EPA compared the modeled methylmercury concentrations to the total mercury NEHC, which may underestimate the impact to wildlife.
Nickel	12.5	67.1	
Selenium	1.13	4	
Thallium	None identified	None identified	The EPA could not complete the analysis for this pollutant – no NEHC available for comparison.
Zinc	904	145	

Source: USGS, 2008.

Acronyms: µg/g (micrograms per gram); NEHC (No Effect Hazard Concentration); T3 (trophic level 3); T4 (trophic level 4).

IRW Model: Wildlife Module Methodology Limitations and Assumptions

The limitations and assumptions of the Wildlife Module include the following:

- ***Cumulative Risks Across Exposure Pathways.*** The Wildlife Module does not consider cumulative risks across exposure pathways. For example, the modeled impacts to wildlife from ingesting contaminated fish do not consider the risk from direct contact with surface water. The receptors chosen for the wildlife ingestion model, minks and eagles, do not spend much time in contact with the surface water; therefore, not including the impact of direct contact with surface water should only minimally underestimate the impacts. In addition, the Wildlife Module does not consider the impact from water ingestion. Because many of the pollutants considered in this analysis are bioaccumulative in nature, the model considers only ingestion of the food source, because it is likely that the dose from the food source is far greater than the dose from water ingestion. However, the Wildlife Module may underestimate bioaccumulation among aquatic species that do ingest relatively greater volumes of water.
- ***Use of BCFs and BAFs***. Where available, the EPA used BAFs to represent the accumulation of pollutants in fish tissue (e.g., for selenium and methylmercury). Otherwise, the EPA used BCFs, which do not account for accumulation of pollutants via the food web. For certain pollutants, exposure via the aquatic food web can be more significant than exposure via ingestion of water.[3] The result of this limitation on the Wildlife Module output for those pollutants that use a BCF is an under-representation of pollutant bioaccumulation in fish tissue where exposure via the aquatic food web is significant. However, BCFs are useful in a screening-level assessment and appropriate for a national-level EA, where site-specific data are not available and collection of site-specific data is not viable. The limitation of using a single, national-level BAF/BCF is undetermined due to site-specific factors.
- ***Receptor Populations Evaluated.*** The EPA considered the limitations and made multiple assumptions in choosing receptor populations to evaluate. First, the EPA assumed that, because this is a national model, the receptor species and receiving water occur together (i.e., all receiving waters evaluated in the Wildlife Module are habitat for the receptor species, even though that may not always be the case). In addition, due to the scope of the project, the EPA considered a limited number of species as receptors. For the wildlife receptors, the EPA chose minks and eagles due to their national distribution and data available to conduct the analysis (USGS, 2008). By choosing a limited number of species, the Wildlife Module inherently excludes the impacts to critical assessment endpoints such as threatened and endangered species.

[3] The EPA Office of Water Health and Ecological Criteria Division agrees that all the routes (food, sediment, and water) by which fish and shellfish are exposed to highly bioaccumulative pollutants may be important in determining the accumulation in fish tissue and the subsequent transfer to human receptors. In addition, the EPA agrees that distributions of BAFs/BCFs may be better than single BAFs/BCFs because they account for changes in bioaccumulation/bioconcentration rates at different water concentrations. The EPA is working to develop BAF/BCF distributions for several pollutants to better represent the bioaccumulation in aquatic organisms.

- ***Wildlife Receptor Diet***. To provide an environmentally protective estimate of dietary pollutant exposure, the Wildlife Module assumes that the diet of adult minks and bald eagles consists entirely of fish inhabiting the immediate receiving waters. The EPA believes this assumption is reasonable based on the following two factors:

  (1) It is possible that in some habitats the diet of both minks and eagles consists largely of fish, and the EPA aims to be protective of wildlife across all habitats. For example, studies have shown dietary composition as high as 75 and 85 percent fish for bald eagles and minks, respectively (U.S. EPA, 1993). In addition, it is likely that the other organisms consumed by minks and eagles are also contaminated with the pollutants of concern and are unaccounted for in the model.

  (2) With respect to home ranges, the case study water quality modeling results in Section 8 of the 2015 Final EA demonstrate that pollutants discharged from coal-fired power plants can continue to occur at elevated levels downstream from the immediate receiving waters, contaminating fish outside of immediate receiving waters and resulting in additional potential for pollutant exposure among piscivorous wildlife.

  Overall, however, this assumption likely results in a potential overestimation of exposure to the modeled species. The Wildlife Module also assumes that the diet of adult minks consists entirely of T3 fish and the diet of bald eagles consists entirely of T4 fish. These assumptions likely result in a potential overestimation of exposure among eagles (whose diet may also include T3 fish) and an underestimation of exposure among eagles (whose diet may also include T4 fish).

- ***Bioavailability and Speciation of Pollutants.*** The IRW Model assumes that all forms of a pollutant are equally bioavailable to ecological receptors. Therefore, data inputs for the Wildlife Module include total pollutant concentration in the water column (i.e., dissolved particles plus particles sorbed to suspended sediment) or sediment concentration for all pollutants analyzed, except where noted. In addition, some pollutant forms are more toxic to organisms, such as various forms of arsenic. While different forms of arsenic exist in the water column, it is not possible to determine the percentages of each due to the complexities of the chemistry of a particular waterbody. Because of bioavailability and pollutant speciation assumptions made for the wildlife impact assessment, the impact to receptors may be over- or underestimated.

- ***Indirect Ecological Effects.*** The Wildlife Module does not consider indirect ecological effects, such as depletion of food sources. Such indirect effects are difficult to assess and are thought to have minimal impact on some wildlife species because the impacted receiving water is only a small portion of the species' habitat. In addition, many species will move into other areas in search of prey if food sources in their current habitat decline.

- ***Full Mixing Effects for Receiving Water.*** The Water Quality Module assumes that the receiving waterbody is fully mixed. In reality, the water in lakes might stratify, especially if they are deep enough. Chemical speciation, mostly based on pH, varies by stratum; for example, if the hypolimnion (i.e., lowest stratum of a lake) has a much lower pH than the epilimnion (i.e., upper stratum), the concentration or speciation of many pollutants may vary between the two layers. Therefore, bottom-dwelling organisms would be exposed to different pollutant species and concentrations. Due to the complexity of these relationships and necessity for site-specific data, none of the impact analyses considered the stratification of receiving waters. The effect of this limitation on the Wildlife Module outputs is undetermined.

