United States
Environmental Protection
Agency

Office of Water
Washington, DC 20460

EPA-821-R-15-006
September 2015

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

United States
Environmental Protection
Agency

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

EPA-821-R-15-006

September 2015

U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
1200 Pennsylvania Avenue, NW
Washington, DC 20460

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

LIST OF TABLES

List of Tables (*Continued*)

Page

List of Tables (*Continued*)

Page

List of Figures

ACRONYMS

ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation factor
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BAT	Best Available Technology Economically Achievable
BCF	Bioconcentration factor
BPT	Best Practicable Control Technology Currently Available
CBI	Confidential business information
CCR	Coal combustion residuals
CFR	Code of Federal Regulations
CSCL	Chemical stressor concentration limit
CSF	Cancer slope factor
CWA	Clean Water Act
DBP	Disinfection by-products
DCN	Document control number
DMR	Discharge monitoring report
DOE	Department of Energy
EA	Environmental assessment
EF	Enrichment factors
EFDC	Environmental Fluid Dynamics Code
ELGs	Effluent Limitations Guidelines and Standards
EP	Extraction procedure
EPA	U.S. Environmental Protection Agency
ER	Exposure-response
ESA	Endangered Species Act
FGD	Flue gas desulfurization
FGMC	Flue gas mercury control
FR	Federal Register
FWS	U.S. Fish and Wildlife Service
IRIS	Integrated Risk Information System
IRW	Immediate receiving water
Kd_{sw}	Suspended sediment-surface water partition coefficient
LADD	Lifetime average daily dose
lbs/yr	Pounds per year
LC_{50}	Median lethal concentration
LECR	Lifetime excess cancer risk

MCL	Maximum contaminant level
MRL	Minimal risk level
MGD	Million gallons per day
mg/day	Milligrams per day
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MW	Megawatt
MWh	Megawatt-hour
NEHC	No effect hazard concentration
NHDPlus	National Hydrography Dataset Plus
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria
NSPS	New Source Performance Standards
NWIS	National Water Information System
ORCR	Office of Resource Conservation and Recovery
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyls
POC	Pollutant of concern
POTW	Publicly owned treatment works
ppm	Parts per million
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
RCRA	Resource Conservation and Recovery Act
RfD	Reference dose
RIA	Regulatory impact analysis
RSEI	Risk-Screening Environmental Indicators
SDWA	Safe Drinking Water Act
SQuiRT	Screening Quick Reference Table
STORET	EPA's STOrage and RETrieval Data Warehouse
T3	Trophic level 3
T4	Trophic level 4
TC	Toxicity characteristic
TCLP	Toxicity characteristic leaching procedure
TDD	Technical Development Document
TDS	Total dissolved solids
TEL	Threshold effects level

TMDL	Total maximum daily load
TOC	Total organic carbon
TRI	Toxics Release Inventory
TSS	Total suspended solids
TTF	Trophic transfer factor
TTHM	Total trihalomethanes
TWF	Toxic weighting factor
TWPE	Toxic weighted pound equivalent
µg/g	Micrograms per gram
µg/L	Micrograms per liter
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WHO	World Health Organization
WMA	Wildlife Management Area
WQI	Water quality index

GLOSSARY

Acute – having a sudden onset or lasting a short time. An acute stimulus is severe enough to induce a response rapidly. The word acute can be used to define either the exposure or the response to an exposure (effect). The duration of an acute aquatic toxicity test is generally 4 days or less and mortality is the response usually measured.

Aquifer – an underground formation or group of formations in rocks and soils containing enough ground water to supply wells and springs.

Benthic – pertaining to the bottom (bed) of a waterbody.

Bioaccumulation – general term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical, resulting in a net accumulation of the chemical by an organism due to uptake from all routes of exposure.

Bioavailability – the ability of a particular contaminant to be assimilated into the tissues of exposed organisms.

Biomagnification – result of the process of bioaccumulation and biotransfer by which tissue concentrations of chemicals in organisms at one trophic level exceed tissue concentrations in organisms at the next lower trophic level in a food chain.

Bottom ash – the ash, including boiler slag, which settles in the furnace or is dislodged from furnace walls. Economizer ash is included when it is collected with bottom ash.

Chronic – involving a stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the species. This term can be used to define either the exposure or the response to an exposure (effect). Chronic exposures typically induce a biological response of relatively slow progress and long duration.

Combustion residuals – solid wastes associated with combustion-related power plant processes, including fly and bottom ash from coal-, petroleum coke-, or oil-fired units; flue gas desulfurization (FGD) solids; flue gas mercury control wastes; and other wastewater treatment solids associated with steam electric power plant wastewater. In addition to the residuals that are associated with coal combustion, this also includes residuals associated with the combustion of other fossil fuels.

Combustion residual leachate – leachate from landfills or surface impoundments containing combustion residuals. Leachate is composed of liquid, including any suspended or dissolved constituents in the liquid, that has percolated through waste or other materials emplaced in a landfill, or that passes through the surface impoundment’s containment structure (*e.g.*, bottom, dikes, berms). Combustion residual leachate includes seepage and/or leakage from a combustion residual landfill or impoundment unit. Combustion residual leachate includes wastewater from landfills and surface impoundments located on non-adjoining property when under the operational control of the permitted facility.

Criterion continuous concentration – an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely (chronic exposure) without resulting in an unacceptable effect.

Criterion maximum concentration – an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly (acute exposure) without resulting in an unacceptable effect.

Direct discharge – (a) Any addition of any “pollutant” or combination of pollutants to “waters of the United States” from any “point source,” or (b) any addition of any pollutant or combination of pollutant to waters of the “contiguous zone” or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation. This definition includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man; discharges though pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works. This term does not include an addition of pollutants by any “indirect discharger.”

Edema – swelling caused by fluid in body tissues.

Effluent limitation – under Clean Water Act (CWA) section 502(11), any restriction, including schedules of compliance, established by a state or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean, including schedules of compliance.

Evaluated wastestreams – subset of steam electric power plant wastewaters evaluated in the environmental assessment (EA) and Benefits and Cost Analysis that includes FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate collected from landfills or surface impoundments.

Exposure – the contact or co-occurrence of a stressor with a receptor.

Flue gas desulfurization (FGD) wastewater – wastewater generated specifically from the wet FGD scrubber system that comes into contact with the flue gas or the FGD solids, including but not limited to, the blowdown or purge from the FGD scrubber system, overflow or underflow from the solids separation process, FGD solids wash water, and the filtrate from the solids dewatering process. Wastewater generated from cleaning the FGD scrubber, cleaning FGD solids separation equipment, cleaning the FGD solids dewatering equipment, or that is collected in floor drains in the FGD process area is not considered FGD wastewater.

Flue gas mercury control (FGMC) wastewater – wastewater generated from an air pollution control system installed or operated for the purpose of removing mercury from flue gas. This includes fly ash collection systems when the particulate control system follows sorbent injection or other controls to remove mercury from flue gas. FGD wastewater generated at plants using oxidizing agents to remove mercury in the FGD system and not in a separate FGMC system is not included in this definition.

Fly ash – the ash that is carried out of the furnace by a gas stream and collected by a capture device such as a mechanical precipitator, electrostatic precipitator, and/or fabric filter. Economizer ash is included in this definition when it is collected with fly ash. Ash is not included in this definition when it is collected in wet scrubber air pollution control systems whose primary purpose is particulate removal.

Gasification wastewater – any wastewater generated at an integrated gasification combined cycle operation from the gasifier or the syngas cleaning, combustion, and cooling processes. Gasification wastewater includes, but is not limited to the following: sour/grey water; CO2/steam stripper wastewater; sulfur recovery unit blowdown, and wastewater resulting from slag handling or fly ash handling, particulate removal, halogen removal, or trace organic removal. Air separation unit blowdown, noncontact cooling water, and runoff from fuel and/or byproduct piles are not considered gasification wastewater. Wastewater that is collected intermittently in floor drains in the gasification process areas from leaks, spills and cleaning occurring during normal operation of the gasification operation is not considered gasification wastewater.

Ground water – water that is found in the saturated part of the ground underneath the land surface.

Hematological – pertaining to or emanating from blood cells.

Histopathological – pertaining to tissue changes.

Immediate receiving water – the segment of a receiving water where discharges from a point source enter the surface water. The segment is defined by the hydrographic dataset supporting the analysis (*e.g.*, National Hydrography Dataset Plus, Version 1).

Impaired waters – a surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat).

Indirect discharge – wastewater discharged or otherwise introduced to a publicly owned treatment works (POTW).

Invertebrates – animals without a backbone or spinal column; *macroinvertebrates* are invertebrates that can be seen without a microscope (macro), such as aquatic insects, worms, clams, snails, and crustaceans.

Landfill – a disposal facility or part of a facility where solid waste, sludges, or other process residuals are placed in or on any natural or manmade formation in the earth for disposal and which is not a storage pile, a land treatment facility, a surface impoundment, an underground injection well, a salt dome or salt bed formation, an underground mine, a cave, or a corrective action management unit.

Leachate – see *combustion residual leachate*.

Lentic – pertaining to still or slow-moving water, such as lakes or ponds.

Lethal – causing death by direct action.

Lotic – pertaining to flowing water, such as streams and rivers.

Median lethal concentration (LC_{50}) – a statistically or graphically estimated concentration that is expected to be lethal to 50 percent of a group of organisms under specified conditions.

Mortality – death rate or proportion of deaths in a population.

Partition coefficient – the ratio of a pollutant concentration in one medium compared to another (*e.g.*, dissolved in the water column, sorbed to suspended sediment, and sorbed to benthic sediment in a receiving water).

Piscivorous – habitually feeds on fish.

Plant-receiving water – the combination of a steam electric power plant and the immediate receiving water into which evaluated wastestreams are discharged from that plant.

Point source – any discernable, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. The term does not include agricultural stormwater discharges or return flows from irrigated agriculture. See CWA section 502(14), 33 U.S.C. 1362(14); 40 CFR §122.2.

Population – an aggregate of individuals of a species within a specified location in space and time.

Publicly owned treatment works (POTW) – any device or system, owned by a state or municipality, used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment. See CWA section 212, 33 U.S.C. 1292; 40 CFR §§122.2, 403.3.

Receptor – the ecological or human entity exposed to a stressor.

Receiving water – surface waters into which treated waste or untreated waste are discharged, including those portions of the surface water downstream from the point source.

Sediment – particulate material lying below water.

Sensitivity – in relation to toxic substances, organisms that are more sensitive exhibit adverse (toxic) effects at lower exposure levels than organisms that are less sensitive.

Steam electric power plant wastewater – wastewaters associated with or resulting from the combustion process, including ash transport water from coal-, petroleum coke-, or oil-fired units; air pollution control wastewater (e.g., FGD wastewater, FGMC wastewater, carbon capture wastewater); and leachate from landfills or surface impoundments containing combustion residuals.

Stressor – any physical, chemical, or biological entity that can induce an adverse response.

Sublethal – below the concentration that directly causes death. Exposure to sublethal concentrations of a substance can produce effects on behavior, biochemical, and/or physiological functions, and the structure of cells and tissues in organisms.

Surface water – all waters of the United States, including rivers, streams, lakes, reservoirs, and seas.

Teratogenic – able to disturb the growth and development of an embryo or fetus.

Transport water – any wastewater that is used to convey fly ash, bottom ash, or economizer ash from the ash collection or storage equipment, or boiler, and has direct contact with the ash. Transport water does not include low volume, short duration discharges of wastewater from minor leaks (*e.g.*, leaks from valve packing, pipe flanges, or piping) or minor maintenance events (*e.g.*, replacement of valves or pipe sections).

Trophic level – position of an organism in the food chain.

Toxic pollutants – as identified under the CWA, 65 pollutants and classes of pollutants, of which 126 specific substances have been designated priority toxic pollutants. See Appendix A to 40 CFR §423.

SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is promulgating revised effluent limitations guidelines and standards (ELGs) for the Steam Electric Power Generating Point Source Category (40 CFR 423). In support of the development of the final rule, EPA conducted an environmental assessment (EA) to evaluate the environmental impact of pollutant loadings released under current (*i.e.*, baseline) discharge practices and assess the potential environmental improvement from pollutant loading removals under the final rule.[1]

Based on evidence in the literature, documented damage cases, and modeled receiving water pollutant concentrations, it is clear that current steam electric power plant wastewater discharge practices impact the water quality in receiving waters, impact the wildlife in the surrounding environments, and pose a human health threat to nearby communities. Substantial evidence exists that metals (*e.g.*, arsenic, cadmium, mercury, selenium) from steam electric power plant wastewater discharges transfer from the aquatic environment to terrestrial food webs, indicating a potential for broader impacts to ecological systems by altering population diversity and community dynamics in the areas surrounding steam electric power plants. Ecosystem recovery from exposure to pollutants in power plant wastewater discharges can be extremely slow, and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years.

Steam electric power plants discharge wastewater, which contains numerous pollutants,[2] into waterbodies used for recreation and can present a threat to human health. Due to steam electric power plant wastewater discharges, fish advisories have been issued to protect the public from exposure to fish with elevated pollutant concentrations. Leaching of pollutants from surface impoundments and landfills containing combustion residuals is known to impact off-site ground water and drinking water wells at concentrations above maximum contaminant level (MCL) drinking water standards, posing a threat to human health.[3]

In this report, EPA uses the term “steam electric power plant wastewater” to represent all combustion-related wastewaters that contain pollutants covered by the revised steam electric ELGs. For the EA, EPA evaluated only a subset of the wastestreams: flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual

---

[1] The Clean Water Act does not require that EPA assess the water-related environmental impacts, or the benefits, of its ELGs, and EPA did not make its decision on the final steam electric ELGs based on the expected benefits of the rule. EPA does, however, inform itself of the benefits of its rule, as required by Executive Order 12866. See the Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category (EPA-821-R-15-005).

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

[3] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

leachate collected from landfills or surface impoundments). The goal of the EA was to answer the following five questions regarding pollutant loadings from the evaluated wastestreams:

- What are the environmental concerns under current (*i.e.*, baseline) discharge practices?
- What are the environmental and exposure pathways for steam electric power plant wastewater discharges to impact water quality, wildlife, and human health?
- What are the baseline environmental impacts to water quality and wildlife?
- What are the impacts to human health from baseline discharges?
- What are the potential improvements to water quality, wildlife, and human health under the final rule?

The EA evaluated environmental concerns and potential exposures (wildlife and humans) to pollutants commonly found in wastewater discharges from steam electric power plants. EPA completed both qualitative and quantitative analyses. Qualitative analyses included reviewing documented site impacts in literature and damage cases; assessing the pollutant loadings to receiving waters and sensitive environments; and reviewing the effects of pollutant exposure on ecological and human receptors. To quantify baseline impacts and improvements under the final rule, EPA developed computer models to determine pollutant concentrations in the immediate and downstream receiving waters, pollutant concentrations in fish tissue, and exposure doses to ecological and human receptors from fish consumption. EPA compared the values calculated by the models to benchmarks to determine the extent of the environmental impacts nationwide. EPA also developed a model to determine the risk of reproductive impacts among fish and waterfowl that have been exposed, via their diet, to selenium from steam electric power plant wastewater discharges.

This report presents the methodology and results of the qualitative and quantitative analyses performed to evaluate baseline discharges from steam electric power plants and improvements under the final rule. The analyses presented in this report incorporate some adjustments to current conditions in the industry. For example, these analyses account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants. These analyses also account for changes to the industry that are expected to occur as a result of the recent CCR rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER). These analyses, however, do not reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)].[4]

In addition to the EA, the final steam electric ELGs are supported by a number of reports including:

Regulatory Impact Analysis for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category, Document No. EPA-821-R-15-004. This report presents a profile of the steam electric power generating industry, a summary of the

---

[4] EPA completed a parallel set of quantitative EA analyses that reflect changes in the industry that may occur as a result of the Clean Power Plan. Appendix I provides the results of those analyses.

costs and impacts associated with the regulatory options, and an assessment of the final rule's impact on employment and small businesses.

Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category (Benefits and Cost Analysis), Document No. EPA-821-R-15-005. This report summarizes the monetary benefits and societal costs that result from implementation of the final rule.

Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD), Document No. EPA-821-R-15-007. This report includes background on the final rule; applicability and summary of the final 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 final rule including cost estimates, pollutant loadings, and non-water-quality impact assessment.

These reports are available in the public record for the final rule and on EPA's website at http://water.epa.gov/scitech/wastetech/guide/steam_index.cfm.

The ELGs for the Steam Electric Power Generating Point Source Category are based on data generated or obtained in accordance with EPA's Quality Policy and Information Quality Guidelines. 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, EPA evaluated the data used and associated data analyses as described in these quality assurance documents to ensure they are of known and documented quality, meet EPA's requirements for objectivity, integrity, and utility, and are appropriate for the intended use.

SECTION 2
BACKGROUND AND SCOPE

The final steam electric effluent limitations guidelines and standards (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. The final rule applies to discharges associated with both the combustion turbine and steam turbine portions of a combined cycle generating unit (see 40 CFR 423.10). EPA is revising or establishing best available technology economically achievable (BAT) limitations, new source performance standards (NSPS), pretreatment standards for existing sources (PSES), and pretreatment standards for new sources (PSNS) that apply to certain discharges of seven wastestreams: flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, combustion residual leachate, flue gas mercury control (FGMC) wastewater, gasification wastewater, and nonchemical metal cleaning wastes. See the Technical Development Document (TDD) (EPA-821-R-15-007) for more information on the rule applicability and definitions, industry description, wastestreams and pollutants of concern, treatment technologies, baseline and regulatory option pollutant loadings, costs of implementing treatment technologies, and revised standards.


Many steam electric power plants use large surface impoundments to store and treat wastewaters. These impoundments are hydrologically connected to surface and ground water.

As discussed in Section 1, EPA uses the term "steam electric power plant wastewater" to represent all combustion-related wastewaters covered by the revised steam electric ELGs. For the environmental assessment (EA), EPA evaluated only a subset of the wastestreams (see Table 2-1 below).[5] "Combustion residuals" are the solid wastes associated with combustion-related power plant processes, including fly and bottom ash; FGD solids; FGMC wastes; and other wastewater treatment solids associated with steam electric power plant wastewater. Steam electric power plants generate solid residuals from fuel combustion and from emission control technologies. These solid residuals include fly ash, bottom ash, and FGD solids. Plants remove these solid materials through both wet and dry handling methods. Dry handling typically involves transferring the solids to a storage silo or outdoor storage pile, to be either disposed of in a landfill or, depending on the particular residual,

---

[5] EPA evaluated technology options associated with FGMC wastewater, gasification wastewater, and nonchemical metal cleaning wastes as part of the regulatory options. However, no plants currently discharge FGMC wastewater, all existing gasification plants are operating the technology used as the basis for the regulatory option, and EPA will continue to reserve BAT/NSPS/PSES/PSNS for nonchemical metal cleaning wastes, as previously established regulations do. Therefore, EPA estimated zero compliance costs and zero pollutant reductions associated with these wastestreams and did not include these three wastestreams in the EA.

used to create beneficial by-products such as wallboard or cement. However, many plants use wet handling systems, which transport the wastes to a surface impoundment (*e.g.*, ash pond) using large quantities of water. For example, in wet systems, bottom ash collects at the bottom of the boiler in a water bath, and the water containing the bottom ash is then typically transported to a surface impoundment for storage and/or disposal. Fly ash may be handled similarly after it is collected from the particulate collection system. The slurry stream exiting wet FGD systems, which contains 10 to 20 percent FGD solids, is typically treated either in a surface impoundment or in an advanced wastewater treatment system, then discharged to a receiving stream or reused in other plant processes. Section 6 of the TDD describes the industry wastestreams in detail. Table 2-1 lists the specific wastestreams evaluated in the EA.

Table 2-1. Steam Electric Power Plant Wastestreams Evaluated in the EA

Evaluated Wastestream	Description
Fly ash transport water	Water used to convey the fly ash particles removed from the flue gas via a collection system. Untreated ash transport waters contain significant concentrations of total suspended solids (TSS) and metals, including arsenic, calcium, and titanium (see Section 6 of the TDD for further details). The effluent from surface impoundments generally contains low concentrations of TSS; however, metals are still present in the wastewater, predominantly in dissolved form.
Bottom ash transport water	Water used to convey the bottom ash particles collected at the bottom of the boiler. As noted above, untreated ash transport waters contain significant concentrations of TSS and metals.
FGD wastewater	Wastewater generated from a wet FGD scrubber system. Wet FGD systems are used to control sulfur dioxide (SO_2) emissions from the flue gas generated in the plant's boiler. The pollutant concentrations in FGD wastewater vary from plant to plant depending on the coal type, the sorbent used, the materials of construction in 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 significant concentrations of chlorides, total dissolved solids (TDS), nutrients, and metals, including bioaccumulative pollutants such as arsenic, mercury, and selenium (see Section 6 of the TDD for further details).
Combustion residual leachate	Collected liquid that has percolated through or drains from a landfill or a surface impoundment, where the steam electric power plant disposes of or stores a variety of wastes from the combustion process. Leachate contains high concentration of metals, such as boron, calcium, chloride, and sodium, similar to FGD wastewaters and ash transport water. The metal concentrations in the leachate are generally lower than those in FGD wastewater and ash transport water (see Section 6 of the TDD for further details).

Surface impoundments accumulate high concentrations of toxic pollutants from fly ash transport water, bottom ash transport water, and FGD wastewater.

Surface impoundments act as a physical treatment process to remove particulate material from wastewater through gravitational settling. The wastewater in surface impoundments can include one specific type of wastewater (*e.g.*, fly ash transport water) or a combination of wastewaters (*e.g.*, fly ash transport water and FGD wastewater). Additionally, plants may transfer wastewater streams from other operations into their on-site impoundments (*e.g.*, cooling tower blowdown or metal cleaning wastes). The wastestreams sent to surface impoundments can also include coal pile runoff. Although coal pile runoff is not the result of a combustion process, it can contain many of the pollutants present in steam electric power plant wastewater. Leachate or seepage may occur from surface impoundments or landfills containing combustion residuals.[6] Regardless of whether they use surface impoundments or an advanced treatment system, steam electric power plants typically discharge wastewater into the natural environment where numerous studies have raised concern regarding the toxicity of these wastestreams [ERG, 2013a; NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2014a through 2014e]. Previous regulations at 40 CFR 423 control pH and polychlorinated biphenyls (PCBs) discharge from all wastestreams and TSS and oil and grease from ash transport waters and other "low volume wastes" that include air pollution control wastewater (see Section 1 of the TDD). Section 6 of the TDD discusses wastewater characterization and selection of pollutants of concern.

Based on data EPA obtained from the 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (Steam Electric Survey), EPA estimates that 1,079 steam electric power plants are subject to the final rule (see Section 4 of the TDD). EPA limited the scope of the EA to those plants that both 1) discharge directly to surface waters and 2) will reduce their pollutant loadings as a result of the regulatory options evaluated, based on EPA projections. Therefore, the EA scope excludes steam electric power plants that meet any of the following criteria:

- Plants that do not discharge any of the wastestreams that are included in the final rule (even if the plant does generate and reuse the wastestream without discharging to surface waters).
- Plants that already comply with final rule or have plans to comply with the final rule prior to the date when the plants would have to meet the new limitations and standards.

---

[6] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the CCR rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

- Plants that that have announced plans to retire steam generating units (that would otherwise be subject to the final rule) prior to the date that the plants would have to meet the new limitations and standards.
- Plants that, based on EPA projections, will either convert to dry ash handling or install tank-based FGD wastewater treatment systems to comply with the CCR rulemaking.
- Plants that discharge only to publicly owned treatment works (POTWs).

In the EA, EPA evaluated the current impact and potential improvement to the environment and human health from 195 plants that discharge directly to surface waters and that EPA projects will reduce pollutant loadings as a result of the regulatory options evaluated. Table 2-2 presents the number of plants by discharge type (direct or indirect) included in the cost and loadings analysis presented in Sections 9 and 10 of the TDD.

Table 2-2. Number of Plants Evaluated in the EA

Plant Description	Number of Plants
Number of Plants in Scope of Final Rule	
Plants that fall under the applicability of the final rule (40 CFR 423)	1,079
Cost and Loadings Analysis	
Plants for which EPA calculated loadings in the cost and loadings analyses (see Sections 9 and 10 of the TDD)	202
Plants that discharge only to surface waters (direct discharger)	191
Plants that discharge only to a POTW (indirect discharger)	7
Plants that discharge to surface waters and to a POTW (direct and indirect discharger)	4
Environmental Assessment	
Plants evaluated in the EA (includes all direct dischargers)[a]	195

a – For the pollutant loadings and removals presented in this report, EPA included indirect dischargers to protect confidential business information.

These 195 steam electric power plants discharge to the 222 immediate receiving waters illustrated in Figure 2-1 (some plants discharge to multiple receiving waters). The EA includes qualitative analysis of the pollutant loadings in evaluated wastestreams discharged from these plants and the associated potential for environmental and human health impacts. As discussed in Section 5, EPA developed and executed a national-scale immediate receiving water (IRW) model to perform further quantitative modeling of the water quality, wildlife, and human health impacts associated with discharges from the majority of these plants. The IRW model, which excludes discharges to the Great Lakes and estuaries, encompasses 188 steam electric power plants that discharge to 209 immediate receiving waters. As discussed in Section 8, EPA also performed more detailed case study modeling of discharges from six steam electric power plants. Figure 2-1 indicates the immediate receiving waters included in the IRW modeling and case study modeling scopes.

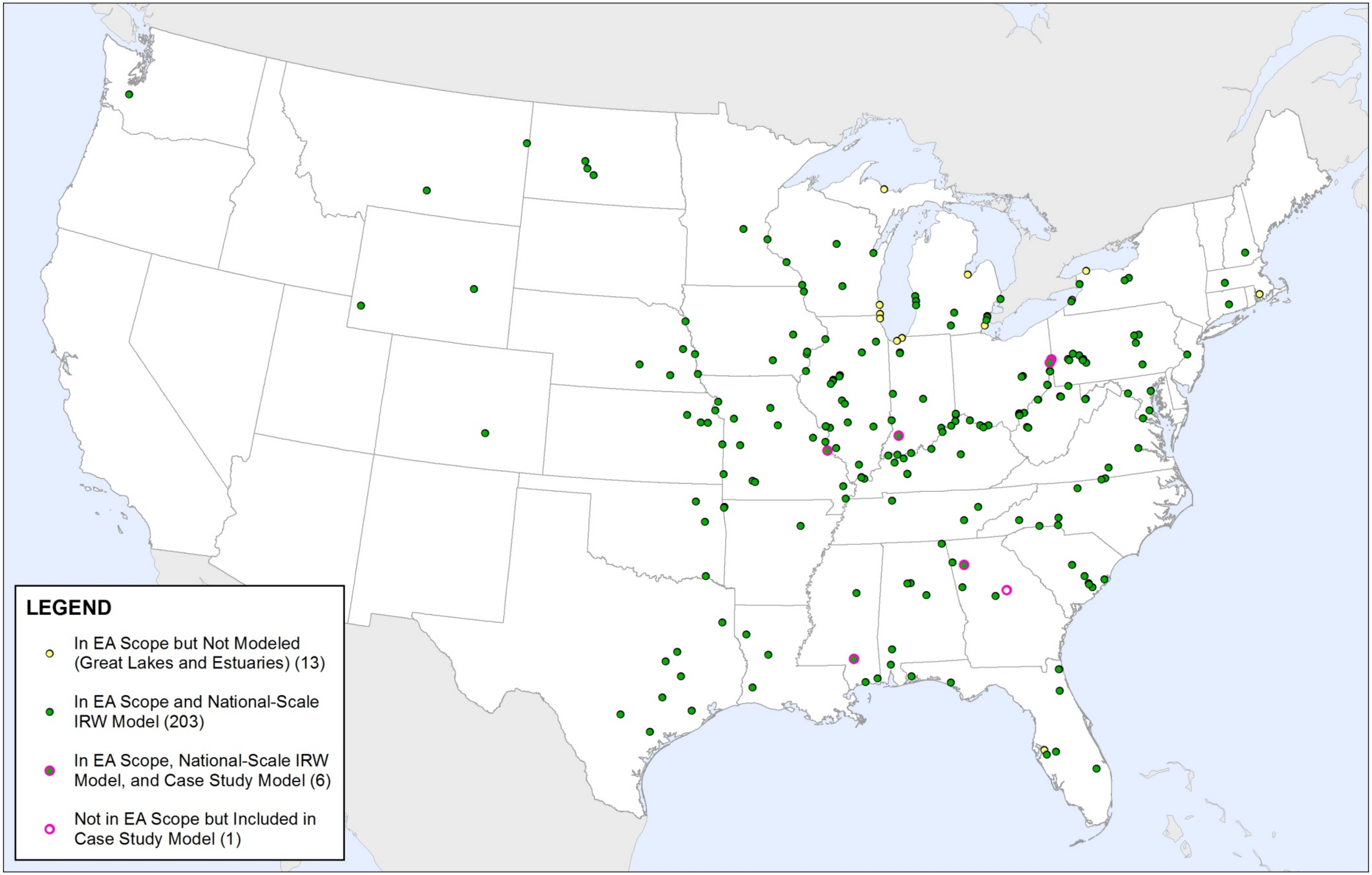


Figure 2-1. Locations and Counts of Immediate Receiving Waters in EA Scope and Modeling Analyses

EPA used the results from quantitative and qualitative assessments combined with the literature review to evaluate and describe the environmental impacts caused by the discharge of the evaluated wastestreams. EPA organized the remainder of this report into the following sections:

- Section 3 describes the environmental concerns associated with the evaluated wastestreams, including a discussion of the pollutants of concern and a review of damage cases and other documented site impacts showing negative impacts to surface water and ground water.
- Section 4 outlines how ecological and human receptors may be exposed to pollutants (i.e., environmental pathways), describes the factors that control environmental impacts for each pathway, and gives an overview of the methodology used to quantitatively evaluate the environmental and human health impacts.
- Section 5 presents the modeling performed to support the EA including an overview of the national-scale IRW model and the ecological risk model.
- Section 6 presents the environmental and human health impacts based on qualitative review and quantitative assessments (modeling of plant-specific discharges) of current (baseline) discharges.
- Section 7 presents the improvements to the environment and human health estimated from the implementation of the regulatory options.
- Section 8 describes EPA's case study modeling of discharges from six steam electric power plants, presents the environmental and human health impacts under baseline conditions, and discusses the modeled improvements under the final rule.
- Section 9 presents EPA's conclusions on the environmental and human health improvements estimated under the final rule.

SECTION 3
ENVIRONMENTAL AND HUMAN HEALTH CONCERNS

Current scientific literature indicates that steam electric power plant wastewater is not a benign waste [NRC, 2006; Rowe *et al*., 2002]. Many of the common pollutants (*e.g.*, selenium, mercury, and arsenic) found in the evaluated wastestreams (*i.e.*, fly ash and bottom ash transport water, flue gas desulfurization (FGD) wastewater, and combustion residual leachate) present an increased ecological threat due to their tendency to persist in the environment and bioaccumulate in organisms. This often results in slow ecological recovery times following exposure. The toxic impacts of steam electric power plant wastewater discharges on surface waters have been well documented in studies of over 30 aquatic ecosystems receiving discharges from steam electric power plants.[7]

Documented exceedances of drinking water maximum contaminant levels (MCLs) downstream of steam electric power plants and the issuance of fish advisories in receiving waters indicate an ongoing human health concern caused by steam electric power plant wastewater discharges. EPA identified more than 30 documented cases where ground water contamination from surface impoundments extended beyond the plant boundaries, illustrating the threat to ground water drinking water sources [ERG, 2015m].[8] In other damage cases, EPA documented locations where selenium in power plant wastewater discharges resulted in fish consumption advisories being issued for surface waters.

The pollutants commonly discharged in the evaluated wastestreams cause environmental harm by contaminating surface water and ground water (*e.g.*, selenium concentrations from steam electric power plants have resulted in fish kills). After being released into the environment, pollutants can reside for a long time in the receiving waters, bioaccumulating and binding with the sediment. There is documented evidence of slow ecological recovery as a result of these pollutant discharges. Steam electric power plants also discharge to sensitive environments (*e.g.*, impaired waters, waters under a fish consumption advisory, Great Lakes, valuable estuaries, and drinking water sources). Some impacts might not be realized for years due to the persistent and bioaccumulative nature of the pollutants released. Based on EPA's calculated baseline pollutant loadings, the total amount of toxic pollutants currently being released in wastewater discharges from steam electric power plants is significant and raises concerns regarding the long-term impacts to aquatic organisms, wildlife, and humans that are exposed to these pollutants. For details on the pollutant loadings analysis, see Section 10 of the Technical Development Document (TDD) (EPA-821-R-15-007).

This section details environmental concerns associated with wastewater discharges from steam electric power plants including changes in surface water quality and sediment contamination levels; changes in ground water quality and potential contamination of private

---

[7] Sources include ATSDR, 1998a, 1998b and 1998c; Charlotte Observer, 2010; DOE, 1992; EIP, 2010a and 2010b; Roe *et al.,* 2005; Sorensen *et al.,* 1983; Sorensen, 1988; Specht *et al.,* 1984; and Vengosh *et al.,* 2009.

[8] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

drinking water wells; bioaccumulation of contaminants in fish and aquatic life, fish eaten by piscivorous wildlife (*i.e.*, fish-eating wildlife), and fish eaten by humans; and toxic effects on fish and aquatic life. The section is organized into the following subsections:

- Section 3.1: Types of pollutants discharged in steam electric power plant wastewater.
- Section 3.2: Pollutant loadings associated with steam electric power plant wastewater.
- Section 3.3: Environmental impacts from steam electric power plant wastewater, including ecological impacts, human health effects, damage cases and other documented site impacts, and potential for impacts to occur in other locations.
- Section 3.4: Sensitive environments, including pollutant loadings to the Great Lakes and Chesapeake Bay watersheds, impaired waters, waters issued fish advisories, threatened and endangered species habitats, and drinking water resources.
- Section 3.5: Long recovery times.

3.1 TYPES OF POLLUTANTS DISCHARGED IN STEAM ELECTRIC POWER PLANT WASTEWATER

This section provides an overview of the pollutants in steam electric power plant wastewater discharges that are frequently cited as affecting local wildlife or pose a threat to human health. A number of variables can affect the composition of steam electric power plant wastewater, including fuel composition, type of combustion process, air pollution control technologies implemented, and management techniques used to dispose of the wastewater [Carlson and Adriano, 1993]. In addition, commingling steam electric power plant wastewater with other wastestreams from the plant in surface impoundments can result in a chemically complex effluent that is released to the environment [Rowe *et al*., 2002]. To identify pollutants of concern for the final rule, EPA used the following sources of wastewater characterization data: EPA's field sampling program; data supplied by industry or members of the public (*e.g.,* in questionnaire responses and public comments on the proposed rule); and various literature sources (see Section 6 of the TDD and the preamble to the final rule for further details on pollutants of concern). Pollutants such as metals, nutrients, and total dissolved solids (TDS), including chloride and bromides, are the common pollutants found in steam electric power plant wastewater that have been associated with documented environmental impacts or could have the potential to cause environmental impacts based on the loadings and concentrations present in the evaluated wastestreams.

3.1.1 Metals and Toxic Bioaccumulative Pollutants

Studies commonly cite metals and toxic bioaccumulative pollutants (*e.g.,* mercury and selenium) as the primary cause of ecological damage following exposure to steam electric power plant wastewater [Rowe *et al*., 1996; Lemly, 1997a; Hopkins *et al*., 2000; Rowe *et al*., 2002] (see Section 3.3.1). An important consideration in evaluating these pollutants is their bioavailability–the ability of a particular contaminant to be assimilated into the tissues of exposed organisms. A pollutant's bioavailability is affected by the characteristics of both the pollutant and surrounding environment (*e.g.*, temperature, pH, salinity, oxidation-reduction (redox) potential, total organic content, suspended particulate content, and water velocity). Environmental conditions influence the tendency of a dissolved pollutant to remain in solution or precipitate out of solution, sorb to either organic or inorganic suspended matter in the water column, or sorb to the mixture of materials (*e.g.*, clays and humic matter) found in sediments [U.S. EPA, 2007a]. Pollutants that precipitate out of solution can become concentrated in the sediments of a waterbody. Regardless, organisms will bioaccumulate pollutants either by consuming pollutant-enriched sediments and suspended particles, and/or by filtering ambient water containing dissolved pollutants.

Table 3-1 lists some of the common metals and toxic bioaccumulative pollutants found in steam electric power plant wastewater that have been associated with documented health and environmental impacts or could potentially cause health and environmental impacts based on the loadings and concentrations present in the wastewater. Table 3-1 is intended to highlight the pollutants of concern in steam electric power plant wastewater that are associated with health and environmental impacts; it does not include all pollutants that may cause adverse impacts. Metals and toxic bioaccumulative pollutants in steam electric power plant wastewater are present in both soluble (*i.e.*, dissolved) and particulate (*i.e.*, suspended) form. For example, EPA sampling data collected for FGD wastewater in support of the steam electric ELGs shows that some pollutants such as arsenic are present mostly in particulate form while other pollutants such as selenium and boron are present mostly in soluble form. The remainder of the section provides additional details on several key metals included in the environmental assessment (EA).

Table 3-1. Key Metals and Toxic Bioaccumulative Pollutants Found In Steam Electric Power Plant Wastewater

Pollutant	Examples of Potential Health and Environmental Concerns
Aluminum	Aluminum contamination can lead to the inability of fish to maintain the balance of their fluids and is associated with damage to amphibian eggs and larvae, mostly in areas under acid stress. Human exposure to high concentrations has been linked to Alzheimer's disease.
Arsenic [a]	Arsenic contamination causes liver poisoning, developmental abnormalities, behavioral impairments, metabolic failure, reduced growth, and appetite loss in fish and is associated with an increased risk of the liver and bladder cancer in humans. Arsenic is also a potent endocrine disruptor at low, environmentally relevant levels. Non-cancer impacts to humans can include dermal, cardiovascular, and respiratory effects. Negative impacts can occur both after high-dose exposure and repeated lower-dose exposures. Chronic exposure via drinking water has been associated with excess incidence of miscarriages, stillbirths, preterm births, and low-birth weights.
Boron	Boron can be toxic to vegetation and to wildlife at certain water concentrations and dietary levels. Human exposure to high concentrations can cause nausea, vomiting, and diarrhea.
Cadmium	Cadmium contamination can lead to developmental impairments in wildlife and skeletal malformations in fish. Human exposure to high concentrations 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.
Chromium [b]	Chromium is not known to bioaccumulate in fish; however, high concentrations of chromium can damage gills, reduce growth, and alter metabolism in fish. Human exposure to high concentrations can cause gastrointestinal bleeding and lung problems.
Copper	Copper contamination can lead to reproductive failure, gill damage, and reduced sense of smell in fish. Human exposure to high concentrations can cause nausea, vomiting, diarrhea, and liver and kidney damage.
Iron	Iron contamination can reduce growth, increase susceptibility to injury and disease, and decrease egg hatchability in fish. Human exposure to high concentrations can cause metabolic changes and damage to the pancreas, liver, spleen, and heart.
Lead	Lead contamination can delay embryonic development, suppress reproduction, and inhibit growth in fish. Human exposure to high concentrations in drinking water can cause serious damage to the brain, kidneys, nervous system, and red blood cells.

Table 3-1. Key Metals and Toxic Bioaccumulative Pollutants Found In Steam Electric Power Plant Wastewater

Pollutant	Examples of Potential Health and Environmental Concerns
Manganese	Manganese primarily accumulates in organisms lower in the food chain such as phytoplankton, algae, mollusks, and some fish. Although high levels can be toxic to humans, manganese is not generally considered toxic when ingested. The most common impacts due to human exposure to high concentrations involve the nervous system.
Mercury [c]	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. Human exposure at levels above the MCL for relatively short periods can result in kidney and brain damage. Fetuses, infants, and children are particularly susceptible to impaired neurological development from methylmercury exposure.
Nickel	At low concentrations, nickel can inhibit the growth of microorganisms and algae. Nickel toxicity in fish and aquatic invertebrates varies among species and can damage the lungs, immune system, liver, and kidneys. Human exposure to high concentrations can cause gastrointestinal and kidney damage.
Selenium [d]	Selenium readily bioaccumulates. Elevated concentrations have caused fish kills and numerous sublethal effects (*e.g.*, organ damage, decreased growth rates, reproductive failure) to aquatic and terrestrial organisms. In humans, short-term exposure at levels above the MCL can cause hair and fingernail changes, damage to the peripheral nervous system, and fatigue and irritability. Long-term exposure can damage the kidney, liver, and nervous and circulatory systems.
Thallium	In humans, short-term exposure to thallium can lead to neurological symptoms, alopecia, gastrointestinal effects, and reproductive and developmental damage. Long-term exposures at levels above the MCL change blood chemistry and damage liver, kidney, intestinal and testicular tissues and cause hair loss.
Vanadium	Vanadium contamination can increase blood pressure and cause neurological effects in animals. There are very few reported cases of oral exposure to vanadium in humans; however, a few reported incidences documented diarrhea and stomach cramps. It also has been linked to the development of some neurological disorders and cardiovascular diseases.
Zinc	Zinc contamination changes behavior, reduces oxygen supply, and impairs reproduction in fish. In humans, short-term exposure can cause nausea, vomiting, and stomach cramps. Long-term exposure can cause anemia.

a – Arsenic exists in two primary forms: arsenic III (arsenite) and arsenic V (arsenate).

b – Chromium exists in two primary forms: chromium III oxide and chromium VI (hexavalent chromium).

c – The EA evaluated two forms of mercury: total mercury and methylmercury.

d – Selenium exists in two primary forms: selenium IV (selenite) and selenium VI (selenate).