- ***Multiple Pollutant Exposures.*** According to the EPA's *Steam Electric Power Generating Point Source Category: Final Detailed Study Report*, Document No. EPA-821-R-09-008 (U.S. EPA, 2009d), receptors will be exposed to multiple constituents simultaneously. However, the Wildlife Module examines the impact of individual pollutants to receptors and does not take into account how the interaction of multiple pollutants impacts the receptors. For example, the EPA did not consider the impact of mercury on the uptake or toxicity of selenium. There is evidence in the literature (Chapman et al., 2009) that these two compounds interact in the environment to decrease each other's impact on a receptor. Conversely, the interaction of other pollutants may increase the impact to a receptor. However, because the TECs and NEHCs are based on the toxicity of individual chemicals, and the relationships between chemicals are complex, it is beyond the scope of this analysis to include the effects of multiple pollutant interactions on receptors.
- ***Ecological Benchmarks.*** The EPA used TECs and NEHCs as described above to identify potential adverse impacts to aquatic organisms. These benchmark values represent the concentrations below which adverse effects are not expected to occur in the exposed organism; an exceedance of these thresholds does not necessarily demonstrate that the exposed organism *will* experience adverse effects. Use of these benchmark values therefore results in an environmentally protective impact estimate.

APPENDIX E
HUMAN HEALTH MODULE METHODOLOGY

This appendix presents the model equations, input variables and constants, benchmark values, and methodology limitations/assumptions for the Human Health Module of the Immediate Receiving Water (IRW) Model. The module quantifies human health impacts to recreational and subsistence fishers (adult and child cohorts) that consume fish exposed to pollutants as a result of discharges from coal-fired power plants. Additionally, the EPA performed an environmental justice (EJ) analysis that evaluated the differences in human health impacts across race categories due to differing fish consumption rates.

For the supplemental environmental assessment (Supplemental EA), the EPA estimated pollutant concentrations in fish using the Model Wildlife Module (see Appendix D). The Human Health Module uses these concentrations as inputs.

The following tables describe the input requirements and data sources used in the Human Health Module:

- Table E-1. Calculation of Consumption Ratio for Trophic Level 3 (F_{T3}) and Trophic Level 4 (F_{T4}) Fish.
- Table E-2. Assigned Values for Input Variables and Constants.
- Table E-3. Cohort-Specific Input Variables.
- Table E-4. Environmental Justice Analysis: Cohort-Specific Input Consumption Rate by Race Category.
- Table E-5. Pollutant-Specific Benchmark Values.

Methodology Updates Subsequent to the 2015 Final EA

The EPA did not identify any necessary revisions to the equations, data sets, or parameter values used in the Human Health Module since the completion of the 2015 Final EA.

IRW Model: Human Health Module Equations

The EPA estimated the pollutant concentrations in fish fillets consumed by humans (i.e., dose) using an assumed consumption ratio of trophic level 3 (T3) and trophic level 4 (T4) fish and site-specific pollutant concentrations in fish. For each cohort, the EPA calculated the average daily dose (ADD) of the pollutant from eating fish and compared this ADD to non-cancer oral reference doses (RfDs). The Human Health Module expresses this comparison as a hazard quotient (HQ). An HQ of higher than one (i.e., pollutant dosage exceeds oral RfD) indicates a potential non-cancer threat to the human cohort. The EPA also calculated a lifetime average daily dose (LADD) and a corresponding lifetime excess cancer risk (LECR) for each cohort. This study used the one-in-a-million cancer risk benchmark when evaluating exposures associated with fish consumption.

The EPA used the equations presented below to calculate the pollutant concentration in the fish fillet; the ADD for arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc; the associated non-cancer threat HQ; and the LADD and LECR values for arsenic.

Equation E-1

$$C_{fish\_fillet} = F_{T3} \times C_{fishT3F} + F_{T4} \times C_{fishT4F}$$

Where:

C_{fish_fillet}	=	Average fish fillet concentration ingested by humans (milligrams per kilograms (mg/kg))	Output from Equation E-1
$C_{fishT3F}$	=	Concentration of contaminant in fish at trophic level 3 (mg/kg)	Site-specific Wildlife Module output from Equation D-2 and Equation D-3
$C_{fishT4F}$	=	Concentration of contaminant in fish at trophic level 4 (mg/kg)	Site-specific Wildlife Module output from Equation D-2 and Equation D-3
F_{T3}	=	Fraction of trophic level 3 fish intake (unitless)	0.36 (see calculation below)
F_{T4}	=	Fraction of trophic level 4 fish intake (unitless)	0.64 (see calculation below)

To determine the fraction of T3 and T4 fish intake for human cohorts, the EPA started with the data presented in the 2011 Emissions Factor Handbook, Table 10-74 (U.S. EPA, 2011c). The EPA then completed the following analysis:

1. Assigned trophic levels to fish if not already listed in the table.
2. Totaled the quantities of fish consumed by trophic level.
3. Determined fraction of fish consumed at each trophic level.

Table E-1 documents the data and analysis performed. The EPA chose to use the factors for fish intake that corresponded to rivers and streams; this is the most common receiving water source in the IRW Model.

Equation E-2 calculates the ADD, which is the daily intake of the contaminant from fish ingestion. Based on a literature review (including references from the EPA and the Agency for Toxic Substances and Disease Registry (ATSDR)), arsenic in fish is mostly in the organic form and not harmful to humans. The inorganic form of arsenic is harmful to humans. The EPA's 1997 document, *Arsenic and Fish Consumption*, reported the inorganic arsenic concentration in fish as between 0.4 and 4 percent of the total arsenic accumulating in fish (U.S. EPA, 1997b). The EPA estimated the inorganic arsenic concentration in fish by assuming that four percent of the total arsenic is inorganic. The EPA used this inorganic arsenic concentration in fish to determine human health impacts. The Human Health Module multiplies the C_{fish_fillet} total arsenic concentration by four percent to estimate the inorganic arsenic concentration in fish.