Selenium

Selenium is the most frequently cited pollutant associated with documented environmental impacts to ecological receptors following exposure to steam electric power plant wastewater [NRC, 2006]. The toxic potential of selenium is related to its chemical form and solubility. The predominant chemical forms of selenium in aquatic systems that receive steam electric power plant wastewater discharges are selenite and selenate [Besser *et al*., 1996]. The uptake of selenium by aquatic organisms is controlled by dissolved oxygen levels, hardness, pH, salinity, temperature, and the other chemical constituents present [NPS, 1997]. In alkaline conditions, selenite [Se(IV)] will oxidize in the presence of oxygen to become selenate [Se(VI)]; selenate is both stable and soluble and is the commonly found form of the chemical in alkaline soils and waters. In acidic conditions, selenite is insoluble due to its tendency to bind to iron and aluminum oxides [WHO, 1987]. Organic forms of selenium are more bioavailable for uptake than selenate and selenite and may play an important role determining selenium toxicity in exposed aquatic organisms [Besser *et al*., 1993; Rosetta and Knight, 1995].

The extent to which selenium is found in ecological receptors is affected by bioaccumulation, biomagnification, and maternal transfer. Bioaccumulation occurs when an organism absorbs a toxic substance through food and exposure to the environment at a faster rate than the body can remove the substance. The bioaccumulation of selenium is of particular concern due to its potential to impact higher trophic levels through biomagnification [Coughlan and Velte, 1989] and offspring through maternal transfer [Hopkins *et al*., 2006; Nagle *et al*., 2001]. A laboratory study demonstrated that diet can be an important source of trace element exposure in aquatic snakes and potentially other amphibians [Hopkins *et al*., 2002]. Hopkins reported that the snakes accumulated significant concentrations of the trace elements, most notably selenium. This study also revealed that amphibian prey species are able to migrate considerable distances and can therefore be exposed to toxic levels of selenium even if they do not inhabit a contaminated site. Because of bioaccumulation and biomagnification, selenium-related environmental impacts can linger for years even after exposure to steam electric power plant wastewater has ceased [Rowe *et al*., 2002].

Toxic Pollutant Impacts to Ecological Receptors

- Selenium discharges have caused numerous cases of fish kills and population decline due to reproductive impacts. Bioaccumulation can cause selenium-related environmental impacts to linger for years even after exposure to steam electric power plant wastewater has ceased.
- Fish and invertebrates exposed to steam electric power plant wastewater have exhibited elevated mercury levels in their tissues and developed sublethal effects such as reduced growth and reproductive success.
- Elevated arsenic tissue concentrations are associated with several biological impacts such as liver tissue death, developmental abnormalities, and reduced growth.

Selenium-related impacts observed by scientists include lethal effects such as fish kills, sublethal effects such as histopathological changes and damage to reproductive and developmental success, and the impacts of these effects on aquatic populations and communities. In a 1991 study, Sorensen found that dissolved selenium levels as low as 3 to 8 micrograms per liter (µg/L) in aquatic environments can be life-threatening to fish [NPS, 1997]. Section 3.3.1 presents further details regarding the lethal and sublethal effects on aquatic organisms caused by selenium from steam electric power plant wastewater.

In addition to ecological impacts, EPA has documented numerous damage cases where selenium in steam electric power plant wastewater discharges resulted in fish consumption advisories being issued for surface waters and selenium MCLs being exceeded in ground water, suggesting that selenium concentrations in power plant wastewater have the potential to impact human health [NRC, 2006; U.S. EPA, 2014a through 2014e]. Short-term exposure at levels above the MCL, 0.05 mg/L [U.S. EPA, 2009e], can cause hair and fingernail changes, damage to the peripheral nervous system, and fatigue and irritability in humans. Long-term exposure can damage the kidney, liver, and nervous and circulatory systems.

Mercury

Mercury is a volatile metal and highly toxic compound that represents an environmental and human health threat even in small concentrations. One of the primary environmental concerns regarding mercury concentrations in steam electric power plant wastewater is the potential for methylmercury to form in combustion residual surface impoundments and constructed wetlands prior to discharge and in surface waters following discharge. Methylmercury is an organic form of mercury that readily bioaccumulates in fish and other organisms and is associated with high rates of reproductive failure [WHO, 1976]. Bacteria found in anaerobic conditions, such as those that may be present in sediments found on the bottom of combustion residual surface impoundments or in river sediments, convert mercury to methylmercury through a process called methylation [WHO, 1976]. Microbial methylation rates increase in acidic and anoxic environments with high concentrations of organic matter. Sublethal effects from mercury exposure include reduced growth and reproductive success, metabolic changes, and abnormalities of the liver and kidneys. Human exposure at levels above the MCL, 0.002 mg/L [U.S. EPA, 2009e], for relatively short periods of time can result in kidney and brain damage. Pregnant women who are exposed to mercury can pass the contaminant to their developing fetus, leading to possible mental retardation and damage to other parts of the nervous system [ATSDR, 1999]. Studies have documented fish and invertebrates exposed to mercury from steam electric power plant wastewater exhibiting elevated levels of mercury in their tissues and developing sublethal effects such as reduced growth and reproductive success [Rowe *et al*., 2002].

Toxic Pollutant Impacts to Human Receptors

- Pregnant women exposed to mercury can pass the contaminant to their developing fetus, leading to possible mental retardation and damage to other parts of the nervous system.
- Inorganic arsenic is a carcinogen (*i.e.*, causes cancer). Cadmium is a probable carcinogen.
- Human exposure to high concentrations of lead in drinking water can cause serious damage to the brain, kidneys, nervous system, and red blood cells, especially in children.

Arsenic

Arsenic, like selenium, is of concern because it is soluble in near-neutral pH and in alkaline conditions, which are commonly associated with steam electric power plant wastewater. As a soluble pollutant, arsenic leaches into ground water and is highly mobile. Arsenic is frequently observed at elevated concentrations at sites located downstream from combustion residual surface impoundments [NRC, 2006]. Inorganic arsenic, a carcinogen, is found in natural and drinking waters mainly as trivalent arsenite (As(III)) or pentavalent arsenate (As(V)) [WHO, 2001]. Both the arsenite and arsenate forms are highly soluble in water.

Arsenic is also of concern due to its tendency to bioaccumulate in aquatic communities and potentially impact higher-trophic-level organisms in the area. For example, studies have documented water snakes, which feed on fish and amphibians, with arsenic tissue concentrations higher than their prey [Rowe *et al*., 2002]. Elevated arsenic tissue concentrations are associated with several biological impacts such as liver tissue death, developmental abnormalities, behavioral impairments, metabolic failure, reduced growth, and appetite loss [NRC, 2006; Rowe *et al*., 2002; U.S. EPA 2011f].

Humans are exposed to arsenic primarily by ingesting contaminated drinking water [WHO, 2001]. Humans are also exposed to arsenic by consuming contaminated fish. Of greatest concern is inorganic arsenic, which can cause cancer in humans. Several studies have shown that most arsenic in fish is organic and not harmful to humans. Inorganic arsenic typically accounts for 4 percent or less of the total arsenic that accumulates in fish.[9] The highest potential exposure is for individuals whose diet is high in fish and particularly shellfish [U.S. EPA, 1997b].

As discussed in Section 3.3.4, EPA has documented several damage cases where arsenic levels exceeded drinking water standards in ground water near combustion residual surface impoundments [U.S. EPA, 2014b through 2014e]. Arsenic contamination of ground water at the levels documented represents a potential human health threat, if either the aquifer is used as a drinking water source or the ground water contaminates a downstream drinking water source.

Cadmium

The speciation and toxicity of cadmium in water depends on the water's salinity, hardness, temperature, and organic content [WHO, 1992]. Cadmium tends to bioaccumulate readily in mollusks, soil invertebrates, and microorganisms. Due to its chemical similarity to calcium, it can also interfere with calcium uptake in aquatic organisms, which can cause sublethal effects in fish such as skeletal malformation. Divalent cadmium (Cd(II)) is the species most commonly found in an aquatic environment, but depending on the quality of the water, cadmium can also occur as cadmium carbonate, hydroxide, sulfite, sulfate, or chlorides.

EPA determined that cadmium is a probable human carcinogen. Studies found lung cancer in humans and rats exposed to cadmium via inhalation. In humans, chronic low-level exposure to cadmium from contaminated air, drinking water, or food can cause kidney failure. Chronic low-level exposure from contaminated drinking water or food can also lead to fragile bones. Exposure via inhalation at high levels can damage lungs and exposure via food and drinking water can irritate the stomach, leading to vomiting and diarrhea [ATSDR, 2012].

Thallium

Thallium typically exists as the monovalent or trivalent thallium ion [WHO, 1996]. It is soluble in most waters and is readily available to aquatic life. Thallium can bioaccumulate in fish and vegetation in fresh and marine waters, as well as marine invertebrates, which suggests that thallium may be a potential threat to higher order organisms in vulnerable ecosystems [U.S. EPA, 2011a]. Studies in humans and animals indicate that thallium compounds are readily absorbed through ingestion of food and water and maternal transfer [WHO, 1996].

In humans, elevated thallium concentrations can lead to neurological symptoms (*e.g.*, weakness, sleep disorders, muscular problems), alopecia (*i.e.*, loss of hair from the head and body), and gastrointestinal effects (*e.g.*, diarrhea and vomiting). Long-term exposures at levels above the MCL, 0.002 mg/L [U.S. EPA, 2009e], lead to changes in blood chemistry, damage to liver, kidney, and intestinal and testicular tissues, and hair loss. Thallium exposure can also cause reproductive and developmental damage [U.S. EPA, 2009a].

---

[9] Based on a 1996 literature review of toxicity and exposure concerns related to arsenic in seafood prepared for U.S. EPA Region 10, inorganic arsenic comprised higher than four percent total arsenic for three species (shark, sturgeon, and sucker). Inorganic arsenic for all other species accounted for less than 4 percent of the total arsenic [U.S. EPA, 1997b].

Lead

Neither metallic lead nor many of its common mineral forms are soluble in water, although it can be soluble in some acids or water with low pH; thus, lead is commonly present in precipitate form in water. Therefore, steam electric power plant wastewater may initially have high concentrations of lead, but later sampling of the wastewater can show decreased concentrations because the lead settles out quickly. Lead will accumulate in aquatic organisms, but depends on the species. Studies have shown lead to delay embryonic development, suppress reproduction, and inhibit growth rate among fish, crab, and several other aquatic organisms [U.S. EPA, 1984]. Human exposure to high concentrations of lead in drinking water can seriously damage the brain, kidneys, nervous system, and red blood cells, especially in children.

Boron

Boron is primarily found in the environment combined with oxygen in compounds called borates [ATSDR, 2010b]. Boron concentrations in North American waters are typically below 0.1 mg/L [WHO, 1998], although areas with natural boron-rich deposits may have ground water levels as high as 300 mg/L [ATSDR, 2010b]. The World Health Organization (WHO) suggests that the potential of adverse effects of boron on the aquatic ecosystem is low because the no-effect concentration (1 mg/L) is much greater than levels found in the ambient environment. Boron does not magnify through the food chain, but does accumulate in aquatic and terrestrial plants. While it is an essential micronutrient for higher plants, there is a small range between deficiency and toxicity in some plants. Studies of acute exposure in fish yielded toxicity values ranging from approximately 10 to 300 mg/L with rainbow trout and zebra fish being the most sensitive. Mallard duckling growth was impacted at dietary levels of 30 and 300 milligrams per kilogram (mg/kg), while survival was reduced at 1,000 mg/kg [WHO, 1998].

EPA has not set a numerical criterion under the National Recommended Water Quality Criteria (NRWQC) for aquatic life, but it has issued a narrative criterion of 0.75 mg/L for sensitive crops that receive long-term irrigation.

EPA has not set a NRWQC for human health. Very few human studies have examined health effects resulting from boron exposure through oral ingestion. However, one study documents nausea, vomiting, and diarrhea in an adult male who ingested 85 mg/kg of boron (30 g as boric acid) [ATSDR, 2010b]. In addition, animal experiments indicate that boron in the form of boric acid and borate affects reproductive and developmental processes at levels that are approximately 100 to 1,000 times greater than normal exposure levels, approximately 1.2 milligrams per day (mg/day) [WHO, 1998].

Manganese

In water, manganese tends to attach to particles or settle into the sediment [ATSDR, 2008b]. It occurs in both dissolved and suspended forms, depending on the water chemistry (*e.g.*, pH) [WHO, 2011]. Manganese can bioaccumulate in lower organisms, such as phytoplankton, algae, mollusks, and some fish, but not in higher organisms. Studies suggest that biomagnification up the food chain is not significant [ATSDR, 2008b].

Due to a high bioaccumulation factor and concentrations in mollusks, EPA established a criterion to protect consumers of marine mollusks—100 micrograms per liter (µg/L) for marine waters [U.S. EPA, 1986]. Although high levels can be toxic to humans, manganese is an essential nutrient required to maintain health and is generally not considered to be toxic when ingested [WHO, 2011]. EPA did not set a primary MCL for manganese in drinking water; however, EPA did set secondary (nonenforceable) standards at 50 µg/L to minimize objectionable qualities in the drinking water that cause laundry stains and objectionable tastes in beverages [U.S. EPA, 2009e].

3.1.2 Nutrients

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

Total nitrogen loadings from coal-fired power plants could potentially increase significantly in the future as air pollution limits become stricter and air pollution control use increases. While wastewater from an individual steam electric power plant can have a relatively low nitrogen concentration the total nitrogen loadings from a single plant can be significant due to high wastewater discharge flow rates. Total nutrient loadings from multiple power plants are especially a concern for waterbodies that are nutrient-impaired or in watersheds that contribute to downstream nutrient problems. High nutrient loadings to surface waters can affect the ecological stability of freshwater and saltwater aquatic systems. For example, excessive levels of nutrients can stimulate rapid growth of plants, algae, and cyanobacteria on or near the waterbody surface, which in turn can obstruct sunlight penetration, increase turbidity, and decrease dissolved oxygen levels [U.S. EPA, 2015a]. These aquatic changes can potentially kill bottom-dwelling aquatic plants. Cyanobacterial blooms can also produce toxic secondary metabolites, known as cyanotoxins, that can have negative impacts to humans and wildlife that consume water contaminated with cyanobacteria. The presence of high levels of cyanotoxins in recreational and drinking water may cause fever, headaches, abdominal pain, and other symptoms in humans. Severe human impacts include seizures, liver failure, respiratory arrest, and (rarely) death [U.S. EPA, 2012d].

3.1.3 TDS

TDS, a reflection of water's salinity level, is a measure of the amount of dissolved matter in water. TDS comprises primarily inorganic salts and dissolved metals, as well as a small amount of organic matter. Common inorganic salts found in TDS can include cations (positively charged ions), such as calcium, magnesium, potassium, and sodium, and anions (negatively charged ions) such as carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS concentrations in steam electric power plants wastestreams include contributions from dissolved metals, chlorides, and bromides. Dissolved metals and other TDS constituents are found in wastewater particularly at acidic pH levels when they exhibit high solubilities. The specific constituents in TDS in steam electric power plant wastewater cause the negative impacts.

Bromides

Bromide is the anion of bromine; it commonly exists as salts with potassium and other cations, which are usually very soluble in water. In water, bromide reacts to form hydrobromic acid (HBr) and hypobromous (HOBr), bromous ($HBrO_2$), and bromic ($HBrO_3$) oxyacids. Bromide is commonly found in nature, with levels ranging from trace amounts to 0.5 mg/L in fresh water and levels ranging from 65 to over 80 mg/L in seawater. The bromide ion has a low degree of toxicity, and animal testing suggests very low acute toxicity upon oral administration [WHO, 2009].

While bromide itself is not thought to be toxic at levels present in the environment, its reaction with other constituents in water may be cause for concern now and into the future. The bromide ion in water can form brominated disinfection by-products (DBPs) when drinking water plants use certain processes including chlorination and ozonation to disinfect the incoming source water. Bromide can react with the ozone, forming bromates, or with chlorine or chlorine-based disinfectants used at drinking water treatment plants, to form brominated and mixed chloro-bromo DBPs, such as trihalomethanes (THMs) or haloacetic acids (HAAs) [WHO, 2009]. EPA has set MCLs for the following DBPs in chlorinated water:

- 0.010 mg/L for bromate due to increased cancer risk from long-term exposure.
- 0.060 for HAAs due to increased cancer risk from long-term exposure HAAs include dichloroacetic acid, trichloroacetic acid, chloracetic acid, bromoacetic acid, and dibromoacetic acid.
- 0.080 mg/L for total trihalomethanes (TTHMs) due to increased cancer risk and liver, kidney, or central nervous system problems from long-term exposure [U.S. EPA, 2009e]. TTHMs include the brominated trihalomethanes (bromodichloromethane, bromoform, dibromochloromethane) and chloroform. MCL goals for the individual trihalomethanes include 0 (zero) for bromodichloromethane and bromoform.

Studies indicate that exposure to THMs and other DBPs from chlorinated water are associated with human bladder cancer [Villanueva *et al*., 2004; Cantor *et al*., 2010]. Bromine-substituted DBPs are generally thought to have higher risks of cancer and other adverse human health effects compared to DBPs containing chlorine instead of bromine [Cantor *et al*., 2010]. EPA has determined that bromodichloromethane and bromoform are likely to be carcinogenic to humans by all exposure routes and there is suggestive evidence of dibromocloromethane carcinogencity. Excess cancer risk (based on increased risk to 1-in-a-million) occurs at concentrations above 0.001 mg/L for bromodichloromethane, 0.008 mg/L for bromoform, and 0.0008 mg/L for dibromochlormethane [U.S. EPA, 2005c].

DBP formation and the individual form of the DBP are influenced by factors such as bromide ion concentration, pH of the source water, the disinfectant dose (ozone or chlorine), reaction or contact time, and organic matter concentration and reactivity [Liang and Singer, 2003; U.S. EPA, 2005c]. Studies have shown that higher bromide levels in source waters shift the distribution of the TTHMs towards brominated species [Krasner *et al*., 1989] and the types of HAAs from chlorinated to brominated and mixed chloro-bromo haloacetic acids [Heller-Grossman, 1993; Cowman and Singer, 1996].

Under the Safe Drinking Water Act (SDWA), drinking water treatment plants must reduce DBPs in their treated water and reduce exposure to customers. EPA conducted a nationwide survey that showed that bromide levels in source water above 400 µg/L corresponded with increased levels of DBPs in the treated water [Weinberg, 2002]. Due to increased bromide concentrations in surface water, drinking water treatment plants have found increased difficulty meeting regulatory limits on DBPs [U.S. EPA, 2012a; Handke, 2009; Fiske *et al.*, 2011; States *et al.*, 2013; Wilson *et al.*, 2013]. In general, drinking water produced using surface water had higher concentrations of the DBPs than drinking water produced using ground water [U.S. EPA, 2005c].

The city of Pittsburgh, in cooperation with the University of Pittsburgh, completed a multiyear study on the Allegheny River to determine the major sources of bromide discharges, including coal-fired power plants. Typically, bromide concentrations are very low in the river, but there are increased levels near industrial sites. The bromide concentration in the source water provided a linear correlation to bromination in the drinking water. At a concentration of 0.050 mg/L in the source water, 62 percent of the TTHMs were the three brominated trihalomethane species. At a concentration of 0.150 mg/L, 83 percent of the TTHMs were the three brominated trihalomethane species [States *et al.*, 2013].

The California Urban Water Agencies (CUWA) evaluated costs associated with increased bromide levels in the source water for baseline and potential future DBP controls. CUWA developed virtual water treatment plants (WTPs) to represent their different source water areas and treatment needs, with virtual WTP design capacities ranging from 40 to 800 million gallons per day. To achieve potential future standards on currently regulated pollutants, including DBPs, CUWA estimated costs for capital improvements and added annual operation and maintenance costs. On the low end, CUWA anticipated spending between $46 million to $923 million in capital improvements and $1 million to $59 million on annual operation and maintenance costs to each virtual WTP (costs vary based on the characteristics of the virtual WTP). On the high end, CUWA anticipated spending between $98 million and almost $2 billion in capital improvements and between $2 million and $127 million in annual operation and maintenance costs for each virtual WTP [CUWA, 2011].

Bromide is naturally present in coal at trace levels and becomes part of the flue gas air emissions following combustion at steam electric power plants. Combusting coal with higher levels of bromide is known to improve removal of mercury from air emissions at steam electric power plants that operate wet FGD scrubbers. Accordingly, steam electric power plant operators might add bromide-containing salts (*e.g.*, calcium bromide) during coal combustion to improve mercury removal efficiency. The bromide-containing salts convert the mercury Hg^0 form into the more water soluble Hg^{2+} form. Bromide is not typically removed from steam electric power plant wastewaters prior to discharge to surface waters. As discussed earlier, bromides in surface waters can react with organic matter in the surface water to form DBPs at drinking water treatment plants. A recent study identified four drinking water treatment plants that experienced increased levels of bromide in their source water, and corresponding increases in the formation of brominated DBPs, after upstream steam electric power plants installed wet FGD scrubbers [McTigue *et al.*, 2014]. Bromide loadings into surface waters from coal-fired steam electric power plants could potentially increase in the future as more plant operators add bromide to help control mercury emissions.