Table E-1. Fish Consumed and Consumption Ratios of Fish at Trophic Levels 3 and 4 (F_{T3} and F_{T4})

Species	Ice Fishing		Lakes and Ponds		Rivers and Streams	
	Number of Fish Consumed	Mass Consumed (kg)	Number of Fish Consumed	Mass Consumed (kg)	Number of Fish Consumed	Mass Consumed (kg)
Trophic Level 3						
Bottom fish (suckers, carp, and sturgeon)	50	81	62	22	100	6.7
Chub	0	0	252	35	219	130
Hornpout (catfish and bullheads)	47	8.2	1,291	100	180	7.8
Lake whitefish	111	20	558	13	55	2.7
Pickerel	1,091	180	553	91	303	45
Smelt	7,808	150	428	4.9	4,269	37
White perch	2,544	160	6,540	380	3,013	180
Yellow perch	235	9.1	1,649	52	188	7.4
Trophic Level 4						
Atlantic salmon	3	1.1	33	9.9	17	11
Bass (smallmouth and largemouth)	474	120	73	5.9	787	130
Brook trout	1,309	100	3,294	210	10,185	420
Brown trout	275	54	375	56	338	23
Landlocked salmon	832	290	928	340	305	120
Togue (Lake trout)	483	200	459	160	33	2.7
Other	201	210	90	110	54	45
Totals by Trophic Level						
T3	11,886	608	11,333	698	8,327	417
T4	3,376	765.1	5,162	781.8	11,665	751.7
Total	15,463	1,583	16,587	1,590	20,046	1,168
Calculation of Factors by Trophic Level						
T3 Factor	0.77	0.38	0.68	0.44	0.42	**0.36**
T4 Factor	0.22	0.48	0.31	0.49	0.58	**0.64**

Source: U.S. EPA, 2011c.

Bold/green indicates factors selected for the Human Health Module.

Equation E-2

$$ADD = \frac{C_{fish\_fillet} \times CR_{fish} \times F_{fish}}{1{,}000 \times BW}$$

Where:

ADD	=	Daily dose of pollutant from fish ingestion (mg per kg of body weight per day (mg/kg bw-day)	Output from Equation E-2
C_{fish_fillet}	=	Average fish fillet concentration ingested by humans (mg/kg)	Output from Equation E-1
CR_{fish}	=	Consumption rate of fish (g wet weight/day)	Cohort-specific value (see Table E-3 and Table E-4)
F_{fish}	=	Fraction of fish intake from contaminated source	Globally assigned value of 1
1,000	=	Conversion factor (grams per kilograms (g/kg))	Conversion factor
BW	=	Body weight (kg)	Cohort-specific value (see Table E-3)

Equation E-3 calculates the LADD, based on the ADD. Arsenic is the only carcinogenic pollutant included in the EA. The model calculates the LADD of arsenic for each child cohort (six recreational and six subsistence) and for each adult cohort (one recreational and one subsistence). The EPA assumed that the exposure durations (ED) for use in the LADD calculation are equal to the length of time in that cohort range. The EPA selected an exposure frequency of 350 days per year, assuming residents take an average of two weeks of vacation away from their homes each year.

Equation E-4 calculates the non-cancer HQ, based on the ADD.

Equation E-5 calculates the LECR for inorganic arsenic, based on the LADD.

Equation E-3

$$LADD = \frac{ADD \times ED \times EF}{AT \times 365}$$

Where:

LADD	=	Lifetime average daily dose (mg/kg bw-day)	Output from Equation E-3
ADD	=	Daily dose of pollutant from fish ingestion (mg/kg bw-day)	Output from Equation E-2

ED	=	Exposure duration for oral ingestion (yr)	Cohort-specific value (assumed value) (see Table E-3)
EF	=	Exposure frequency (days/yr)	Globally assigned value of 350
AT	=	Averaging time (yr)	Globally assigned value of 70 (U.S. EPA, 2011c)
365	=	Conversion factor (days/yr)	

Equation E-4

$$HQ = \frac{ADD}{RfD}$$

Where:

HQ	=	Hazard quotient	Output from Equation E-4
ADD	=	Daily dose of pollutant from fish ingestion (mg/kg bw-day)	Output from Equation E-2
RfD	=	Non-cancer oral reference dose (mg/kg bw-day)	Pollutant-specific value (see Table E-5)

Equation E-5

$$LECR = LADD \times CSF$$

Where:

LECR	=	Lifetime excess cancer risk	Output from Equation E-5
LADD	=	Lifetime average daily dose (mg/kg bw-day)	Output from Equation E-3
CSF	=	Cancer slope factor $(mg/kg\ bw\text{-}day)^{-1}$	Pollutant-specific value (see Table E-5)

IRW Model: Human Health Module Inputs and Benchmark Values

For the EA and economic benefits analyses,[4] the EPA focused on human exposure to contaminated fish for recreational and subsistence fishers. Recreational fishers are non-commercial, non-subsistence fishers and are more vulnerable to pollutant exposure by intake of contaminated fish from a specific waterbody compared to the general population. Subsistence fishers are individuals who consume fresh caught fish as a major food source. Intake rates for subsistence fishers are generally higher than for the general population, and subsistence fishers are more vulnerable to pollutant exposure by intake of contaminated fish from a specific

[4] See the *Benefit and Cost Analysis for Proposed Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report), Document No. EPA-821-R-19-009 (U.S. EPA, 2019b).

waterbody compared to both recreational fishers and the general population. Because of the focus of human exposure on a subset of the general population that more frequently consume local fish, the EPA selected fish consumption rates from studies based on "consumer only" data. Consumer-only fish consumption rates are the average intake rates across only those individuals that consumed fish and shellfish during the survey time period. See the memorandum "Fish Consumption Rates Used in the Environmental Assessment Human Health Module" for further details (ERG, 2015).

The Human Health Module calculates annual-average daily doses of pollutants for recreational and subsistence fishers and does not calculate the annual-average daily doses of pollutants for the general population. In its economic benefits analysis (see the BCA Report), the EPA evaluates impacts to a subset of the population living near the immediate and downstream receiving waters.

Table 5-1 of the 2000 EPA document *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* provides protective fish intake rates based on the following percentiles by fisher type: 1) general population and recreational fisher: 90^{th} percentile of per capita data and 2) subsistence fisher: 99^{th} percentile of per capita data (U.S. EPA, 2000c). The document does not provide guidance on which percentiles to use for consumer-only fish intake rates. Therefore, the EPA used best professional judgment and used the mean of consumer-only data to represent recreational fishers and the 95^{th} percentile of consumer-only data to represent subsistence fishers.

Table E-2. Assigned Values for Input Variables and Constants

Input Variable or Constant	Description	Assigned Value	Rationale/Data Source
F_{T3}	Fraction of trophic level 3 fish intake	0.36	U.S. EPA, 2011c
F_{T4}	Fraction of trophic level 4 fish intake	0.64	U.S. EPA, 2011c
F_{fish}	Fraction of fish intake from contaminated source	1	The EPA assumed that all fish consumed by the cohort is from the contaminated surface water.
EF	Exposure frequency (days/yr)	350	The EPA assumed that the fisher (cohort) travels away from home for 15 days per year and does not eat fish from contaminated surface water during that period.
AT	Averaging time (yr)	70	U.S. EPA, 2011c

Table E-3. Cohort-Specific Input Variables

Age and Fish Consumption Cohort [a]		Body Weight (kg) [a]	Consumption Rate (g/kg-day) [b]	Consumption Rate (g/day) [b]	Exposure Duration (years)
Child Recreational Fisher	1 to <2 years	11.4	1.60	18.2	1
	2 to <3 years	13.8	1.60	22.1	1
	3 to <6 years	18.6	1.30	24.2	3
	6 to <11 years	31.8	1.10	35.0	5
	11 to <16 years	56.8	0.660	37.5	5
	16 to <21 years	71.6	0.660	47.3	5
Child Subsistence Fisher	1 to <2 years	11.4	4.90	55.9	1
	2 to <3 years	13.8	4.90	67.6	1
	3 to <6 years	18.6	3.60	67.0	3
	6 to <11 years	31.8	2.90	92.2	5
	11 to <16 years	56.8	1.70	96.6	5
	16 to <21 years	71.6	1.70	122	5
Adult Recreational Fisher [c]		80	0.665	53.2	49
Adult Subsistence Fisher [c]		80	2.05	164	49

Sources: U.S. EPA, 2008b; U.S. EPA, 2011c.

Acronyms: g/day (grams per day); g/kg-day (grams per kilogram of body weight per day); kg (kilograms).

a – The child cohort age ranges correspond to the ranges provided in the 2008 *Child-Specific Exposure Factors Handbook (EFH)* for body weights (U.S. EPA, 2008b).

b – The EPA determined consumption rates for child cohorts using data from Table 10-1 (Recommend Per Capita and Consumer-Only Values for Fish Intake) for finfish consumption (U.S. EPA, 2011c). The EPA used consumer-only fish consumption rates: mean values for recreational fishers and 95th percentile values for subsistence fishers. The EPA converted the listed consumption rate (g/kg-day) to g/day by multiplying by mean body weight for each cohort as described in ERG (2015). Fish intake rates provided in U.S. EPA (2011c) are recommended for the consumer-only population; the selection of consumption rates for exposure assessment purposes may vary depending on the exposure scenarios being evaluated.

c – Table 10-1 (U.S. EPA, 2011c) presented multiple adult groups. The EPA used the average fish consumption rate for age groups “21 to <50 years” and “50+ years” to calculate a single adult cohort fish consumption rate.

Table E-4. Environmental Justice Analysis: Cohort-Specific Input Consumption Rate by Race Category

Fish Consumption and Race Category Cohort		CR_{fish}, g/kg-day (All ages) [a]	Consumption Rate (CR_{fish}), g/day, by Cohort [b]						
			1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 to <16 Years	16 to <21 Years	Adult
Recreational	Non-Hispanic White	0.67	7.64	9.25	12.5	21.3	38.1	48	53.6
	Non-Hispanic Black	0.77	8.78	10.6	14.3	24.5	43.7	55.1	61.6
	Mexican-American	0.93	10.6	12.8	17.3	29.6	52.8	66.6	74.4
	Other Hispanic	0.82	9.35	11.3	15.3	26.1	46.6	58.7	65.6
	Other, including Multiple Races	0.96	10.9	13.2	17.9	30.5	54.5	68.7	76.8
Subsistence	Non-Hispanic White	1.9	21.7	26.2	35.3	60.4	108	136	152
	Non-Hispanic Black	2.1	23.9	29.0	39.1	66.8	119	150	168
	Mexican-American	2.8	31.9	38.6	52.1	89.0	159	200	224
	Other Hispanic [c]	2.7	30.8	37.3	50.2	85.9	153	193	216
	Other, including Multiple Races [c]	3.6	41.0	49.7	67.0	114	204	258	288

Source: U.S. EPA, 2011c.

Acronyms: CR_{fish} (consumption rate); g/day (grams per day); g/kg-day (grams per kilogram body weight per day).

a – For recreational fishers, the EPA used the mean, consumer-only fish consumption rate for finfish (excludes shellfish). For subsistence fishers, the EPA used the 95th percentile, consumer-only fish consumption rate for finfish (excludes shellfish). See Table 10-8 of U.S. EPA, 2011c.

b – Consumption rates provided as single value by race category (as g/kg-day). The EPA multiplied these values by cohort-specific body weights, as listed in Table E-3, to calculate a cohort-specific consumption rate in g/day. Numbers presented as three significant digits.

c – Consumption rates for this race category are less statistically reliable due to the comparatively smaller data set.