Chlorides

Studies have found that combustion residual leachate reaching ground water has caused chloride levels to exceed secondary MCLs [NRC, 2006]. Chlorides contribute to the high TDS levels typical of steam electric power plant wastewater, as do calcium and magnesium. Both chlorides and TDS levels affect the availability and toxicity of other steam electric power plant wastewater constituents, including metals. As TDS and chlorides levels fluctuate, so do the amounts of other metals that dissolve due to solubility characteristics.

EPA recommends the following for chlorides: criterion maximum concentration of 860 mg/L (acute effects) and criterion continuous concentration of 230 mg/L (chronic effects) [U.S. EPA, 2009d]. Exceeding these chlorides levels in wastewater discharges can be harmful to animals and plants in nonmarine surface waters and can disrupt ecosystem structure. It can also adversely affect biological wastewater treatment processes. Furthermore, excessively high chlorides concentrations in surface waters can impair their use as source waters for potable water supplies. If sodium is the predominant cation present, the water will have an unpleasant taste due to the corrosive action of chloride ions.

3.2 LOADINGS ASSOCIATED WITH STEAM ELECTRIC POWER PLANT WASTEWATER

As discussed above, the pollutants commonly found in steam electric power plant wastewater such as metals, nutrients, and TDS (including bromides and chlorides) can cause considerable harm to surface waters, aquatic life, wildlife, and human health. EPA estimated pollutant loadings for the steam electric power plant wastestreams evaluated and considered as part of the revision to the steam electric ELGs (*i.e.*, FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate). The total pollutant loadings for the evaluated wastestreams are significant, with these discharges accounting for over one-third of the toxic pollutants reported to be discharged in industrial National Pollutant Discharge Elimination System (NPDES) permits [ERG, 2015a]. EPA estimated the amount of pollutants (*i.e.*, loadings) discharged by steam electric power plants throughout the United States for the evaluated wastestreams as almost 3 million toxic-weighted pound equivalents (TWPE) annually.[10] EPA uses TWFs as a way to better understand how treatment technologies and industry discharges compare to one another [U.S. EPA, 2012b]. Although EPA uses TWFs and the estimated TWPE as an indicator of a pollutant's relative potential to cause harm, EPA does not use TWPE to represent actual aquatic or human health impacts that may have occurred at specific locations due to these pollutant loadings. To assess

Pollutant Loadings: How Does the Steam Electric Power Generating Industry Compare?

EPA estimates that discharges from steam electric power plants alone contribute approximately one-third of the toxic weighted pound equivalent (TWPE) pollutant loadings to the environment among all industrial categories that report discharges under NPDES permits.

---

[10] To calculate the TWPE, EPA multiplies a mass loading of a pollutant in pounds per year (lb/yr) by a pollutant-specific weighting factor, called the toxic weighting factor (TWF), to derive a "toxic equivalent" loading (lb-equivalent/yr), or TWPE. TWFs account for differences in toxicity across pollutants and allow mass loadings of different pollutants to be compared on the basis of their toxic potential. EPA has developed TWFs for more than 1,000 pollutants based on aquatic life and human health toxicity data, as well as physical/chemical property data [U.S. EPA, 2012b].

impacts to aquatic life or human health, EPA uses the amount of pollutant loadings discharged to the surface water and the resulting concentrations in the surface waters.

When coupled with the types of impacts associated with the pollutants, the magnitude of the loadings raises concern about the risks that these discharges present to the aquatic environment and the surrounding ecosystem. This section presents the annual baseline[11] pollutant loadings associated with the evaluated wastestreams and compares steam electric discharges to those of other industries to provide perspective on the magnitude of the loadings and subsequent potential impact these wastestreams pose to the environment.

3.2.1 Annual Baseline Pollutant Loadings

In support of the final rule, EPA estimated the pollutant loadings discharged from steam electric power plants for the evaluated wastestreams, as described in Section 10 of the TDD.[12] Table 3-2 presents the baseline annual pollutant loadings discharged for select pollutants considered for analysis in the EA.[13] EPA presents these loadings in terms of pounds and TWPE and lists the TWF where applicable. The pollutants with the highest annual TWPE discharges are manganese, cadmium, boron, thallium, mercury, selenium, and arsenic. Although the total pounds discharged of arsenic, cadmium, mercury, and thallium are lower than other pollutants, their relative toxicity (as represented by the TWF) results in a large TWPE. Other pollutants, such as boron and manganese, are relatively low in toxicity but have a high TWPE due to the fairly high amount of these pollutants in steam electric power plant wastewater discharges. The high TWPE for selenium results from a combination of its quantity discharged in steam electric power plant wastewaters and its TWF.

Pollutant Loadings from Steam Electric Power Plants Evaluated Wastestreams

- 2,210,000,000 pounds of pollutants per year.
- 2,680,000 pounds of TWPE per year.

---

[11] The analyses presented in this report incorporate some adjustments to current conditions in the industry. See Section 1 for further details.

[12] Prior to finalizing the rulemaking, EPA revised the datasets used to calculate pollutant loadings for bottom ash transport water and fly ash transport water. The final industry loadings calculated using these revised datasets are presented in the TDD. The total industry loadings presented in Section 3.2 reflect the revised datasets. However, EPA did not rerun the EA models and other analyses to reflect the final loadings dataset. EA analyses used previously calculated version of the steam electric power plant pollutant loadings that were derived following the same methodology. The EA pollutant loadings are included in DCN SE05620. Pollutant-specific loadings and removals presented in this report are based on the previously calculated version. Appendix J presents the results of a sensitivity analysis that evaluated the potential for these loadings revisions to affect the EA analyses.

[13] EPA selected the pollutants listed in Table 3-2 (which represent a subset of all steam electric pollutants of concern) for analysis in the EA based on the following factors for each pollutant: presence of the pollutant in the evaluated wastestreams (see Table 2-1); documented elevated levels of the pollutant in surface waters or wildlife from exposure to steam electric power plant wastewater; and magnitude of the pollutant loadings to receiving waters.

Table 3-2. Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams)

Pollutant [a]	TWF [b]	Annual Discharge, pounds (lbs) [c]	Annual TWPE, pound-equivalent (lb-eq) [c]
Metals and Toxic Bioaccumulative Pollutants			
Manganese	0.103	7,530,000	773,000
Cadmium	22.8	13,300	303,000
Boron	0.00834	31,300,000	261,000
Thallium	2.85	63,700	182,000
Mercury	110.0	1,490	164,000
Selenium	1.12	140,000	157,000
Arsenic	3.47	29,600	103,000
Aluminum	0.0647	1,410,000	91,500
Lead	2.24	19,700	44,100
Copper	0.623	31,200	19,500
Vanadium	0.280	66,000	18,500
Iron	0.00560	2,740,000	15,400
Nickel	0.109	120,000	13,100
Zinc	0.0469	174,000	8,160
Chromium VI	0.517	156	80.5
Nutrients			
Total Nitrogen [d]	Not applicable	16,900,000	Not applicable
Total Phosphorus	Not applicable	214,000	Not applicable
Other			
Chlorides	2.435×10^{-5}	930,000,000	22,600
Total dissolved solids			Not applicable
Total Pollutants [e]		2,210,000,000	2,680,000

Sources: Abt, 2008; ERG, 2015a; ERG, 2015b; ERG, 2015f; U.S. EPA, 2012c.

Note: Numbers are rounded to three significant figures.

a – The list of pollutants included in this table is only a subset of pollutants included in the loadings analysis (see Section 10 of the TDD).

b – TWFs for the following metals apply to all metal compounds: arsenic, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. EPA updated TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium for the steam electric ELGs pollutant loadings analysis.

c – These loadings reflect adjustments to current conditions in the industry. See Section 1 for further details. Data source for pollutant specific loadings is DCN SE05620.

d – Total nitrogen is the sum of total Kjeldahl nitrogen and nitrate/nitrite as N.

e – The totals represent the pollutant loadings in discharges of the evaluated wastestreams – specifically, FGD wastewater, fly ash transport wastewater, bottom ash transport wastewater, and combustion residual leachate (see Section 10 of the TDD). Loadings presented are based on the final loadings analysis presented in the TDD. The totals exclude loadings for pollutants not identified as POCs and for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total dissolved solids (TDS), and total suspended solids (TSS).

3.2.2 Comparison of Steam Electric Power Plant Loadings to Other Industries

The total TWPE discharges from the steam electric power generating industry are higher than the TWPEs estimated for many other industries. As part of the Preliminary 2010 Effluent Guidelines Program Plan published on October 30, 2009 (74 FR 68599), EPA identified 10 point source categories, out of 56, that represented the bulk of the estimated toxic wastewater discharges (as measured by TWPE) from existing industrial point source categories. EPA ranked each point source category by the amount of toxic pollutants in its discharges and identified the Steam Electric Power Generating Point Source Category (40 CFR 423) as the category with the highest TWPE. Table 3-3 presents the total TWPE estimated as part of the 2010 Effluent Guidelines Planning Process for the remaining nine point source categories with the highest TWPE [U.S. EPA, 2011d]. The TWPE estimated for the 2010 Effluent Guidelines Planning Process includes pollutant loadings estimated from discharge monitoring reports (DMRs) and Toxic Release Inventory (TRI) reporting. Therefore, the industry totals may include double-counting of certain chemical discharges (*i.e.*, a facility must report a chemical on both its DMR and its TRI reporting form).

Table 3-3. Pollutant Loadings for the Final 2010 Effluent Guidelines Planning Process: Top 10 Point Source Categories

40 CFR Part	Point Source Category	Total TWPE [a] (lb-eq/yr)
423	Steam Electric Power Generating	2,680000 [b]
430	Pulp, Paper, And Paperboard	1,030,000
419	Petroleum Refining	1,030,000
421	Nonferrous Metals Manufacturing	994,000
418	Fertilizer Manufacturing	826,000
414	Organic Chemicals, Plastics, And Synthetic Fibers	649,000
440	Ore Mining And Dressing	448,000
415	Inorganic Chemicals Manufacturing	299,000
444	Waste Combustors	254,000
410	Textile Mills	250,000

Source: U.S. EPA, 2011d.

a – Only TWPE totals for the steam electric power generating industry include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium. The TWPE for all other point source categories is estimated from DMRs and TRI reporting and may include double-counting of certain pollutant discharges (*i.e.*, a facility must report a pollutant on both its DMR and its TRI reporting form). Loadings are rounded to three significant figures.

b –EPA calculated the steam electric power generating industry (40 CFR 423) discharges for the final rule as total 2,680,000 TWPE annually (see Section 10 of the TDD). These loadings reflect adjustments to current conditions in the industry. See Section 1 for further details.

EPA estimated that the total baseline TWPE from steam electric power plant wastewater is almost three times the amount estimated for the pulp, paper, and paperboard industry, petroleum refining industry, and nonferrous metals manufacturing (second, third, and fourth highest ranking), and it is over five times the TWPE for four of the six other industries identified as the top TWPE dischargers in the Final 2010 Effluent Guidelines Program Plan [U.S. EPA, 2011d].[14] This suggests that the loadings from the subset of evaluated wastestreams represent a greater environmental concern within the context of all industrial dischargers across the United States.

3.2.3 Comparison of Steam Electric Power Plant Loadings to Publicly Owned Treatment Works

To provide additional perspective on the magnitude of the pollutant loadings from steam electric power plants, EPA compared loadings for the evaluated wastestreams to those of an average publicly owned treatment works (POTW). EPA selected POTWs for comparison because, for point sources, POTWs and steam electric power plants dwarf all other point source discharges in terms of total TWPE of metals discharged to waters in the United States [U.S. EPA, 2010c].[15] In addition, the more than 16,000 POTWs are located across the United States and provide a common metric to use for point source evaluations.

EPA calculated the average pollutant loadings discharged from a typical POTW using EPA's Effluent Guidelines Program Plan DMR database, DMRLoadsAnalysis2009_v02.mdb. EPA assumed that a typical POTW discharges wastewater at a rate of 3 to 5 million gallons per day (MGD)[16] based on the number of facilities by discharge flow rate reported in Metcalf and Eddy, 2003 [ERG, 2015a]. EPA developed queries in the DMRLoadsAnalysis2009_v02.mdb to do the following: 1) select POTWs that discharge between 3 and 5 MGD, and 2) calculate the average DMR loadings (in pounds and TWPE per year) for each pollutant [ERG, 2015a]. Table 3-4 compares the average steam electric pollutant loadings by wastestream[17] to the pollutant

---

[14] Data sources for the other industry discharges include DMRs and TRI reports. EPA recognizes that the DMR and TRI data have limitations (*e.g.*, only a subset of facilities and a subset of pollutants might be included in the estimated loadings); however, these are the most readily available data sets that represent discharges across the United States.

[15] Based on metal loadings (total TWPE) calculated by EPA's DMR Pollutant Loading Tool, 2010 data, by Standard Industrial Classification (SIC) code. The top two industries are SIC 4952 – Sewerage Systems (*i.e.*, POTWs) and SIC 4911 – Electrical Services. EPA's DMR Pollutant Loading Tool is an online tool (http://cfpub.epa.gov/dmr/) that calculates pollutant loadings from permit and DMR data from EPA's Permit Compliance System (PCS) and Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES). The tool also ranks dischargers, industries, and watersheds based on pollutant mass and toxicity, and presents "top 10" lists to help users determine which facilities and industries are producing these discharges and which watersheds are impacted. Facilities report pollutant discharge monitoring data in their DMR as mass-based quantities (*e.g.*, pounds per day) and/or concentrations (*e.g.*, mg/L). The DMR Pollutant Loading Tool allows users to gather annual loadings data. For this EA, EPA reviewed the 2010 loadings reported in DMRs.

The use of the DMR data has its limitations. Only pollutants included in the facility's NPDES permit are included in the PCS and ICIS-NPDES databases; therefore, if a facility does not have mercury limitations, mercury discharges from that facility will not be included in the total for industrial discharges. States (or other permitting authority) have some discretion as to which data they make available (or enter) to PCS and ICIS-NPDES. For example, permitting authorities enter DMR and permit information for facilities that are considered major dischargers. However, they do not necessarily enter DMR or permit information into PCS for minor dischargers or facilities covered by a general permit.

[16] For comparison, the average discharge flow rates for the evaluated wastestreams are 0.45 MGD for FGD wastewater; 3.5 MGD for fly ash transport water; 2.1 MGD for bottom ash transport water; and 0.08-0.09 MGD for leachate [see Section 6 of the TDD].

[17] EPA calculated the average pollutant loadings for each wastestream by dividing the total pollutant loadings for the wastestream by the number of steam electric power plants discharging the wastestream [ERG, 2015a].

loadings from an average POTW assumed to discharge 3 to 5 MGD. The results of the analysis demonstrate the following:

- Average FGD wastewater discharges contain over 200 times more boron and manganese, over 75 times more selenium, and approximately 20 times more cadmium and nickel than average POTW discharges.
- Average fly ash transport water discharges contain over 10 times more boron, cadmium and thallium and over five times more arsenic, nickel, and selenium than average POTW discharges.
- Average bottom ash transport water discharges contain 30 times more thallium; approximately 10 times more manganese and nickel; and five times more cadmium than average POTW discharges.
- Average combustion residual leachate wastewater discharges contain more boron, iron, manganese, and selenium than average POTW discharges.

Loadings of the Evaluated Wastestreams Compared to POTWs

- FGD wastewater discharges contain:
    - 200 times more manganese
    - 200 times more boron
    - 75 times more selenium
    - 20 times more nickel
    - 20 times more cadmium
- Bottom ash transport water discharges contain 30 times more thallium and 10 times more manganese and nickel.
- Fly ash transport water discharges contain five times more arsenic, nickel, and selenium and 10 times more boron, cadmium, and thallium.
- Combustion residual leachate contains over four times more boron and iron.

Nutrient loadings (total nitrogen and total phosphorus) from the average steam electric wastestreams are generally lower than the nutrient loadings from an average POTW. Total nitrogen loadings from an average FGD wastestream are approximately equal to those of an average POTW. Nitrogen loadings from average fly ash and bottom ash transport waters are less than the total nitrogen discharges from an average POTW (approximately 20 percent). The amount of total phosphorus discharged by an average POTW is over 20 times higher than that in the average fly ash transport water, bottom ash transport water discharges, and FGD wastewater. EPA did not calculate nutrient loadings for combustion residual leachate.

For chlorides, EPA found that average FGD wastewater discharges contain approximately six times greater chlorides loadings than an average POTW discharge. The average discharges of fly ash transport water, bottom ash transport water, and combustion residual leachate from a steam electric power plant contain less chlorides than a typical POTW discharge (less than 10 percent). EPA's DMR data did not include pollutant loadings for TDS from POTWs; therefore, EPA could not compare these pollutant loadings between steam electric and POTW discharges.

Table 3-4. Comparison of Average Pollutant Loadings in the Evaluated Wastestreams to an Average POTW

Pollutant	Average Plant FGD Wastewater Discharge [a,b]		Average Plant Fly Ash Transport Water Discharge [a,c]		Average Plant Bottom Ash Transport Water Discharge [a,d]		Average Plant Combustion Residual Leachate Discharge [a,e]		Average POTW Discharge [a,f]	
	Loadings (lbs/yr)	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**
Aluminum	1,530	99.1	8,490	549	4,240	274	837	54.1	3,590	215
Arsenic	9.54	33.1	312	1,080	66.5	231	10.8	37.5	45.9	159
Boron	334,000	2,790	17,900	149	2,190	18.3	6,530	54.5	1,540	12.8
Cadmium	81.2	1,850	47.7	1,090	19.1	435	2.87	65.3	3.54	80.6
Chromium VI	(g)	(g)	2.62	1.35	0.136	0.070	(g)	(g)	17.7	9.02
Copper	17.9	11.1	263	164	89.0	55.5	2.16	1.34	154	95.3
Iron	1,150	6.42	5,140	28.8	7,610	42.6	10,400	58.4	2,530	14.2
Lead	5.71	12.8	152	340	63.4	142	(g)	(g)	48.5	109
Manganese	74,500	7,650	486	49.9	4,770	490	790	81.1	354	36.1
Mercury	5.50	605	7.85	864	3.19	351	0.298	32.8	3,180	350,000
Nickel	620	67.6	180	19.6	301	32.7	13.1	1.43	30.6	3.06
Selenium	1,410	1,580	134	150	32.4	36.3	31.2	35.0	18.5	20.7
Thallium	16.7	47.7	137	392	302	863	0.338	0.964	9.94	28.2
Vanadium	20.8	5.82	220	61.7	11.4	3.21	538	151	No data	No data
Zinc	983	46.1	734	34.4	247	11.6	59.1	2.77	453	18.1
Total Nitrogen	128,000	--	23,400	--	24,600	--	(g)	--	123,000	--
Total Phosphorus	457	--	864	--	715	--	(g)	--	17,800	--
Chlorides	10,200,000	248	83,500	2.03	96,700	2.35	120,000	2.93	1,610,000	39.3
TDS	40,400,000	--	1,760,000	--	2,560,000	--	1,020,000	--	No data	--

Note: Numbers are rounded to three significant figures.

a – TWPE presented in the table include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium.

b – Average loadings based on 88 plants assumed to discharge FGD wastewater under baseline conditions [ERG, 2015a].

c – Average loadings based on 50 plants assumed to discharge fly ash transport water under baseline conditions [ERG, 2015a].

d – Average loadings based on 183 plants assumed to discharge bottom ash transport water under baseline conditions [ERG, 2015a].

e – Average loadings based on 95 plants assumed to discharge combustion residual leachate under baseline conditions [ERG, 2015a].

f – Average loadings based on average loadings calculated for POTWs discharging 3 to 5 MGD of wastewater (see DCN SE01961).

g – EPA did not calculate loadings for this pollutant and wastestream. See the Costs and Loads Report (DCN SE05831).

To provide additional perspective on the magnitude of the loadings, EPA calculated the equivalent number of typical POTWs that would discharge loadings equal to the 202 steam electric power plants[18] included in the baseline loadings analysis. Table 3-5 presents total pollutant loadings for the evaluated wastestreams (for the 202 plants) and the number of typical POTWs that would discharge equivalent loadings. The results demonstrate that the magnitude of the total loadings from 202 steam electric power plants is equivalent to a significantly larger number of typical POTWs for many of the pollutants commonly known to cause environmental harm. For example, EPA estimated that the total loadings in discharges of the evaluated wastestreams from these 202 plants are equivalent to approximately 20,000 POTW discharges of boron and manganese; over 7,500 POTW discharges of selenium; over 6,000 POTW discharges of thallium; over 3,500 POTW discharges of cadmium and nickel; over 1,000 POTW discharges of iron; and over 500 POTW discharges of arsenic and chlorides. This suggests that, for the evaluated wastestreams, 202 steam electric power plants contribute substantial pollutant loadings to the environment.

Table 3-5. Estimated Number of POTW Equivalents for Total Pollutant Loadings from the Evaluated Wastestreams

Pollutant	Annual Discharge pounds (lbs)	Equivalent Number of Average POTWs [a]
Aluminum	1,410,000	394
Arsenic	29,600	646
Boron	31,300,000	20,300
Cadmium	13,300	3,760
Chromium VI	156	8.81
Copper	31,200	203
Iron	2,740,000	1,080
Lead	19,700	406
Manganese	7,530,000	21,300
Mercury	1,490	<1
Nickel	120,000	3,920
Selenium	140,000	7,560
Thallium	63,700	6,410
Vanadium	66,000	No values for comparison
Zinc	174,000	384
Total Nitrogen	16,900,000	138
Total Phosphorus	214,000	12.0
Chlorides	930,000,000	578
TDS	4,210,000,000	No values for comparison

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Equivalent number of POTWs is estimated by dividing the total annual pollutant loadings from the 202 steam electric power plants by the average POTW loadings presented in Table 3-4 for a 4-MGD POTW.

---

[18] The count of 202 steam electric power plants includes seven indirect dischargers that discharge wastewater to a POTW and do not discharge any of the evaluated wastestreams directly to surface waters. EPA included these indirect dischargers to protect confidential business information.

3.3 ENVIRONMENTAL IMPACTS FROM STEAM ELECTRIC POWER PLANT WASTEWATER

EPA identified environmental impacts from EPA's assessment of damage cases and literature sources ("other documented site impacts") caused by steam electric power plant wastewater and combustion residuals. EPA found over 150 steam electric power plants causing environmental impacts to surface water and ground water environments following exposure to steam electric power plant wastewater. Impacts identified in the damage cases and other documented site impacts include lethal and sublethal impacts on fish, impacts on the diversity and size of populations in the ecosystem, and impacts on drinking water quality. While these impacted sites are often assumed to be anomalies, mounting evidence indicates that the characteristics contributing to the documented impact (*e.g.*, magnitude of the pollutant loadings, type of pollutant present, plant operations, and wastewater handling techniques) are common among steam electric power plant receiving water locations [Cherry *et al*., 2000; NRC, 2006; Rowe *et al*., 2002].

Section 3.3.1 presents a qualitative discussion of the lethal and sublethal ecological effects of pollutants in steam electric power plant wastewater. Section 3.3.2 summarizes documented instances where steam electric power plant wastewater discharges have caused fish advisories or exceeded MCLs presenting a potential human health concern. Section 3.3.3 and Section 3.3.4 summarize the damage cases and other documented site impacts to surface water and ground water, respectively. Section 3.3.5 discusses the potential for these environmental impacts to occur at other locations.

3.3.1 Ecological Impacts

Documented ecological impacts associated with exposure to steam electric power plant wastewater include acute effects (*e.g.*, fish kills) and chronic effects (*e.g.*, malformations, and metabolic, hormonal, and behavioral disorders) upon biota within the receiving water and surrounding environment. Effects have included reduced growth and reduced survival of aquatic organisms and changes to the local habitat [Carlson and Adriano, 1993; Rowe *et al*., 2002].

This section provides examples of the lethal and sublethal effects on organisms exposed to steam electric power plant wastewater pollutants (*e.g.*, arsenic, cadmium, chromium, copper, mercury, and selenium) in surface waters and sediment. Scientific studies reported in the literature included:

- Field studies in which organisms collected from known contaminated sites were compared to those collected from uncontaminated sites.
- Laboratory experiments in which organisms intentionally exposed to steam electric power plant wastewater were compared to those unexposed.

Many of the scientific studies documented in the literature focused on selenium as a key pollutant of environmental concern within steam electric power plant wastewater. However, due to the complex nature of the wastewater, many studies evaluated the environmental effects of metals in steam electric power plant wastewater in aggregate.

Lethal and Sublethal Effects of Selenium

Selenium can bioaccumulate to toxic levels in organisms inhabiting environments with low selenium concentrations. For example, Lemly conducted a field study that investigated the patterns of selenium biomagnification and toxicity in aquatic organisms inhabiting a cooling water reservoir that received effluent from a power plant's surface impoundment [Lemly, 1985a]. Throughout the study, selenium concentrations in the reservoir averaged 10 µg/L; however, Lemly reported that fish tissue concentrations reached levels ranging from 500 to 4,000 times the average reservoir water selenium concentration. The results of the study indicated that the extent of selenium bioaccumulation depended on the trophic level of the fish present in the reservoir. Lemly observed that the selenium accumulation increased as the trophic level increased, which potentially correlated with the observed elimination of multiple higher-tropic-level fish species. Therefore, these findings suggest that—even at low concentration within a surface water—selenium can accumulate and biomagnify to toxic levels in aquatic organisms and pose a lethal threat to fish at the top of the trophic structure [Lemly, 1985a]. Predicting the impacts of selenium in aquatic ecosystems can be particularly challenging, because impacts to the ecosystem cannot be determined solely on the selenium concentration in the receiving water as demonstrated in this study.

Selenium discharges also impact species diversity in receiving waters. In 1977, two years after the initial operation of the Belews Creek Steam Station in North Carolina, the fish community inhabiting the plant's cooling water reservoir (a lake) underwent rapid decline, and species diversity drastically altered [Lemly, 1985a]. Lemly observed that 17 of the 20 fish species originally present in the lake were eliminated after the power plant began operation, including all game species (temperate perch [*Percichthyidae*], true perch and pike perch [*Percidae*], and sunfish [*Centrarchidae*]). Lemly reported significant levels of selenium accumulation in the eliminated species and statistically unchanged levels of selenium accumulation in the surviving species, relative to levels before the power plant began operation. Only three species maintained reproducing populations in the reservoir: one native species (mosquitofish) and two introduced non-native species of minnows (fathead minnows and red shiners) [Lemly, 1985a].

A number of scientific studies express concern over selenium exposure within lakes and reservoirs where longer residence times allow for further bioaccumulation and a greater potential to reach lethal concentrations. This is demonstrated by a series of major fish kills that occurred in 1978 and 1979 at Martin Creek Lake (Texas) due to the elevated concentrations of selenium in the water and fish tissue [U.S. EPA, 2014b]. In particular, studies concluded that elevated selenium concentrations were likely the primary contributor to fish kills in lakes and reservoirs, decreasing population density and community diversity [Coughlan and Velte, 1989; Crutchfield, 2000b; Crutchfield and Ferguson, 2000a; Cumbie and Van Horn, 1978].

The sublethal effects of selenium vary widely and can impact growth, reproduction, and survival of susceptible organisms. Scientists have demonstrated that various fish and amphibian species are sensitive to elevated selenium concentrations such as those found in steam electric power plant wastewater. In addition to lethal effects described above, these fish and amphibian species have developed sublethal symptoms such as accumulation of selenium in tissue (histopathological effects) and in the blood (hematological effects), resulting in decreased growth, changes in weight, abnormal morphology, and reduced hatching success [Coughlan and Velte, 1989; Lemly, 1993; Sager and Colfield, 1984; Sorensen, 1988; Sorensen and Bauer, 1984a; Sorensen *et al*., 1982, 1983, 1984b].

The literature indicates that the extent of selenium accumulation in fish tissue varies by species, and selenium accumulates most significantly in the liver and reproductive tissues in most species [Baumann and Gillespie, 1986; Sager and Colfield, 1984; Sorensen, 1988]. Other studies have reported accumulation in the skeletal muscle, kidneys, gills, and hearts of fish, resulting in pathological lesions, morphological changes, increased organ weight, and decreased growth [Coughlan and Velte, 1989; Lemly, 2002; Sorensen and Bauer, 1984b]. Aquatic organisms exposed to steam electric power plant wastewater have exhibited elevated selenium concentrations in organs such as kidneys, liver, and gonads, resulting in abnormalities that hinder growth and survival [Rowe *et al*., 2002].

In addition, selenium is highly teratogenic (*i.e.*, able to disturb the growth and development of an embryo or fetus) and readily transferable from mother to egg [Chapman *et al*., 2009; Janz *et al*., 2010; Lemly, 1997b; Maier and Knight, 1994]. Selenium is known to bioaccumulate in the reproductive organs of fish and amphibian species. In one study, ovarian selenium concentrations in bluegill fish were observed at levels 1,000 times greater than the surrounding surface water [Baumann and Gillespie, 1986]. Multiple studies have documented reproductive failure or diminished reproductive success in both fish and amphibians inhabiting ponds, lakes, and reservoirs contaminated with selenium from steam electric power plant wastewater discharges [Baumann and Gillespie, 1986; Crutchfield, 2000b; Cumbie and Van Horn, 1978; Gillepsie *et al*., 1986; Hopkins *et al*., 2002; Nagle *et al*., 2001]. For example, Hopkins *et al*. [2006] observed reduced hatching success, abnormal swimming, and abnormalities in the face and skull in the offspring of selenium-contaminated female toads. Field and captive feeding studies also show reproductive impairment (reduced hatchability of eggs) among waterfowl exposed to elevated levels of selenium [Adams *et al*., 2003; Ohlendorf, 2003 and 2007; Beckon *et al*., 2008; U.S. DOI, 1998; Smith *et al*., 1998].

Histopathological effects (*i.e.*, observable changes in tissue), increased metabolic rate, and decreased growth rates are effects typically caused by contamination from steam electric power plant wastewater. Water and fish samples collected before and after the discharge of power plant wastewater from the surface impoundment to the Texas Utilities Martin Creek Lake found that selenium concentrations were significantly elevated in the reservoir and in fish livers, kidneys, and gonads. In 1984, Garrett and Inman reported that elevated selenium concentrations persisted in the livers and kidneys of several species of fish for up to 3 years after the power plant wastewater discharges ceased. Additionally, a 1988 study by Sorensen found that red ear sunfish native to the reservoir exhibited ovary abnormalities related to elevated selenium concentrations up to 8 years following an 8-month exposure to power plant wastewater discharges. Although the surface impoundment discharge was short-lived, many of the histopathological effects persisted for years after the discharge had ceased [Rowe *et al*., 2002].

These sublethal effects of selenium, while not directly resulting in the mortality of exposed aquatic wildlife, can ultimately cause the types of population-level impacts described under lethal impacts above. The available scientific evidence indicates that reproductive success—specifically, offspring mortality and severe development abnormalities that affect the ability of fish to swim, feed, and successfully avoid predation—is the critical assessment endpoint when evaluating the potential for selenium exposure to result in population-level impacts to resident fish species.

For a summary of the impacts of selenium on surface water, refer to Table A-10 in Appendix A.

Lethal Effects of Other Pollutants

Scientific studies have confirmed that both acute and chronic exposure to pollutants in steam electric power plant wastewater can be lethal to a wide range of aquatic organisms. For example, Guthrie and Cherry [1976] found that shrimp darters and salamanders were highly sensitive to acute exposures of steam electric power plant wastewater and experienced nearly 100 percent mortality following a five-day exposure to power plant wastewater discharges. Invertebrates and fish also evaluated in the study were less sensitive to the acute exposure to power plant wastewater and reported lower rates of mortality [Guthrie and Cherry, 1976]. Chronic exposures to power plant wastewater are also of concern; however, studies show extreme differences in species sensitivity [Rowe *et al*., 2002]. For example, juvenile chubsuckers (a benthic fish) exposed for 45 days to sediments, water, and food contaminated with power plant wastewater experienced a 75 percent mortality rate [Hopkins *et al*., 2001]. In another study, bullfrogs exposed to sediment and water from a combustion residual surface impoundment for 34 days demonstrated an 87 percent mortality rate (which was 41 percent greater than the mortality rate of bullfrogs included in control group) [Rowe *et al*., 2002]. A third study reported no lethal effects for banded snakes exposed for 2 years to fish collected from combustion residual surface impoundments [Hopkins *et al*., 2002].

Other studies examined lethal effects of sediments contaminated with combustion residuals. For example, eggs and hatchlings of fish and reptiles raised in contaminated sediment reported higher mortality rates (16 to 94 percent) than eggs and hatchlings from control groups [Hopkins *et al*., 2000; Nagle *et al*., 2001; Roe *et al*., 2006; Rowe *et al*., 1998a, 1998b, 2001; Snodgrass *et al*., 2004]. Each of the studies observed elevated mortality rates in conjunction with higher concentrations of steam electric power plant wastewater pollutants (*e.g.*, arsenic, cadmium, chromium, copper, selenium) in the exposed sediment.

Three studies evaluated the lethal effects of specific pollutants in steam electric power plant wastewater on a variety of organisms (*i.e.*, insects, fish, and amphibians) and determined the median lethal concentration (LC_{50}) for each pollutant-organism combination. LC_{50} is the concentration expected to be lethal to 50 percent of a group of organisms exposed for a given time duration. Table 3-6 summarizes the results from the three experiments and Table 3-7 presents the LC_{50} concentrations reported in the studies. Overall, the LC_{50} studies report species-specific differences, particularly among species living downstream of fly ash surface impoundment discharges. The downstream species developed resistance to pollutants compared to those living in unpolluted ponds. Because the LC_{50} concentrations were much higher than actual aquatic concentrations, there was no evidence in these experiments of acute lethal effects, though long-term (1 to 3 months) lethal effects could not be ruled out [Benson and Birge, 1985; Birge, 1978; Specht *et al*., 1984].

Sublethal Effects of Other Pollutants

Although the majority of sublethal effects documented in the literature primarily focus on selenium concentrations in steam electric power plant wastewater, several studies discussed the sublethal effects of other pollutants, such as arsenic, cadmium, chromium, copper, and lead [Rowe *et al*., 2002]. Sublethal effects from exposure to pollutants other than selenium in power plant wastewater can include changes to morphology (*e.g.*, fin erosion, oral deformities), behavior (*e.g.*, swimming ability, ability to catch prey, ability to escape from predators), and metabolism that can negatively affect long-term survival. For example, a study of larval bullfrogs living in combustion residual surface impoundments found that more than 95 percent of individuals had abnormal oral structures, such as the absence of grazing teeth or entire rows of teeth, which altered feeding habits and subsequently reduced growth rates in the affected bullfrogs [Rowe *et al*., 1996]. In another study, tail malformations in larval bullfrogs attributed to power plant wastewater exposure caused abnormal swimming behavior, and the affected bullfrogs were preyed upon more frequently than bullfrogs from unpolluted sites [Raimondo *et al*., 1998].

Several studies have demonstrated increased metabolic rates and decreased growth rates in aquatic organisms exposed to steam electric power plant wastewater. Increased metabolism causes organisms to waste energy during normal metabolic processes, which can affect growth. In a 1998 study by Rowe, grass shrimp caged in a surface impoundment for eight months experienced a 51 percent increase in standard metabolic rate. Similarly, crayfish captured near the impoundment experienced increased metabolic rates and decreased growth rates—effects that were also observed in crayfish collected from unpolluted sites and exposed to contaminated sediments from the combustion residual surface impoundment [Rowe *et al*., 2002].

Table 3-6. Summary of Studies Evaluating Lethal Effects of Pollutants in Steam Electric Power Plant Wastewater

Citation	Studied Organism	Test Performed	Trace Elements Studied	Summary of Results
Birge, 1978	Eggs from goldfish, trout, and toads	7- to 28-day lethal effects	22 elements	Among the 22 elements tested, cadmium, chromium, mercury, nickel, lead, and silver were the most toxic to all three species, with most LC_{50} being 0.1 milligrams per liter (mg/L) or less.
Benson and Birge, 1985	Minnows (fish) living in fly ash-polluted ponds in Kentucky compared to those living in uncontaminated ponds	Acute (96-hour) toxicity	Cadmium Copper Zinc	The study found a higher tolerance to cadmium and copper in the exposed fish compared to the fish from unpolluted ponds. However, both exposed and unexposed populations exhibited similar tolerance to zinc. See Table 3-7 for LC_{50} values.
Specht *et al*., 1984	Insects (coleopterans, mayflies, and other insects) exposed to fly ash surface impoundment effluent from the Appalachian Power Plant in Giles County, Virginia, compared to those living in an uncontaminated pond	Acute (96-hour) toxicity	Cadmium Copper Zinc	The study observed a higher tolerance to pollutants in exposed insects compared to those living in unpolluted ponds. See Table 3-7 for LC_{50} values.

Table 3-7. Median Lethal Concentrations (LC_{50}) for Pollutants in Steam Electric Power Plant Wastewater

	LC_{50}, mg/L						
	7- to 28-Day Exposure			**96-Hour Exposure**			
Pollutant	**Trout [Birge, 1978]**	**Goldfish [Birge, 1978]**	**Toad [Birge, 1978]**	**Exposed Minnows [Benson and Birge, 1985]**	**Control Minnows [Benson and Birge, 1985]**	**Mayflies [Specht *et al*., 1984]**	**Other Insects [Specht *et al*., 1984]**
Aluminum	0.56	0.15	0.05				
Arsenic	0.54	0.49	0.04				
Cadmium	0.13	0.17	0.04	3.89 [a] 9.55 [b]	3.06 [a] 7.16 [b]	0.27	1.2-250
Chromium	0.18	0.66	0.03				
Cobalt	0.47	0.81	0.05				
Copper	0.09	5.2	0.04	0.36 [a] 0.41 [b]	0.21 [a] 0.39 [b]	0.18	0.03-8.3
Lead	0.18	1.66	0.04				
Mercury	0.005	0.12	0.001				
Nickel	0.05	2.14	0.05				
Selenium	4.18	8.78	0.09				
Silver	0.01	0.03	0.01				
Vanadium	0.16	4.6	0.25				
Zinc	1.06	2.54	0.01	6.14 [a] 5.96 [b]	6.09 [a] 7.45 [b]	18.44	18.2

Acronyms: mg/L – milligrams per liter.

Shaded cells indicate that the pollutant was not evaluated.

a – Nominal water hardness of 100 mg/L calcium carbonate ($CaCO_3$).

b – Nominal water hardness of 250 mg/L calcium carbonate ($CaCO_3$).

3.3.2 Human Health Effects

Exposure to pollutants can cause non-cancer effects in humans, including damage to the circulatory, respiratory, or digestive systems and neurological and developmental effects. Steam electric power plant wastewater includes toxic pollutants and known or suspected carcinogens (*e.g.*, arsenic and cadmium). In the literature review, EPA identified potential human impacts from consuming fish in contaminated waters and from ingesting drinking water contaminated by pollutants from combustion residuals.[19]

Numerous damage cases show exceedances of drinking water standards at ground water and drinking water wells due to leachate from nearby impoundments and landfills.

During the late 1970s, three power plant cooling water reservoirs in Texas received discharges from surface impoundments containing elevated selenium levels, resulting in a series of fish kills. The reservoirs included Brandy Branch Reservoir, located in Harrison County; Welsh Reservoir, located in Titus County; and Martin Creek Lake, located in Rusk County. Investigations at the reservoirs implicated elevated selenium levels in the fish tissue as the cause. In 1992, the Texas Department of Health issued a fish consumption advisory for the three reservoirs after determining that the level of selenium in fish could pose a potential health risk to humans, especially children 6 years or younger and pregnant women.

Ground water and drinking water supplies can be degraded by pollutants in steam electric power plant wastewater and combustion residual leachate [Cross, 1981]. Combustion residual leachate can migrate from the site in the ground water at concentrations that could contaminate public or private drinking water wells and surface waters, even years following disposal of combustion residuals [NRC, 2006], as exemplified in the following example. The Wisconsin Electric Power Company (WEPCO) plant in Port Washington, Wisconsin, had disposed of fly ash in a quarry for over 20 years (1943-1971) at a depth of 40 to 60 feet, with some of the disposed ash below the water table. The disposal site is located in an upland area where down-gradient ground water is used as a source of drinking water. The Wisconsin Department of Natural Resources was notified in January 1980 and November 1990 that elevated levels of sulfates, selenium, and boron were found in a private drinking water well located 250 feet down-gradient from the coal-fired power plant waste disposal site. The impacted private well was replaced with a deeper well to avoid further contamination [U.S. EPA, 2014c].

---

[19] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the CCR rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

As discussed in Section 3.3.4 and Appendix A, there have been documented exceedances of MCL drinking water standards at off-site ground water and drinking water wells. Exceedances of MCLs in the ground water indicate potential human health impacts if the pollutants enter private drinking water wells. Section 3.3.4 outlines three documented instances where combustion residual leachate contamination caused impacts to private drinking water wells.