Table E-5. Pollutant-Specific Benchmark Values

Pollutant in Human Health Impact Assessment	Oral RfD (mg/kg-day)	CSF (mg/kg-day) $^{-1}$	Notes [a]
Arsenic, inorganic	3.00×10^{-4}	1.50	Oral RfD and CSF for drinking water ingestion.
Cadmium, total	1.00×10^{-3}		Oral RfD for food consumption.
Copper	1.00×10^{-2}		Used the intermediate oral minimal risk level (MRL) as the oral RfD (ATSDR, 2010b).
Lead, total	None available		
Methylmercury	1.00×10^{-4}		Oral RfD for fish consumption only.
Nickel, total	2.00×10^{-2}		Oral RfD for soluble salts; used for food consumption.
Selenium, total	5.00×10^{-3}		Oral RfD for food consumption.
Thallium, total	1.00×10^{-5}		Used value cited in U.S. EPA, 2010a for thallium chloride as the oral RfD; used for chronic oral exposure.
Zinc, total	3.00×10^{-1}		Oral RfD for food consumption.

Acronyms: CSF (cancer slope factor); mg/kg-day (milligrams per kilogram body weight per day); RfD (reference dose).

a – References include ATSDR (2010b) for copper; U.S. EPA (2010a) for thallium, and U.S. EPA (2019e) for all other pollutants.

IRW Model: Human Health Module Limitations and Assumptions

The Human Health Module limitations and assumptions include the following:

- ***Cumulative Risks Across Exposure Pathways.*** The Human Health Module does not consider cumulative risks across exposure pathways. For example, the module assumes that the human population consuming the fish is not also ingesting contaminated drinking water. Exposures from fish consumption and drinking water are likely to occur over different time frames (because of ground water travel) and may involve different receptors (e.g., a resident near a receiving water exposed to ground water contamination may not be a recreational fisher). Similarly, the module assumes that these populations are not coming in direct contact with contaminated surface water or sediment through recreation. Based on these assumptions, the model may underestimate total risk to human health from discharges of the evaluated wastestreams.
- ***Bioavailability and Speciation of Pollutants.*** The assumptions listed for the Wildlife Module in Appendix D apply to pollutant concentrations modeled in fish and therefore affect the human health impact assessment.
- ***Full Mixing Effects for Receiving Water.*** The assumptions listed for the Wildlife Module in Appendix D apply to pollutant concentrations modeled in fish and therefore affect the human health impact assessment.

- ***Multiple Pollutant Exposures.*** According to previous analyses and literature reviewed (U.S. EPA, 2009d), people who ingest fish from impacted waters will be exposed to multiple pollutants from the wastestreams evaluated. However, the module evaluates each pollutant individually. Such an approach does not account for interactive effects that might be associated with exposures to mixtures. For example, some pollutants may have a higher risk when consumed together because of their interaction, whereas other pollutants may have less impact on human health when consumed together. Due to the complexity of these interactions and because benchmark values are based on the toxicity of individual pollutants, it is not possible to examine these synergistic effects in this analysis. Based on this limitation, risks of pollutants may be over- or underestimated.
- ***Sources of Consumed Fish***. The Human Health Module assumes that all of the fish consumed by recreational and subsistence fishers is caught from the immediate receiving water, except during a two-week time period once per year. This assumption potentially overestimates the annual-average daily dose of the pollutants for these cohorts, particularly for recreational fishers. The proportion of fish eaten by an individual from local surface waters will vary (e.g., consumption rate estimates in studies might include seafood purchased from a grocery store and not locally caught).
- ***Human Exposure Factors.*** Individual exposure factors, such as ingestion rate, body weight, and exposure duration, are variable due to the physical characteristics, activities, and behavior of the individual. The EPA used the most current data regarding exposure assumptions, and these values represent the EPA's current guidance on exposure data (U.S. EPA, 2008b; U.S. EPA, 2011c).
- ***Human Health Benchmark Values.*** Uncertainties generally associated with human health benchmark values are discussed in detail in the EPA's *Guidelines for Carcinogen Risk Assessment* (U.S. EPA, 2005c) and Integrated Risk Information System (IRIS) (U.S. EPA, 2019e). IRIS defines the oral RfD as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable threat of deleterious effects during a lifetime." While doses less than the oral RfD are not likely to be associated with adverse health risks, it should not be categorically concluded that all doses below the oral RfD are risk-free, particularly for pollutants (e.g., arsenic and nickel) whose oral RfDs have not been established with a high level of confidence. Additionally, oral RfDs are typically based on an assumption of lifetime exposure and may not be appropriate when applied to less-than-lifetime exposure situations (U.S. EPA, 2019e). The cancer slope factor is an estimate of the human cancer risk per milligram of chemical per kilogram body weight per day. To calculate the LADD used for the cancer risk assessment, the EPA used the time in the cohort group (i.e., 1, 3, or 5 years, depending on child cohort, and 49 years for adult cohort) as the ED. The ED is the length of time exposure occurs at the concentration. This analysis may over- or under-estimate the cancer risk if exposure is shorter than or longer than the ED, respectively. LADDs are appropriate when developing screening-level estimates; however, the EPA recommends calculating that risk by integrating exposures or risks through all life stages (e.g., chronic exposure for a child may occur across cohorts) (U.S. EPA, 2011c).

APPENDIX F
ADDITIONAL IRW MODEL RESULTS

This appendix presents pollutant loadings and additional model outputs for all pollutants included in the Immediate Receiving Water (IRW) Model, specifically: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. Section 3 of the supplemental environmental assessment report (Supplemental EA) and Appendices C, D, and E describe the methodologies associated with the Water Quality Module, Wildlife Module, and Human Health Module. This appendix presents additional results beyond those discussed in Section 4 of the Supplemental EA and includes the following tables:

- Table F-1. Modeled IRWs Exceeding Benchmark Values for Any Pollutant under Baseline and Four Regulatory Options
- Table F-2. Modeled IRWs Exceeding Arsenic Benchmark Values under Baseline and Four Regulatory Options
- Table F-3. Modeled IRWs Exceeding Cadmium Benchmark Values under Baseline and Four Regulatory Options
- Table F-4. Modeled IRWs Exceeding Copper Benchmark Values under Baseline and Four Regulatory Options
- Table F-5. Modeled IRWs Exceeding Lead Benchmark Values under Baseline and Four Regulatory Options
- Table F-6. Modeled IRWs Exceeding Mercury Benchmark Values under Baseline and Four Regulatory Options
- Table F-7. Modeled IRWs Exceeding Nickel Benchmark Values under Baseline and Four Regulatory Options
- Table F-8. Modeled IRWs Exceeding Selenium Benchmark Values under Baseline and Four Regulatory Options
- Table F-9. Modeled IRWs Exceeding Thallium Benchmark Values under Baseline and Four Regulatory Options
- Table F-10. Modeled IRWs Exceeding Zinc Benchmark Values under Baseline and Four Regulatory Options
- Table F-11. Modeled IRWs Exceeding Non-Cancer Oral Reference Dose Values under Baseline and Four Regulatory Options, by Race Category
- Table F-12. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million under Baseline and Four Regulatory Options, by Race Category