Drinking water standards can also be exceeded in surface waters. For example, Duke Energy's Riverbend Plant discharges surface impoundment effluent into Mountain Island Lake, which supplies drinking water to 700,000 people. The county detected arsenic and zinc concentrations above state standards in an area near the surface impoundment discharge pipe [*Charlotte Observer*, 2010]. While most of the pollutants in the surface water would likely be reduced to safe levels during drinking water treatment, elevated levels of pollutants in source water can impact the effectiveness of drinking water treatment processes and the ability of drinking water treatment plants to meet MCLs. Section 3.4.6 presents further details on drinking water resources near steam electric power plants.

3.3.3 Damage Cases and Other Documented Surface Water Impacts

Changes in surface water chemistry due to contamination from steam electric power plant wastewater can negatively impact all levels of an ecosystem, including lower food chain organisms, which affect the ecosystem's food web; fish inhabiting the surface water; and wildlife and humans when they bathe in or drink the water. As described in earlier sections, pollutants in surface water can accumulate in aquatic organisms such as fish. When wildlife or humans ingest these aquatic organisms, they can be exposed to a higher dose of contamination than through direct exposure to the surface water. Documented surface water impacts associated with discharges of steam electric power plant wastewater include damage to fish populations (*i.e.*, physiological and morphological abnormalities and various behavioral, reproductive, and developmental effects), decreased diversity in insect populations, and decline of aquatic macroinvertebrate population. Impacts that affect humans include exceedances of NRWQC, fish consumption advisories, and designation of surface waters as impaired (limiting recreational activities).

EPA's damage case assessment found 26 proven damage case sites and 31 potential damage case sites with surface water impacts [U.S. EPA, 2014a through 2014e]. Including documented site impacts from the literature review, EPA identified impacts to surface waters at nearly 70 steam electric power plants following exposure to wastewater (more than 140 documented site impacts) [ERG, 2015m]. Some of the documented impact sites are the same locations identified by EPA as damage case sites. Table 3-8 highlights several damage case and other documented impact sites where

Some wastewater surface impoundments are located in, or near, large river floodplains. Failure of the embankments of surface impoundments can release catastrophic amounts of pollutants into surrounding ecosystems.

negative surface water impacts from steam electric power plant wastewater discharges have been studied. In most cases, negative impacts have been studied and documented in multiple articles and reports. Tables A-6 and A-7 in Appendix A summarize the damage cases from combustion residual surface impoundments and landfills, respectively.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Belews Lake, NC	13	Proven damage case [U.S. EPA, 2014b]	In 1970, Duke Power Company constructed Belews Lake as a cooling water reservoir to support the Belews Creek Steam Station. Almost immediately after surface impoundment effluent began discharging into the lake, fish populations experienced morphological changes, reproductive failure, and eventually death. In 1985, the Belews Creek Steam Station converted to a dry-ash transport system, ending the surface impoundment discharges to the lake. However, even 11 years after the discharges ceased, reproductive abnormalities persisted in the fish populations. Due to selenium concentrations, 16 of the 20 populations originally present in the reservoir were entirely eliminated, including all primary sport fish [Lemly, 1997a; U.S. EPA, 2014b].
Brandy Branch Reservoir, TX	1	Proven damage case [U.S. EPA, 2014b]	Brandy Branch Reservoir serves as a cooling water reservoir for Pirkey Power Plant. From 1986 to 1989, the Texas Parks and Wildlife Department's) reported increases in the selenium concentrations of the fish inhabiting the receiving water. As a result, the Texas Department of Health issued a fish consumption advisory for the reservoir, because of the potential health impact due to the levels of selenium in fish. Since the fish kills in the 1980s, Southwestern Electric Power Company has worked cooperatively to monitor fish tissue selenium concentrations, which have decreased since the late 1980s [ATSDR, 1998a].
Euharlee Creek, GA	1	Proven damage case [U.S. EPA, 2014b]	On July 28, 2002, a sinkhole developed in the surface impoundment at the Georgia Power Company in Cartersville, GA. The sinkhole expanded to 4 acres, and an estimated 2.25 million gallons of ash/water mixture was released to a tributary of the Euharlee Creek. Approximately 80 tons of ash entered Euharlee Creek through a stormwater drainage pipe. This discharge deposited an ash blanket in the creek up to 8 inches deep over 1,850 square feet of the stream bottom. Sampling at the ash discharge site found that concentrations of certain metals (arsenic, cadmium, chromium, copper, lead, mercury, and nickel) exceeded EPA Region IV ecological sediment screening values (ESV'S) indicating a potential for adverse impacts to aquatic life. Sediment concentrations of arsenic measured 14 ppm dry weight–over five times the toxic threshold. Biological sampling indicated that benthic organisms in the tributary and ash deposition zone of Euharlee Creek were either killed by contaminants or physically smothered. The resident fish community, which consisted of at least 25 species, was displaced due to the irritation of high turbidity in the ash plume as it moved through during the spill. One month after the spill, concentrations of selenium and cadmium were elevated in crayfish, clams, mollusks, and insects at a Euharlee Creek site downstream from the ash deposit.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Gibson Lake, IN	4	Proven damage case [U.S. EPA, 2014b]	Gibson Lake is a man-made, shallow impoundment that receives surface impoundment effluent from Gibson Generating Station. Starting in 1986, least terns, an endangered species of migratory birds, began using the dike in Gibson Lake as a nesting ground for breeding. To protect the birds from potential toxic exposure, the plant began a cooperative program with the Indiana Department of Natural Resources to protect the nesting birds by creating a nearby alternative habitat, known as Cane Ridge Wildlife Management Area (WMA), which received water pumped from Gibson Lake. In April 2007, Duke Energy closed access to the lake for recreational fishing due to elevated selenium levels. A year later, the U.S. Fish and Wildlife Service (USFWS) became concerned about selenium levels in the water and fish in the Cane Ridge WMA. The USFWS stopped the flow of water from Gibson Lake into Cane Ridge, discouraged least terns from using the refuge, removed the contaminated fish, and plowed Cane Ridge to redistribute and bury the selenium in the soil. Subsequently, the USFWS stopped the flow of water from Gibson Lake into Cane Ridge and piped water from Wabash River instead. Cane Ridge was restocked with fish to lure back migratory birds. As of 2010, fish populations in Gibson Lake still had selenium levels above the toxic threshold [U.S. EPA, 2014b].
Glen Lyn, VA	5	Proven damage case [U.S. EPA, 2014b]	Glen Lyn Plant discharged fly ash transport water from a surface impoundment into Adair Run, a tributary of the New River. A 1984 study reported that the local insect diversity and density remained essentially the same upstream (reference site) and downstream of the surface impoundment when the impoundment was not close to capacity. However, as the settling impoundment reached its capacity, the insect density and diversity declined downstream. After closure of the surface impoundment, it took up to 10 months for the insect populations to recover [Specht *et al*., 1984].
Hyco Lake, NC	8	Proven damage case [U.S. EPA, 2014b]	Hyco Lake is a large cooling water reservoir that received effluent from a power plant, including combustion residual leachate and fly ash transport water discharges containing high levels of selenium. In 1981, a large-scale fish kill occurred in the reservoir, prompting numerous scientific studies to examine the extent and cause of the environmental damage. Multiple studies detected selenium concentrations in the water and tissue of fish inhabiting the reservoir, while other trace elements were within normal concentration ranges. The selenium accumulated in the fish in the lake, impacting reproduction and causing declines in fish populations in the late 1970s and the 1980s. A fish consumption advisory was issued in 1988 for this lake due to selenium contamination.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Martin Creek Lake, TX	8	Proven damage case [U.S. EPA, 2014b]	Martin Creek Lake is a cooling water reservoir that also receives steam electric power plant wastewater discharges. In 1978 and 1979, a series of major fish kills occurred due to the elevated concentrations of selenium in the water and fish tissue. Numerous studies conducted throughout the 1980s documented histopathological and reproductive damage in the fish populations inhabiting the lake. In addition, the studies determined that, even 8 years after discharge ceased, the overall health of the aquatic populations near the discharge site remained adversely affected by the selenium pollution. In 1992, a fish consumption advisory was issued for the lake due to discharges from the steam electric power plant [U.S. EPA, 2014b].
McCoy Branch, TN	3	Proven damage case [U.S. EPA, 2014b]	In 1986, coal ash slurry discharges from the Department of Energy's (DOE's) Chestnut Ridge Y-12 power plant into McCoy Branch were found to contain elevated concentrations of trace elements, which violated the Tennessee Water Quality Act. A 1992 report written by DOE documented bioaccumulation of contaminants in fish tissues, decreased diversity in benthic macroinvertebrate communities, and increased fish mortality and abnormalities at the site [U.S. DOE, 1992].
Mountain Island Lake, NC	5	Location not assessed	Duke Energy's Riverbend Plant discharges surface impoundment effluent into Mountain Island Lake, which supplies drinking water to 700,000 people. The county staff has detected arsenic and zinc concentrations above state standards in an area near the surface impoundment discharge pipe [*Charlotte Observer*, 2010]. The plant continues to extensively monitor metal concentrations in Mountain Island Lake surrounding the point of discharge [NCDENR, 2011].
North Carolina (Multiple Locations)	Not applicable, multiple sites	Location not assessed	A study of receiving waters (including lakes and rivers) for 10 steam electric power plants in North Carolina evaluated the environmental and ecological impacts that wastewater discharges have on surface waters. The study found that the receiving waters at the 10 plants contain high levels of contaminants as a result of wastewater discharges. From the data collected between 2010 and 2012, contaminant levels at multiple surface waters exceeded drinking water standards and/or NRWQC. For example, arsenic concentrations at two outfalls were as high as 45 µg/L and 92 µg/L, respectively (the drinking water MCL for arsenic is 10 µg/L). When compared to the upstream pollutant concentrations at the 10 North Carolina locations, data showed elevated levels of contaminants such as boron, chromium, selenium, bromine, arsenic, and thallium. Elevated pollutant concentrations were also found in lake sediments (arsenic and selenium) and pore water near lake bottoms (including manganese, arsenic, nickel, and bromine). The study found elevated levels of arsenic and selenium in fish tissues for two of the lakes (Hyco Lake and Mayo Lake). A report on fish in Mayo Lake found deformities consistent with ingestion of high selenium levels [Ruhl *et al.*, 2012].

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Rocky Run Creek, WI	5	Proven damage case [U.S. EPA, 2014b]	Rocky Run Creek, a tributary of the Wisconsin River, receives effluent from Columbia Power Station's surface impoundments. After the power station began operation in 1975, the aquatic macroinvertebrate populations declined in the area. Two studies conducted at this site concluded that population density decreased, not because of death due to coal ash toxicity, but because the aquatic macroinvertebrate populations avoided the area due to sublethal alterations in the creek. Studies found increased TDS and total suspended solids (TSS), as well as a number of heavy metals, downstream from the discharge. Some species of macroinvertebrates were totally eliminated 4 months after discharges began.
Savannah River Site, SC	23	Proven damage case [U.S. EPA, 2014b]	The Savannah River Site, which is owned by DOE, is divided into several areas, based on production, land use, and other related characteristics. The D-area, a site utilized by numerous ecologists to study the impacts of coal-fired power plant waste, houses a coal-fired power plant that discharges ash into a series of surface impoundments and a swamp that ultimately drains into the Savannah River. Numerous studies observed organisms within these habitats accumulated high concentrations of trace elements in their tissues and exhibited various physiological, behavioral, and developmental effects. Sediments, water, and biota in the disposal system have elevated concentrations of trace elements and heavy metals derived from bottom ash and fly ash deposited in the basins. The studies documented several impacts to amphibians, reptiles, and fish, including five species of fish that have been eliminated.
TVA's Kingston Fossil Plant, TN	6	Proven damage case [U.S. EPA, 2014b]	On December 22, 2008, the retaining wall of a surface impoundment at TVA's Kingston Fossil Plant broke and released billions of gallons of coal ash slurry into the Emory, Clinch, and Tennessee Rivers. Tennessee Department of Environment and Conservation found exceedances of the more stringent criteria for chronic exposure of fish and aquatic life at least once in January 2009 for several metals (*e.g.*, aluminum, cadmium, iron, and lead). Seven months after the spill, all fish collected had concentrations of selenium above a toxic threshold, and most were still contaminated at that level 14 months after the spill. Twenty-one months after the spill, a high percentage of fish were found with lesions, deformities, and infections, all symptoms of extreme stress. In addition, studies have shown elevated levels of arsenic and mercury in sediments near the ash spill, as well as selenium levels exceeding the MCL in three wells underneath the Kingston's coal ash disposal area, ash processing area, and gypsum disposal facility [U.S. EPA, 2014b].

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Welsh Reservoir, TX	2	Proven damage case [U.S. EPA, 2014b]	Welsh Reservoir serves as a cooling water reservoir for Welsh Power Plant. From 1986 to 1989, the Texas Park and Wildlife Department reported increases in the selenium concentrations of the fish inhabiting the receiving water. As a result, the Texas Department of Health (TDH) issued a fish consumption advisory for the reservoir because of the potential health impact due to the levels of selenium in fish. In 1998, TDH collected 20 fish for reevaluation and observed an average selenium concentration in the fish above the reported national averages. Therefore, the Agency for Toxic Substances and Disease Registry (ATSDR) concluded in a report that there was no clear indication of an overall change in selenium fish tissue concentrations over the 12 years [ATSDR, 1998b].

Sources: ATSDR, 1998a; ATSDR, 1998b; *Charlotte Observer*, 2010; ERG, 2013b; Lemly, 1997a; NCDENR, 2011; Ruhl *et al.*, 2012; Specht *et al*., 1984; U.S. DOE, 1992; U.S. EPA, 2014b.

3.3.4 Damage Cases and Other Documented Ground Water Impacts

Pollutants in combustion residuals can leach into ground water from surface impoundments and landfills at the site. Older surface impoundments and landfills are of particular concern because they were often built without liners and leachate collection systems. Liners are typically made of synthetic material, asphalt, clay, or a composite of materials (*e.g.*, synthetic and clay) and are designed to collect leachate and prevent ground water contamination. Combustion residuals held in unlined surface impoundments can enter the subsurface and contaminate ground water. Pollutants in unlined landfills, used for the dry disposal of combustion residuals, can also leach as precipitation flows through the residuals pile and dissolves pollutants; the combustion residual leachate can eventually migrate into ground water. New plants are increasingly installing liners in surface impoundments and landfills, but pollutants can also enter the ground water when liners fail or when a disposal site is situated such that natural ground water fluctuations come into contact with the disposed waste. Furthermore, state regulation on leachate collection systems and impermeable liners is not uniform [EPRI, 1997; 65 FR 32214-32237, 2000].

Numerous damage cases and other documented site impacts demonstrate the toxic effects of steam electric power plant wastewater contamination to ground water and the potential to impact off-site sources due to combustion residual leachate migrating from landfills and surface impoundments (often unlined). EPA's damage case assessment found 24 proven damage case sites and 110 potential damage case sites with ground water impacts [U.S. EPA, 2014a through 2014e]. EPA identified impacts to ground water quality caused by combustion residual leachate from 140 steam electric power plants (more than 130 documented site impacts) [ERG, 2015m]. Some of these documented site impacts are caused by ash contributions from multiple plants (*e.g.*, a landfill that stores ash from multiple plants). EPA identified some of the documented impact sites as also being damage case sites. The majority of the damage cases and documented site impacts reported ground water pollutant levels in on-site wells above regulatory levels; however, only a portion of the cases indicated off-site contamination. Documented impacts to off-site ground water resources may be lower due to long migration times within the subsurface until the combustion residual leachate reaches a known monitoring point [NRC, 2006]. Further, the limited number of studies documenting off-site contamination might reflect less extensive monitoring of off-site ground water wells for evidence of impacts from combustion residual leachate, which suggests off-site impacts may be underrepresented in the documented ground water impacts [Cherry, 2000].

In surface impoundments, combustion residuals are in constant contact with water, allowing toxic pollutants to leach into and eventually contaminate ground water. From an environmental impact perspective, combustion residual surface impoundments are generally considered less desirable than landfills for disposal because they provide constant saturated or nearly saturated conditions and a relatively large hydraulic driving force to move combustion residual leachate into the subsurface [Theis and Gardner, 1990]. Table A-4 in Appendix A summarizes documented ground water damage cases from combustion residual surface impoundments [U.S. EPA, 2014a through 2014e].

Although more desirable than surface impoundments, landfills pose their own ground water contamination risks. If the landfills are not properly lined, the pollutants in combustion residuals can leach into the soil during precipitation. In areas with acid rain, the precipitation's low pH can accelerate the leaching of contaminants into ground water. In addition, heavy precipitation can not only accelerate leaching, but also carry pollutants in stormwater runoff, potentially contaminating ground water or surface water resources [Andersen and Madsen, 1983]. Table A-5 in Appendix A summarizes documented ground water damage cases from combustion residual landfills [MDNRE, 2010; U.S. EPA, 2014a through 2014e].

While many damage cases document elevated pollutant levels in ground water wells, it is unclear how many of these are private drinking water wells (as opposed to monitoring wells). However, the fact that many sites reported MCL exceedances in ground water testing suggests that potential impacts to drinking water resources are a realistic concern. The following three damage cases are documented instances where uncollected combustion residual leachate contaminated ground water and resulted in impacts to private drinking water wells.

Constellation Ash Disposal at Waugh Chapel and Turner Pits – Anne Arundel County, Maryland

For over a decade, Constellation Energy Group (Constellation) supplied fly ash for structural fill at the B.B.S.S. Inc. (BBSS) sand and gravel mines in Anne Arundel County, Maryland. Fly ash from Constellation's Brandon Shores and Wagner plants was used to reclaim portions of BBSS's Turner Pit starting in 1995 and the Waugh Chapel Pit starting in 2000. In the fall of 2006, Anne Arundel County Health Department officials documented concentrations of sulfate and metals (*i.e.*, antimony, beryllium, cadmium, manganese, and nickel) exceeding the state's screening criteria for potable aquifers in residential wells located downgradient from Waugh Chapel and Turner Pits [MDNR, 2007].

An independent study of the contamination confirmed that the elevated concentrations of sulfate and metals observed in the wells directly resulted from precipitation infiltrating the fly ash deposited in the BBSS sand and gravel mines [MDNR, 2007]. In October 2007, the Maryland Department of the Environment (MDE) fined Constellation and BBSS $1 million for the ground water contamination and required the companies to restore the local aquifer water quality [MDE, 2008]. In addition, Anne Arundel homeowners impacted by the contamination filed a class action lawsuit against Constellation and were awarded a $45 million settlement. The settlement required Constellation to pay the costs for converting 84 homes from well water to public water; cease future deliveries of new coal ash to the quarry; and to establish trust funds to compensate impacted property owners, enhance the neighborhood, and remediate and restore a former quarry site [Schultz, 2008].

Gibson Generating Station Plant – Gibson County, Indiana

The Gibson Generating Station Plant has six unlined surface impoundments (four surface impoundments and two settling/decant basins) and a landfill for combustion residuals. The landfill consists of a 94-acre older portion built in the late 1970s that is unlined and a 43-acre portion built in 2002 with a composite liner and leachate collection system. Additionally, the plant has a 400-acre landfill (South Landfill), permitted in 2005, which also has a composite liner and leachate collection system.

Samples from monitoring wells downgradient from the older landfill show high levels of arsenic, boron, iron, and manganese. Leaching from the landfill has contaminated 12 drinking water wells in the hamlet of East Mount Carmel, Indiana, with boron, manganese, iron, sulfate, sodium, and TDS. Sampling performed by Duke Energy in 2007 and by the Natural Resources Defense Council in 2008 show drinking water contamination from boron, iron, and manganese in at least nine off-site private residential wells [U.S. EPA, 2014b].

Ground Water Violations Near North Carolina Power Plants With Surface Impoundments – North Carolina

The North Carolina Department of Environment and Natural Resources reported ground water contamination near combustion residual surface impoundments at all 14 of the state's coal-fired power plants. Duke Energy and Progress Energy each own seven of the plants and perform ground water monitoring as required by the state. Manganese and lead concentrations exceeded state ground water standards at all 14 locations and TDS and chromium concentrations exceeded state standards at seven locations. Boron levels at six plants exceeded state ground water standards, and some plants had elevated levels of arsenic, selenium, thallium, antimony, chlorides, and nickel. The state and plants have not identified the source of the contamination but noted that the exceedances occurred at newly located wells. Drilling the wells may have affected the concentration of naturally occurring elements such as lead and manganese [Ballard, 2012].[20]

3.3.5 Potential for Impacts to Occur in Other Locations

Key environmental characteristics that contributed to the impacts documented in Sections 3.3.3 and 3.3.4, such as chronic exposure to large pollutant loadings, plants discharging to waters with long residence times, and unlined surface impoundments or landfills, are common at steam electric power plants. This suggests that the impacts documented above indicate the greater potential threat that steam electric power plant wastewater discharges pose to the environment. Although substantial events such as fish kills are well documented, the extent to which more subtle damages, such as histopathological changes, morphological deformities, and damage to reproductive success, occur elsewhere is not known due to the limited extent of monitoring programs.