Table F-1. Modeled IRWs Exceeding Benchmark Values for Any Pollutant under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Pollutant Loadings (lb/yr) [a]				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	4,560	63,500	27,900	17,200	14,700
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Benchmark Value [a,b]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC	0	2	0	0	0
Freshwater Chronic NRWQC	0	10	3	2	2
Human Health Water and Organism NRWQC	9	20	17	16	13
Human Health Organism Only NRWQC	4	9	8	7	7
Drinking Water MCL	1	3	3	2	1
Wildlife Results					
Sediment TEC	2	20	10	7	6
Fish Ingestion NEHC for Minks	0	10	4	2	2
Fish Ingestion NEHC for Eagles	1	11	7	5	3
Human Health Results – Fish Consumption Advisories					
T4 Fish Tissue Concentration Screening Value (Recreational)	2	8	7	6	5
T4 Fish Tissue Concentration Screening Value (Subsistence)	6	18	14	11	9
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	6	15	12	10	8
Oral RfD for Child (Subsistence)	9	23	19	14	11
Oral RfD for Adult (Recreational)	4	10	7	7	7
Oral RfD for Adult (Subsistence)	6	16	12	10	8
Human Health Results – Cancer					
LECR for Child (Recreational)	0	0	1	0	0
LECR for Child (Subsistence)	0	0	1	0	0
LECR for Adult (Recreational)	0	1	2	1	1
LECR for Adult (Subsistence)	0	1	2	1	1

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures.

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.

b – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-2. Modeled IRWs Exceeding Arsenic Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Arsenic Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	407	503	1,010	433	182
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Arsenic Benchmark Value [d]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	0	0	0
Human Health Water and Organism NRWQC [b]	9	20	17	16	13
Human Health Organism Only NRWQC [b]	4	9	8	7	7
Drinking Water MCL	0	1	2	1	1
Wildlife Results					
Sediment TEC	0	0	1	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) [b,c]	0	0	0	0	0
T4 Fish Tissue Concentration Screening Value (Subsistence) [b,c]	0	0	1	0	0
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational) [b]	0	0	0	0	0
Oral RfD for Child (Subsistence) [b]	0	0	0	0	0
Oral RfD for Adult (Recreational) [b]	0	0	0	0	0
Oral RfD for Adult (Subsistence) [b]	0	0	0	0	0
Human Health Results – Cancer					
LECR for Child (Recreational) [b]	0	0	1	0	0
LECR for Child (Subsistence) [b]	0	0	1	0	0
LECR for Adult (Recreational) [b]	0	1	2	1	1
LECR for Adult (Subsistence) [b]	0	1	2	1	1

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total arsenic concentration, unless otherwise stated.

a – Benchmark value is based on dissolved arsenic.

b – Benchmark value is based on inorganic arsenic.

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

d – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-3. Modeled IRWs Exceeding Cadmium Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Cadmium Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	302	309	318	259	78.5
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Cadmium Benchmark Value [c]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	1	0	0
Human Health Water and Organism NRWQC	[b]	[b]	[b]	[b]	[b]
Human Health Organism Only NRWQC	[b]	[b]	[b]	[b]	[b]
Drinking Water MCL	0	0	1	0	0
Wildlife Results					
Sediment TEC	1	1	2	1	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)	0	0	0	0	0
T4 Fish Tissue Concentration Screening Value (Subsistence)	0	0	1	0	0
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	0	0	0	0	0
Oral RfD for Child (Subsistence)	0	0	1	0	0
Oral RfD for Adult (Recreational)	0	0	0	0	0
Oral RfD for Adult (Subsistence)	0	0	1	0	0
Human Health Results – Cancer					
LECR for Child (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total cadmium concentration, unless otherwise stated.

a – Benchmark value is based on dissolved cadmium.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-4. Modeled IRWs Exceeding Copper Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Copper Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	264	304	506	259	96.9
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Copper Benchmark Value [c]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	1	0	0
Human Health Water and Organism NRWQC	0	0	0	0	0
Human Health Organism Only NRWQC	[b]	[b]	[b]	[b]	[b]
Drinking Water MCL	0	0	0	0	0
Wildlife Results					
Sediment TEC	0	0	1	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)	[b]	[b]	[b]	[b]	[b]
T4 Fish Tissue Concentration Screening Value (Subsistence)	[b]	[b]	[b]	[b]	[b]
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)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total copper concentration, unless otherwise stated.

a – Benchmark value is based on dissolved copper.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-5. Modeled IRWs Exceeding Lead Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Lead Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	240	347	933	306	161
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Lead Benchmark Value [c]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	1	0	0
Human Health Water and Organism NRWQC	[b]	[b]	[b]	[b]	[b]
Human Health Organism Only NRWQC	[b]	[b]	[b]	[b]	[b]
Drinking Water MCL	0	1	2	1	1
Wildlife Results					
Sediment TEC	0	0	1	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)	[b]	[b]	[b]	[b]	[b]
T4 Fish Tissue Concentration Screening Value (Subsistence)	[b]	[b]	[b]	[b]	[b]
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	[b]	[b]	[b]	[b]	[b]
Oral RfD for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
Oral RfD for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
Oral RfD for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]
Human Health Results – Cancer					
LECR for Child (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total lead concentration, unless otherwise stated.