Some of the documented environmental impacts discussed above occurred following discharges of steam electric power plant wastewater under normal operations. Although the actual amounts of pollutant loadings discharged may vary among steam electric power plants, documented site impacts under normal operations do not indicate that the pollutant loadings associated with the impacts are unusual for steam electric power plants. This suggests that chronic exposure to typical steam electric power plant wastewater pollutant loadings can impact the environment at other sites not documented in the literature.

The residence time of steam electric power plant wastewater pollutants in surface water is a major factor in determining the impact to the environment and the length of the recovery time. Many documented impact sites are lentic waterbodies such as lakes (*i.e.*, still waters) where pollutants can reside for long periods of time. These types of surface waters are at particular risk to impacts from steam electric power plant wastewater discharges. Steam electric power plants that discharge to a pond, lake, or reservoir may experience similar environmental effects as those observed in the documented impacts from analogous aquatic systems [ERG, 2015j].

---

[20] EPA notes that the impacts reported at North Carolina plants have not been documented in a peer-reviewed literature source; however, the information shows that elevated levels of metal contamination can occur near ash ponds.

3.4 DISCHARGE TO SENSITIVE ENVIRONMENTS

The pollutant loadings, ecological impacts, and human health concerns discussed in Section 3.2 and Section 3.3 are also of concern due to the proximity of many steam electric power plants to sensitive environments where the characteristics of steam electric power plant wastewater may impair water quality (*e.g.*, 303(d)-listed waters and waters with fish advisories) or pose a threat to threatened and endangered species.[21] EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located in close proximity to the following sensitive environments:

- Great Lakes watershed (Section 3.4.1).
- Chesapeake Bay watershed (Section 3.4.2).
- Impaired waters (Section 3.4.3).
- Fish consumption advisory waters (Section 3.4.4).
- Threatened and endangered species habitats (Section 3.4.5).
- Drinking water resources (Section 3.4.6).

Table 3-9 summarizes the number and percentage of immediate receiving waters located in sensitive environments.

Table 3-9. Number and Percentage of Immediate Receiving Waters Identified as Sensitive Environments

Sensitive Environment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Great Lakes watershed	25 (11%)
Chesapeake Bay watershed	13 (6%)
Impaired water	111 (50%)
Surface water impaired for a subset of pollutants associated with the evaluated wastestreams [b]	59 (27%)
Fish consumption advisory water	140 (63%)
Surface water with a fish consumption advisory for a subset of pollutants associated with the evaluated wastestreams [c]	93 (42%)
Drinking water resource within 5 miles	199 (90%)

a – For the sensitive environment proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – Table B-1 in Appendix B contains a complete list of the impairment categories identified in EPA's 303(d)-listed waters and designates the subset of pollutants evaluated.

c – Table B-2 in Appendix B contains a complete list of the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

3.4.1 Pollutant Loadings to the Great Lakes Watershed

The Great Lakes watershed includes hundreds of tributaries, thousands of smaller lakes, and extensive mineral deposits. The watershed provides a unique habitat that supports a wide range of flora and fauna, including over 200 globally rare plants and animals and more than 40 species found only in the Great Lakes watershed. Rare species include the white catspaw pearly mussel, the copper redhorse fish, and the Kirtland's warbler. The watershed provides a habitat

---

[21] See the ERG memorandum "Proximity Analysis Methodology" (DCN SE04448) for a description of the methodology used to evaluate the proximity of steam electric power plants to sensitive environments.

and food web for an estimated 180 species of native fish, including small- and large-mouth bass, muskellunge, northern pike, lake herring, whitefish, walleye, and lake trout [Great Lakes Restoration Initiative, 2010].

The Great Lakes provide humans with transportation, power, and recreational opportunities including fishing and boating. Between the United States and Canada, the Great Lakes have more than 10,000 miles of coastline and 30,000 islands. The watershed is home to more than 30 million people. Recreational spending directly supports 107,000 jobs and nearly 250,000 jobs when secondary impacts are taken into consideration [Great Lakes Restoration Initiative, 2010].

Environmental impacts documented in the Great Lakes are associated with a range of stressors, including toxic and nutrient pollutants, invasive species, and habitat degradation. EPA and Environment Canada have focused their Great Lakes Binational Toxics Strategy on persistent toxic substances such as mercury [U.S. EPA and Environment Canada, 1997; Great Lakes Restoration Initiative, 2010]. Mercury is a concern in all of the Great Lakes due to its bioaccumulation in fish and wildlife and potential impacts on humans. For example, in a study of 65 hair samples from fish-eating and non-fish-eating women, average mercury concentrations in hair were significantly greater (*i.e.*, 128 to 443 percent higher concentration) for women who ate several meals of sport-caught fish from the Great Lakes. EPA and Environment Canada have documented a range of wildlife impacts from mercury in the Great Lakes such as an increase of physiological abnormalities in herring gulls [U.S. EPA and Environment Canada, 2009].

Annual Discharges to the Great Lakes Watershed from the Evaluated Wastestreams

- 1.15 million pounds of total nitrogen
- 9,570 pounds of thallium
- 8,730 pounds of zinc
- 5,020 pounds of selenium
- 2,170 pounds of arsenic
- 1,900 pounds of lead

As part of the EA, EPA wanted to determine the extent of impacts to the Great Lakes watershed that might be caused by discharges of the evaluated wastestreams. The primary source of mercury in the Great Lakes watershed is atmospheric deposition from sources around the Great Lakes watershed (*e.g.*, fuel combustion, incineration, and manufacturing) emitting approximately 70,000 pounds of mercury annually [Evers *et al.*, 2011]. When compared to atmospheric deposition, mercury contributions from point source discharges are less of a concern. Due to the bioaccumulative nature of mercury, EPA has placed strict controls (*e.g.*, mixing zones are not allowed in permits) to limit the total amount of mercury entering the Great Lakes watershed. Monitoring within the Great Lakes watershed has indicated a decrease in mercury point source discharges, primarily because of implemented control strategies. EPA identified 23 steam electric power plants discharging to the Great Lakes watershed with the majority discharging to Lake Michigan (11 plants) and Lake Erie (6 plants) [ERG, 2015a]. In the Lake Erie Management Plan, EPA identified steam electric discharges as contributing 57 percent of the mercury to Lake Erie from wastewater sources [U.S. EPA, 2008b].

The potential for bioaccumulative pollutant retention in still or slow-moving water, such as the Great Lakes, is a particular concern. Many pollutants in steam electric power plant wastewater can bioaccumulate in fish and then affect higher trophic levels and terrestrial environments. Table 3-10 presents total pollutant loadings for the evaluated wastestreams discharging to the Great Lakes watershed.

Table 3-10. Pollutant Loadings to the Great Lakes Watershed from the Evaluated Wastestreams

Pollutant	Annual Discharge to the Great Lakes Watershed (lbs)	Annual TWPE Discharge to the Great Lakes Watershed (lb-eq)
Arsenic	2,170	7,510
Boron	997,000	8,310
Cadmium	648	14,700
Chromium VI	0.548	0.283
Copper	2,550	1,590
Lead	1,900	4,250
Manganese	242,000	24,900
Mercury	82.8	9,110
Nickel	9,840	1,070
Selenium	5,020	5,630
Thallium	9,570	27,300
Zinc	8,730	409
Total Nitrogen	1,150,000	--
Total Phosphorus	23,100	--
Chlorides	31,900,000	778
Total Dissolved Solids	186,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

3.4.2 Pollutant Loadings to the Chesapeake Bay Watershed

The Chesapeake Bay is the largest estuary in the United States and is a complex ecosystem that provides habitats and food webs for diverse groups of animals and plants. A variety of fish either live in the Chesapeake Bay and its tributaries year-round or visit its waters as they migrate along the East Coast. The Chesapeake Bay Watershed covers 64,000 square miles, with 11,684 miles of shoreline, and includes areas in six states: Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, plus Washington, DC. The watershed includes approximately 284,000 acres of tidal wetlands that provide critical habitats for fish, birds, crabs, and other species [Chesapeake Bay Program, 2015a and 2015b].

The Chesapeake Bay and its tributaries provide recreational and commercial opportunities, with more than 100,000 streams, creeks, and rivers in the watershed. Fishers commonly catch striped bass and white perch and seafood production from the Bay totals approximately 500 million pounds per year [Chesapeake Bay Program, 2015].

Annual Discharges to the Chesapeake Bay from the Evaluated Wastestreams

- 993,000 pounds of total nitrogen
- 6,560 pounds of selenium
- 5,830 pounds of zinc
- 5,280 pounds of thallium
  2,510 pounds of arsenic

The Chesapeake Bay was the first estuary in the nation to be selected for restoration as an integrated watershed and ecosystem. The watershed supports over 2,700 species of plants and animals, including 348 species of finfish and 173 species of shellfish. Other aquatic life includes algae, bay grasses, and other invertebrates. The watershed provides habitats for at least 29 species of waterfowl, with a population of nearly one million during the winter (representing approximately one-third of the Atlantic Coast's migratory population) [Chesapeake Bay Program, 2015].

Most of the Chesapeake Bay and its tidal waters are listed as impaired for excess nitrogen, phosphorus, and sediment. These pollutants cause oxygen-consuming algae blooms and create "dead zones" where fish and shellfish cannot survive, block sunlight that is needed for underwater grasses, and smother aquatic life on the bottom of the Bay. To restore water quality in the Bay, EPA established Total Maximum Daily Load (TMDL) limits for the Chesapeake Bay watershed in December 2010. These limits are 186 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds of sediment each year, reducing the discharges to the watershed by 25 percent for nitrogen, 24 percent for phosphorus, and 20 percent for sediment. Pollutant loadings to the Chesapeake Bay watershed come from both point sources and nonpoint sources. Point sources include municipal wastewater treatment facilities, industrial discharge facilities (*e.g.*, steam electric power plants and concentrated animal feeding operations), NPDES permitted stormwater (municipal separate storm sewer systems (MS4) and construction and industrial sites), and other sources. Nonpoint sources include agricultural land runoff, atmospheric deposition, forest land runoff, nonregulated stormwater runoff, stream banks and tidal shorelines, tidal resuspension, the ocean, wildlife, and natural background [U.S. EPA, 2010d].

EPA identified nine steam electric power plants discharging to the Chesapeake Bay watershed and estimated that these plants discharge almost one million pounds of nitrogen and over 16,000 pounds of phosphorus to the Bay annually [ERG, 2015a]. Table 3-11 presents the baseline pollutant loadings for the evaluated wastestreams.

Table 3-11. Pollutant Loadings to the Chesapeake Bay Watershed from the Evaluated Wastestreams

Pollutant	Annual Discharge to the Chesapeake Bay Watershed (lbs)	Annual TWPE Discharge to the Chesapeake Bay Watershed (lb-eq)
Arsenic	2,510	8,720
Boron	1,390,000	11,600
Cadmium	513	11,700
Chromium VI	16.7	8.62
Copper	2,210	1,380
Lead	1,560	3,490
Manganese	148,000	15,200
Mercury	88.8	9,770
Nickel	5,280	575
Selenium	6,560	7,360
Thallium	5,280	15,100
Zinc	5,830	273
Total Nitrogen	993,000	--
Total Phosphorus	16,800	--
Chlorides	43,000,000	1,050
Total Dissolved Solids	186,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

3.4.3 Proximity to Impaired Waters

A surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat). Based on that definition, half of the immediate receiving waters included in the EA are impaired waters.[22] EPA reviewed the identified 303(d) impairment categories and determined that approximately 27 percent of the immediate receiving waters are impaired for a pollutant associated with the evaluated wastestreams, as shown in Table 3-12. Figure 3-1, Figure 3-2, and Figure 3-3 illustrate the geographical location of plants that directly discharge wastewater to a water classified as impaired by high concentrations of mercury, metals (other than mercury), and nutrients.

Table 3-12. Number and Percentage of Immediate Receiving Waters Classified as Impaired for a Pollutant Associated with the Evaluated Wastestreams

Pollutant Causing Impairment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Mercury	30 (14%)
Metals, other than mercury [b]	28 (13%)
Nutrients	19 (9%)
TDS, including chlorides	4 (2%)
Total for Any Pollutant [c]	**70 (32%)**

a – For the impaired waters proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – The EPA impaired water database listed 28 immediate receiving waters as impaired based on the “metal, other than mercury” impairment category. Of those 28 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals in the EA analysis (arsenic, cadmium, chromium, copper, lead, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

c – Total does not equal the sum of the immediate receiving waters listed in the table. Some immediate receiving waters are impaired for multiple pollutants.

---

[22] Table B-1 in Appendix B lists the impairment categories identified under the sensitive environments proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

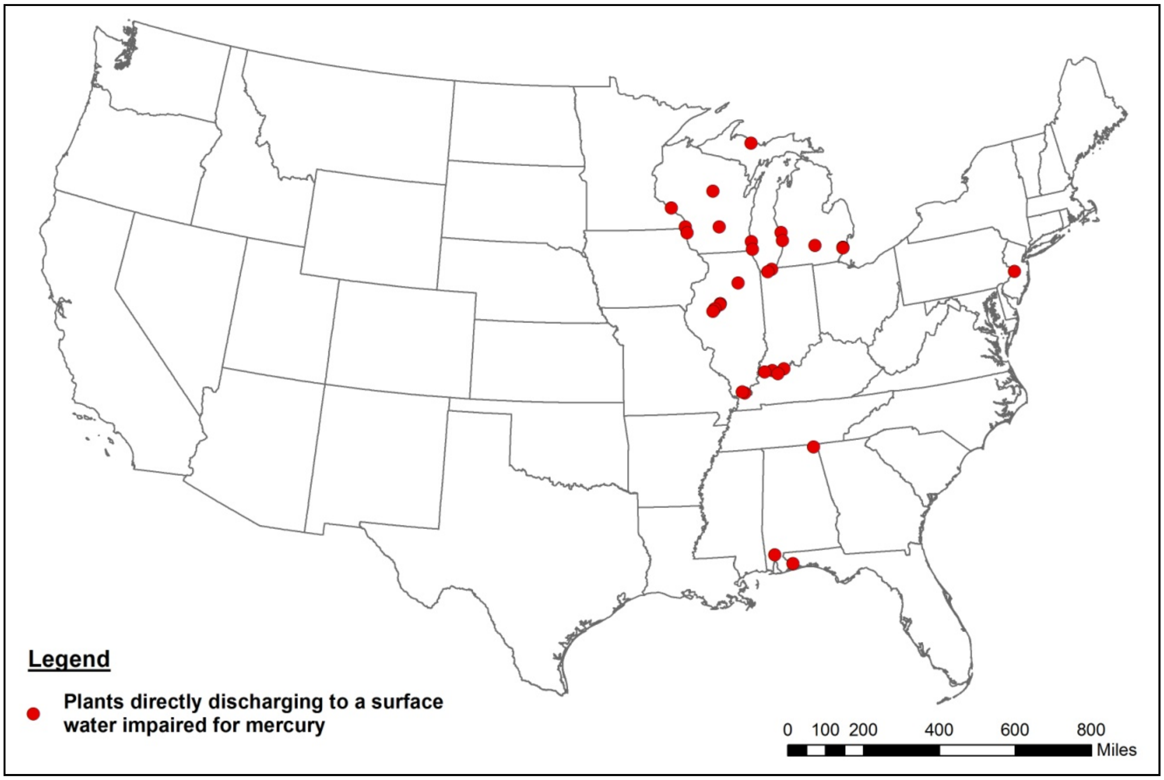


Figure 3-1. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Mercury

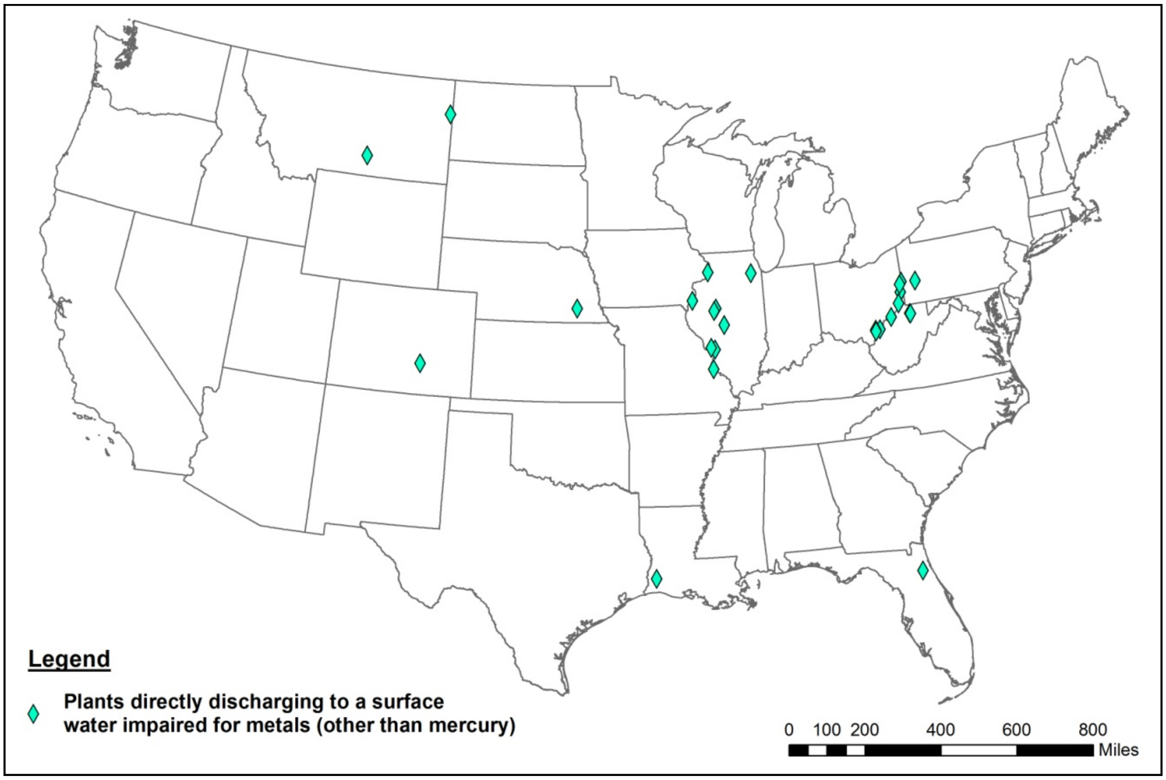


Figure 3-2. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Metals, Other than Mercury

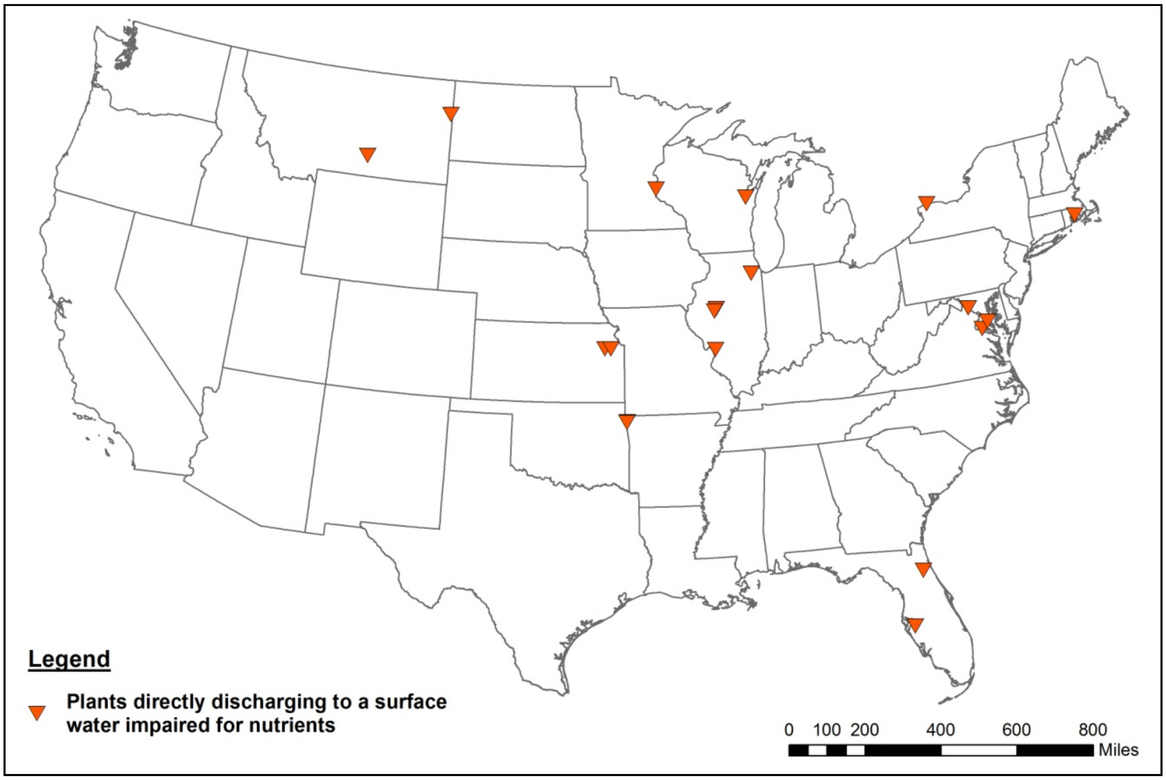


Figure 3-3. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Nutrients

3.4.4 Proximity to Fish Consumption Advisory Waters

States, territories, and authorized tribes issue fish consumption advisories when pollutant concentrations in fish tissue are considered unsafe for consumption [U.S. EPA, 2011e]. EPA determined that 140 of the immediate receiving waters included in the EA (63 percent) are under fish consumption advisories; 93 of the immediate receiving waters (42 percent) are under an advisory for a pollutant associated with the evaluated wastestreams.[23] All of these 93 immediate receiving waters are under a fish consumption advisory for mercury and one of the receiving waters is also under a fish consumption advisory for lead. EPA also reviewed fish consumption advisories for arsenic, cadmium, and selenium but did not identify any immediate receiving waters under advisories for these pollutants. Figure 3-4 illustrates the geographical location of plants that directly discharge steam electric power plant wastewater to surface waters with a fish consumption advisory for lead or mercury.