a – Benchmark value is based on dissolved lead.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-6. Modeled IRWs Exceeding Mercury Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Mercury Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	4.50	11.1	12.8	6.13	3.96
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Mercury Benchmark Value [f]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	0	0	0
Human Health Water and Organism NRWQC	[b]	[b]	[b]	[b]	[b]
Human Health Organism Only NRWQC	[b]	[b]	[b]	[b]	[b]
Drinking Water MCL [c]	0	0	0	0	0
Wildlife Results					
Sediment TEC	0	5	4	3	2
Fish Ingestion NEHC for Minks [d]	0	3	3	2	2
Fish Ingestion NEHC for Eagles [d]	1	6	6	5	3
Human Health Results – Fish Consumption Advisories					
T4 Fish Tissue Concentration Screening Value (Recreational) [d]	2	7	7	6	5
T4 Fish Tissue Concentration Screening Value (Subsistence) [d]	6	16	14	11	9
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational) [d,e]	5	11	10	9	8
Oral RfD for Child (Subsistence) [d,e]	6	19	17	14	11
Oral RfD for Adult (Recreational) [d,e]	3	10	7	7	7
Oral RfD for Adult (Subsistence) [d,e]	6	14	12	10	8
Human Health Results – Cancer					
LECR for Child (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total mercury concentration, unless otherwise stated.

a – Benchmark value is based on dissolved mercury.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – Benchmark value is based on inorganic mercury.

d – Comparison to benchmark value is based on modeled methylmercury concentration in fish tissue.

e – Benchmark value is based on methylmercury.

f – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-7. Modeled IRWs Exceeding Nickel Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Nickel Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	554	909	1,769	695	423
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Nickel Benchmark Value [c]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	0	0	1	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	[b]	[b]	[b]	[b]	[b]
Wildlife Results					
Sediment TEC	0	3	4	3	2
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)	[b]	[b]	[b]	[b]	[b]
T4 Fish Tissue Concentration Screening Value (Subsistence)	[b]	[b]	[b]	[b]	[b]
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)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total nickel concentration, unless otherwise stated.

a – Benchmark value is based on dissolved nickel.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-8. Modeled IRWs Exceeding Selenium Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Selenium Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	547	58,500	18,900	13,000	12,800
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Selenium Benchmark Value [b]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC	0	2	0	0	0
Freshwater Chronic NRWQC	0	10	3	2	2
Human Health Water and Organism NRWQC	0	1	0	0	0
Human Health Organism Only NRWQC	0	0	0	0	0
Drinking Water MCL	0	2	1	0	0
Wildlife Results					
Sediment TEC	2	20	10	7	6
Fish Ingestion NEHC for Minks	0	9	3	1	1
Fish Ingestion NEHC for Eagles	0	9	3	1	1
Human Health Results – Fish Consumption Advisories					
T4 Fish Tissue Concentration Screening Value (Recreational)	0	5	2	1	1
T4 Fish Tissue Concentration Screening Value (Subsistence)	0	12	6	4	2
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	0	9	3	1	1
Oral RfD for Child (Subsistence)	2	16	9	5	3
Oral RfD for Adult (Recreational)	0	6	2	1	1
Oral RfD for Adult (Subsistence)	0	10	4	2	1
Human Health Results – Cancer					
LECR for Child (Recreational)	[a]	[a]	[a]	[a]	[a]
LECR for Child (Subsistence)	[a]	[a]	[a]	[a]	[a]
LECR for Adult (Recreational)	[a]	[a]	[a]	[a]	[a]
LECR for Adult (Subsistence)	[a]	[a]	[a]	[a]	[a]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total selenium concentration, unless otherwise stated.

a – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

b – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-9. Modeled IRWs Exceeding Thallium Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Thallium Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	675	687	674	569	146
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Thallium Benchmark Value [b]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC	[a]	[a]	[a]	[a]	[a]
Freshwater Chronic NRWQC	[a]	[a]	[a]	[a]	[a]
Human Health Water and Organism NRWQC	4	5	4	3	1
Human Health Organism Only NRWQC	3	4	4	3	1
Drinking Water MCL	1	1	2	1	0
Wildlife Results					
Sediment TEC	[a]	[a]	[a]	[a]	[a]
Fish Ingestion NEHC for Minks	[a]	[a]	[a]	[a]	[a]
Fish Ingestion NEHC for Eagles	[a]	[a]	[a]	[a]	[a]
Human Health Results – Fish Consumption Advisories					
T4 Fish Tissue Concentration Screening Value (Recreational)	[a]	[a]	[a]	[a]	[a]
T4 Fish Tissue Concentration Screening Value (Subsistence)	[a]	[a]	[a]	[a]	[a]
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	6	9	8	7	4
Oral RfD for Child (Subsistence)	9	14	11	10	7
Oral RfD for Adult (Recreational)	4	6	5	4	2
Oral RfD for Adult (Subsistence)	6	10	8	8	6
Human Health Results – Cancer					
LECR for Child (Recreational)	[a]	[a]	[a]	[a]	[a]
LECR for Child (Subsistence)	[a]	[a]	[a]	[a]	[a]
LECR for Adult (Recreational)	[a]	[a]	[a]	[a]	[a]
LECR for Adult (Subsistence)	[a]	[a]	[a]	[a]	[a]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total thallium concentration, unless otherwise stated.

a – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

b – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-10. Modeled IRWs Exceeding Zinc Benchmark Values under Baseline and Four Regulatory Options

Pollutant Loadings Basis	Industry Zinc Loadings (lb/yr)				
	Baseline	Option 1	Option 2	Option 3	Option 4
Mass Loadings from all 112 Coal-Fired Power Plants in Pollutant Loadings Analysis	1,560	1,910	3,740	1,670	813
Evaluation Benchmark	**Modeled Number of IRWs Exceeding Zinc Benchmark Value [c]**				
	Baseline	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Water Quality Results					
Freshwater Acute NRWQC [a]	0	0	0	0	0
Freshwater Chronic NRWQC [a]	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	0	0	1	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)	[b]	[b]	[b]	[b]	[b]
T4 Fish Tissue Concentration Screening Value (Subsistence)	[b]	[b]	[b]	[b]	[b]
Human Health Results – Non-Cancer					
Oral RfD for Child (Recreational)	0	0	0	0	0
Oral RfD for Child (Subsistence)	0	0	1	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)	[b]	[b]	[b]	[b]	[b]
LECR for Child (Subsistence)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Recreational)	[b]	[b]	[b]	[b]	[b]
LECR for Adult (Subsistence)	[b]	[b]	[b]	[b]	[b]

Source: ERG, 2019e; ERG, 2019i.

Acronyms: IRW (immediate receiving water); lb/yr (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).

Note: Pollutant loadings are rounded to three significant figures. All benchmark values are based on total zinc concentration, unless otherwise stated.

a – Benchmark value is based on dissolved zinc.

b – A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

c – The IRW Model, which excludes the Great Lakes and estuaries, analyzes 106 total immediate receiving waters and loadings from 105 coal-fired power plants (some of which discharge to multiple receiving waters).

Table F-11. Modeled IRWs Exceeding Non-Cancer Oral Reference Dose Values under Baseline and Four Regulatory Options, by Race Category

Age and Type of Fish Consumption Cohort	Race Category	Modeled Number IRWs Exceeding Non-Cancer Oral RfD of Named Pollutant									
		Total Arsenic					Cadmium				
		Base-line	Option 1	Option 2	Option 3	Option 4	Base-line	Option 1	Option 2	Option 3	Option 4
Recreational (All age cohorts)	Non-Hispanic White	0	0	0	0	0	0	0	0	0	0
	Non-Hispanic Black	0	0	0	0	0	0	0	0	0	0
	Mexican-American	0	0	0	0	0	0	0	0	0	0
	Other Hispanic	0	0	0	0	0	0	0	0	0	0
	Other, incl. Multiple Races	0	0	0	0	0	0	0	0	0	0
Subsistence (All age cohorts)	Non-Hispanic White	0	0	0	0	0	0	0	1	0	0
	Non-Hispanic Black	0	0	0	0	0	0	0	1	0	0
	Mexican-American	0	0	0	0	0	0	0	1	0	0
	Other Hispanic	0	0	0	0	0	0	0	1	0	0
	Other, incl. Multiple Races	0	0	0	0	0	0	0	1	0	0
Age and Type of Fish Consumption Cohort	**Race Category**	**Copper**					**Mercury (as Methylmercury)**				
		Base-line	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Base-line**	**Option 1**	**Option 2**	**Option 3**	**Option 4**
Recreational (All age cohorts)	Non-Hispanic White	0	0	0	0	0	3	10	7	7	7
	Non-Hispanic Black	0	0	0	0	0	3	10	7	7	7
	Mexican-American	0	0	0	0	0	3	11	8	8	8
	Other Hispanic	0	0	0	0	0	3	10	7	7	7
	Other, incl. Multiple Races	0	0	0	0	0	3	11	8	8	8
Subsistence (All age cohorts)	Non-Hispanic White	0	0	0	0	0	5	14	11	10	8
	Non-Hispanic Black	0	0	0	0	0	6	14	12	10	8
	Mexican-American	0	0	0	0	0	6	16	14	11	9
	Other Hispanic	0	0	0	0	0	6	16	14	11	9
	Other, incl. Multiple Races	0	0	0	0	0	6	17	15	12	10

Table F-11. Modeled IRWs Exceeding Non-Cancer Oral Reference Dose Values under Baseline and Four Regulatory Options, by Race Category

Age and Type of Fish Consumption Cohort	Race Category	Number IRWs Exceeding Non-Cancer Oral RfD of Named Pollutant									
		Nickel					Selenium				
		Base-line	Option 1	Option 2	Option 3	Option 4	Base-line	Option 1	Option 2	Option 3	Option 4
Recreational (All age cohorts)	Non-Hispanic White	0	0	0	0	0	0	6	2	1	1
	Non-Hispanic Black	0	0	0	0	0	0	6	2	1	1
	Mexican-American	0	0	0	0	0	0	6	2	1	1
	Other Hispanic	0	0	0	0	0	0	6	2	1	1
	Other, incl. Multiple Races	0	0	0	0	0	0	6	2	1	1
Subsistence (All age cohorts)	Non-Hispanic White	0	0	0	0	0	0	10	4	2	1
	Non-Hispanic Black	0	0	0	0	0	0	10	4	2	1
	Mexican-American	0	0	0	0	0	0	12	6	4	2
	Other Hispanic	0	0	0	0	0	0	12	6	4	2
	Other, incl. Multiple Races	0	0	0	0	0	1	12	6	4	2

Age and Type of Fish Consumption Cohort	Race Category	Thallium					Zinc				
		Base-line	Option 1	Option 2	Option 3	Option 4	Base-line	Option 1	Option 2	Option 3	Option 4
Recreational (All age cohorts)	Non-Hispanic White	4	6	5	4	2	0	0	0	0	0
	Non-Hispanic Black	4	6	5	4	2	0	0	0	0	0
	Mexican-American	5	7	6	5	2	0	0	0	0	0
	Other Hispanic	4	6	5	4	2	0	0	0	0	0
	Other, incl. Multiple Races	5	7	6	5	2	0	0	0	0	0
Subsistence (All age cohorts)	Non-Hispanic White	6	10	8	8	5	0	0	0	0	0
	Non-Hispanic Black	6	10	8	8	6	0	0	0	0	0
	Mexican-American	6	11	9	9	7	0	0	0	0	0
	Other Hispanic	6	11	9	9	7	0	0	0	0	0
	Other, incl. Multiple Races	8	14	10	10	7	0	0	1	0	0

Source: ERG, 2019i.

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

Table F-12. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million under Baseline and Four Regulatory Options, by Race Category

Age and Type of Fish Consumption Cohort	Race Category	Modeled Number of IRWs Exceeding LECR				
		Baseline	Option 1	Option 2	Option 3	Option 4
Recreational (All age cohorts)	Non-Hispanic White	0	1	2	1	1
	Non-Hispanic Black	0	1	2	1	1
	Mexican-American	0	1	2	1	1
	Other Hispanic	0	1	2	1	1
	Other, including Multiple Races	0	1	2	1	1
Subsistence (All age cohorts)	Non-Hispanic White	0	1	2	1	1
	Non-Hispanic Black	0	1	2	1	1
	Mexican-American	0	1	2	1	1
	Other Hispanic	0	1	2	1	1
	Other, including Multiple Races	0	2	3	2	1

Source: ERG, 2019i.

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