---

[23] Table B-2 in Appendix B lists the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

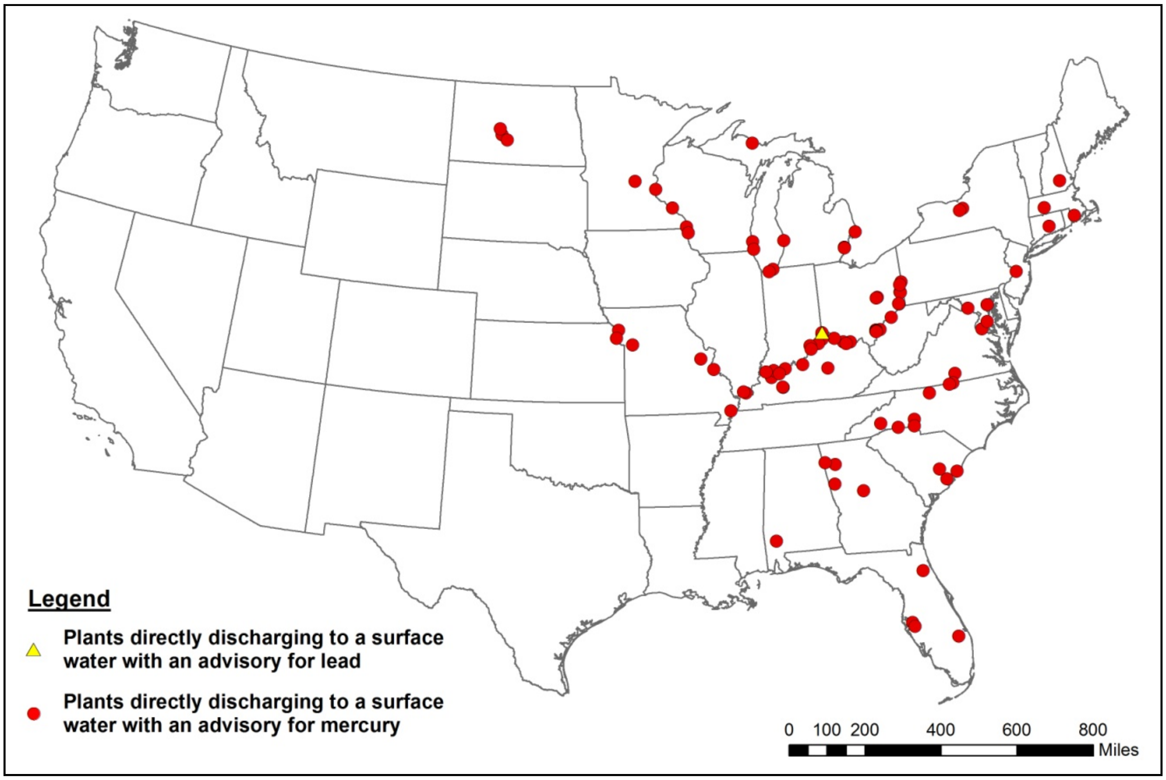


Figure 3-4. Location of Plants that Directly Discharge to a Surface Water with a Fish Consumption Advisory

3.4.5 Proximity to Threatened and Endangered Species Habitats

Under the Endangered Species Act (ESA), endangered species are those in danger of extinction throughout all or a significant portion of its range. Threatened species are those species that are likely to become endangered within the foreseeable future. A species may be listed solely on the basis of their biological status and threats to their existence. The USFWS considers five factors for listing: 1) damage to, or destruction of, a species' habitat; 2) overutilization of the species for commercial, recreational, scientific, or education purposes; 3) disease or predation; 4) inadequacy of existing protection; and 5) other natural or man-made factors that affect the continued existence of the species.

EPA evaluated the extent to which the estimated range and critical habitats of currently listed threatened and endangered species, or those in consideration for listing under the ESA (as of December 2014), overlap with surface waters that are potentially affected by the final rule. As described in the Benefits and Cost Analysis (EPA-821-R-15-005), these "affected areas" are receiving waters that do not meet water quality metrics recognized to cause harm in organisms under baseline conditions, but which do meet these metrics under the most stringent regulatory option EPA analyzed (Option E). EPA identified 138 threatened and endangered species whose habitats overlap with, or are located within, an "affected" surface water under baseline conditions.[24]

---

[24] The habitat locations evaluated for this analysis include waters downstream from steam electric power plant discharges and reflect changes in the industry as a result of the Clean Power Plan [Clean Air Act Section 111(d)].

In addition, EPA assessed the vulnerability of each species identified to changes in water quality and developed the following categories:

- High vulnerability: species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources.
- Moderate vulnerability: species living in aquatic habitats for one life history stage and/or species that obtain some of their food from aquatic sources.
- Low vulnerability: species whose habitats overlap bodies of water, but whose life history traits and food sources are terrestrial.

EPA classified 54 percent of the species (75 of 138 species) with habitats located within an "affected" surface water as highly vulnerable to changes in water quality. The habitats of these highly vulnerable species overlap a total of 145 affected stream reaches. For further details on the threatened and endangered species analysis and results, see the Benefits and Cost Analysis (EPA-821-R-15-005).

3.4.6 Proximity to Drinking Water Resources

EPA also evaluated the potential for steam electric power plants to pose a threat to public sources of drinking water. Although many of the pollutants (*e.g.*, selenium, mercury, arsenic, nitrates) in the evaluated wastestreams would likely be reduced to safe levels during drinking water treatment, these pollutants could potentially impact the effectiveness of the treatment processes, which could increase public drinking water treatment costs.[25] EPA evaluated the proximity of steam electric power plants to the following sensitive environments for drinking water resources:

- Drinking water intakes – drinking water sources that collect surface water through a public water system. Intakes are protected under the SDWA of 1974 and its 1986 and 1996 amendments, which require delegated states and tribes to perform routine testing to ensure that they meet state drinking water standards.
- Public wells – drinking water sources that collect ground water through a public water system. Public wells are protected under the SDWA, which requires delegated states and tribes to perform routine testing to ensure that they meet state drinking water standards.
- Sole-source aquifers – drinking water sources that supply at least 50 percent of the drinking water consumed in the area overlying the aquifer. These areas can have no reasonably available alternative drinking water source(s) if the aquifer were to become contaminated.

Table 3-13 summarizes the number and percentages of plants included in the national-scale proximity analysis that are located within five miles of the evaluated drinking water resources. The table also presents the number of drinking water resources that are located within this five-mile buffer zone. For example, 67 steam electric power plants are located within 5 miles

---

[25] For more information on drinking water treatment processes used to reduce or eliminate metals commonly detected in the evaluated wastestreams from steam electric power plants, see the ERG memorandum "Drinking Water Treatment Technologies that Can Reduce Metal and Selenium Concentrations Associated with Discharges from Steam Electric Power Plants" (DCN SE02154).

of a drinking water system intake or drinking water reservoir. Within 5 miles of these 67 plants are 113 drinking water system intakes or reservoirs.

Table 3-13. Comparison of Number and Percentage of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource

Type of Drinking Water Resource	Number of Drinking Water Resources within 5 Miles of a Steam Electric Power Plant	Number (Percentage) of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource [a]
Intakes and reservoirs	113	67 (33%)
Public wells [b]	2,057	157 (81%)
Sole-source aquifers	8	7 (4%)

Sources: ERG, 2015c; ERG, 2015d

a – For the drinking water resource proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams from 195 steam electric power plants.

b – Counts include two springs and 29 wellheads.

3.5 LONG ENVIRONMENTAL RECOVERY TIMES ASSOCIATED WITH POLLUTANTS IN STEAM ELECTRIC POWER PLANT WASTEWATER

Recovery of the environment from exposure to steam electric power plant wastewater is affected by continued cycling of contaminants within the ecosystem, bioaccumulation, and the potential alterations to ecological processes, such as population and community dynamics in the surrounding ecosystems. The ability of aquatic and adjacent terrestrial environments to recover from even short periods of exposure to steam electric power plant wastewater depends on the distance from discharge, the pollutant concentrations, pollutant residence time, and the time elapsed since exposure. In particular, accumulation of metals and other bioacummulative pollutants in sediments can slow recovery of aquatic systems following exposure to power plant wastewater due to the potential for resuspension in the water column and for benthic organisms to provide a pathway for exposure long after power plant wastewater discharges have ended. For example, Lemly [1985a, 1997a, 1999] documented that benthic pathways can continue to provide toxic doses of selenium to wildlife even 10 years after water column selenium concentrations are below levels of concern. Ruhl *et al.* [2012] documented elevated levels of power plant wastewater pollutants (including arsenic and selenium) in pore water, even in cases where the water column concentrations are not elevated. This study found that arsenic is retained in lake sediments and pore water through a cycle of adsorption and desorption, likely in response to seasonal changes in the lake water chemistry [Ruhl *et al.*, 2012].

Short Exposures to Steam Electric Power Plant Wastewater Can Equate to Lasting Ecological Effects

In Martin Creek Lake, ecological effects persisted for at least 8 years following 8 months of fly ash discharges into the lake.

Ash pond discharges to Belews Lake in North Carolina resulted in elevated levels of arsenic, selenium, and zinc in the water and impacts to fish populations. Even 11 years after discharges ceased, selenium levels in the sediments still posed a risk to wildlife that feed on benthic organisms.

As discussed in Section 3.1, many of the pollutants in steam electric power plant wastewater (*e.g.*, arsenic, mercury, selenium) readily bioaccumulate in exposed biota. The bioaccumulation of these pollutants is of particular concern due to their impact on higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater. Aquatic systems with long residence times and potential contamination with bioaccumulative pollutants often experience persistent environmental effects following exposure to steam electric power plant wastewater.

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

Studies have linked historical discharges of selenium from the Belews Creek Steam Station with persistent ecological impacts in the plant's cooling reservoir.

Belews Lake, a 1,500-hectare cooling reservoir constructed to support the Belews Creek Steam Station in Stokes County, North Carolina, is a well-documented site that highlights the effects that steam electric power plant wastewater can have on fish populations and the subsequent long recovery time. In 1970, Duke Energy began monitoring the fish populations in Belews Lake prior to any discharges of steam electric power plant wastewater. From 1974 to 1985, Duke Energy discharged surface impoundment effluent into Belews Lake. Almost immediately after these discharges began, rapid and dramatic changes in the fish populations were observed [Lemly, 1993]. By 1975, morphological abnormalities (*e.g.*, partial fin loss, head deformities, cataracts) were reported for all 19 fish species monitored in the lake. Within 2 years after surface impoundment effluent was released into the lake, several species stopped reproducing, leaving only four species by 1978 (*i.e.*, 4 years after discharges began). Water samples collected in the lake reported elevated levels of arsenic, selenium, and zinc. Large predatory fish were some of the first species to die out completely, due to the lethal and sublethal effects of exposure to surface impoundment effluent. Because a top predator was gone, some fish that exhibited developmental abnormalities were able to survive, despite their otherwise high susceptibility to predation [Lemly, 1993]. The study eventually correlated the observed fish abnormalities with high selenium whole-body concentrations, and identified the planktonic community as the key source of selenium to the impacted fish. In 1985, the Belews Creek Steam Station switched to disposing of the coal ash in a dry landfill and ended the surface impoundment discharges to the lake. In a 1997 study, Lemly determined that there was evidence that the lake was recovering; however, even 11 years after the discharges ceased, selenium levels in the sediments still posed a risk to wildlife that feed on benthic organisms. Lemly also observed that despite the reduction in the selenium concentration in fish ovaries, reproductive abnormalities remained persistent, highlighting the long ecological recovery time observed in Belews Lake.

In addition to population density effects, the diversity of species in the communities in both field and experimental studies exposed to steam electric power plant wastewater has altered, which can further prolong ecosystem recovery [Benson and Birge, 1985; Guthrie and Cherry, 1976; Rowe *et al*., 2001; Specht *et al*., 1984]. In a study of fish populations in Martin Creek Lake following a short 8-month period in which the lake received fly ash surface impoundment discharges, both planktivorous (*i.e.*, diet primarily consists of plankton) and carnivorous (*i.e.*, diet primarily consists of meat) fish populations were severely reduced [Garrett and Inman, 1984]. Three years after the effluent release was halted, planktivorous fish populations remained extremely low, while carnivorous fish populations had nearly recovered. Carnivorous fish have a more diverse diet than planktivorous fish and therefore benefited from an increase in food availability as the aquatic system recovered; however, the size of carnivorous fish in the lake suggested that surviving adults continued to have reproductive impairments [Garrett and Inman, 1984]. Sorensen (1988) documented that ecological impacts in the lake remained evident even up to 8 years after the 8-month exposure to fly ash transport water discharges, with sunfish populations continuing to exhibit tissue damage to the liver, kidneys, gills, and ovaries and impaired overall reproductive health. Fish samples taken in 1996 and 1997 showed that the selenium concentration (2.3 parts per million (ppm) average for all sample fish) remained well above the national average range of between 0.1 and 1.5 ppm [ATSDR, 1998a].

SECTION 4
ASSESSMENT OF EXPOSURE PATHWAYS

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

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

Pollutants from steam electric power plant wastewater stored in surface impoundments can reach receptor populations (such as wildlife or people) through various exposure pathways.

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

EPA identified four primary exposure pathways of concern for steam electric power plant wastewater entering the environment: 1) discharges entering surface waters, 2) uncollected combustion residual leachate infiltrating through soil to nearby surface water, 3) uncollected combustion residual leachate entering ground water, and 4) direct contact with steam electric power plant wastewater stored in surface impoundments. This section describes the factors that control the magnitude of impacts to water quality, wildlife, and human health associated with exposure to steam electric power plant discharges and presents an overview of EPA's environmental assessment (EA) of the steam electric power generating industry, in which EPA evaluated the national-scale effects of power plant wastewater pollutants on the environment. Table 4-1 presents the environmental pathways, routes of exposure, and environmental concerns identified during the literature review and the types of analyses conducted to determine the impacts under baseline conditions and regulatory options.

Table 4-1. Steam Electric Power Plant Wastewater Environmental Pathways and Routes of Exposure Evaluated in the EA

Environmental Pathway	Route of Exposure	Environmental Concern	Analysis to Determine Environmental Impact
Steam electric power plant wastewater discharges to surface waters	Direct contact with surface water	Toxic effects on aquatic organisms [a]	Water quality impacts analysis (quantitative) – see Section 4.1.2
	Ingestion of surface water	Degradation of surface water quality used as intake to drinking water plants	
	Direct contact with sediment	Toxic effects on benthic organisms	Wildlife impacts analysis (quantitative) – see Section 4.1.2
	Consumption of aquatic organisms	Bioaccumulation of contaminants and resulting toxic effects on wildlife	
		Toxic effects on humans consuming contaminated fish	Human health impacts analysis (quantitative) – see Section 4.1.2
Uncollected combustion residual leachate infiltration to nearby surface waters from combustion residual surface impoundment or landfill	Direct contact with surface water or sediment	Toxic effects on humans and aquatic wildlife	Ground water quality impacts analysis (qualitative) – see Section 4.2.2
Uncollected combustion residual leachate entering ground water from combustion residual surface impoundment or landfill	Ingestion of ground water	Changes in ground water quality	
		Contaminated private drinking water wells	
Combustion residual surface impoundment	Direct contact with or ingestion of surface water	Toxic effects on wildlife	Attractive nuisances analysis (qualitative) – see Section 4.3
		Bioaccumulation of contaminants in wildlife	

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

4.1 DISCHARGE AND LEACHING TO SURFACE WATERS

Steam electric power plants commonly discharge wastewater directly to surface waters following storage and treatment (*e.g.*, particulate settling) in surface impoundments. In addition to effluent discharges, uncollected combustion residual leachate can migrate through the soil and into the surface water. Section 4.2 further discusses the impacts of uncollected combustion residual leachate.

4.1.1 Factors Controlling Environmental Impacts in Surface Waters

One of the primary factors controlling the environmental impact of steam electric power plant wastewater on surface waters is the residence time of the pollutants once they enter an aquatic system. Residence times are often determined by the flow rate of the receiving water and type of ecosystem it supports. The potential for pollutant retention in lentic aquatic systems (*i.e.*, still or slow-moving water, such as lakes or ponds) and the creation of hot spots in lotic aquatic systems (*i.e.*, flowing water, such as streams and rivers) are of particular concern when bioaccumulative pollutants are present. Many of the pollutants in steam electric power plant wastewater discharges bioaccumulate, complicating estimates of potential impacts in surface waters because the pollutants can affect higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater.

Based on industry responses to EPA's 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guideline* (Steam Electric Survey),[26] EPA determined that 18 percent of the 222 receiving waters included in the scope of the EA, all of which receive steam electric power plant wastewater discharges, are lentic systems such as lakes, ponds, reservoirs, and estuaries (Table 4-2). The majority of ecological studies on the impact of power plant wastewater in aquatic environments have focused on lentic systems [Rowe *et al*., 2002]. In lentic aquatic systems, the hydraulic residence time, or the amount of time it takes for the water in the aquatic system to be replaced by inflowing streams or precipitation is relatively long, allowing pollutants to build up over time and making these systems more vulnerable to impacts from power plant wastewater. In addition, aquatic organisms are limited in their ability to avoid areas of high pollutant concentrations and are restricted to the food supply available only within the waterbody.

Table 4-2. Receiving Water Types for Steam Electric Power Plants Evaluated in the EA

Receiving Water Type	Number (Percentage) of Immediate Receiving Waters [a]
River/Stream	183 (82%)
Lake/Pond/Reservoir	26 (12%)
Great Lakes	11 (5%)
Estuary and others (bay)	2 (1%)
Total Receiving Waters	**222 (100%)**

Source: ERG, 2015d.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The immediate receiving water (IRW) model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters and loadings from 188 steam electric power plants.

Based on responses to EPA's Steam Electric Survey, EPA determined that 82 percent of aquatic environments that receive discharges of the evaluated wastestreams are lotic systems such as rivers and streams [ERG, 2015j]. Lotic systems dilute discharges more quickly than lentic systems. The moving water in lotic systems also provides a transport mechanism to disperse pollutants greater distances from the power plant, and enables aquatic organisms to move away from the areas contaminated by steam electric power plant discharges [Rowe *et al*.,

---

[26] Results presented in this report are based on plant responses to the Steam Electric Survey, which represent 2009 data. However, the analyses presented in this report incorporate some adjustments to current conditions in the industry. See Section 1 for further details.

2002]. Although power plant wastewater discharges into a lotic system can distribute pollutants across a greater spatial area, changes in flow velocity may result in the concentration of pollutants at a single location further downstream [Rowe *et al*., 2002]. For example, power plant wastewater discharged to a river may encounter areas of slower moving water downstream where pollutants would fall out of suspension and concentrate in a limited area. These pockets of higher pollutant concentrations, or hot spots, could be vulnerable to continued resuspension as stream velocities are affected by rainfall, resulting in the aquatic organisms being exposed to pollutants over much longer periods of time [Lemly, 1997a; Rowe *et al*., 2002].

4.1.2 Assessment of the Surface Water Exposure Pathway

EPA developed and executed models to quantify the water quality, wildlife, and human health impacts resulting from discharges of the evaluated wastestreams to surface waters. These models consist of the following: 1) a national-scale IRW model that evaluates the discharges from 186 steam electric power plants and focuses on impacts within the immediate surface water[27] where discharges occur, and 2) case study models that perform more sophisticated and extensive modeling of selected waterbodies that receive, or are downstream from, steam electric power plant wastewater discharges. Section 5 describes the IRW model and Section 8 describes the case study models. In addition, as part of the benefits and cost analysis, EPA also evaluated surface water concentrations downstream from steam electric discharges using EPA's Risk-Screening Environmental Indicators (RSEI) model; see the Benefits and Cost Analysis (EPA-821-R-15-005).

The remainder of this section discusses the scope of EPA's environmental assessment of the steam electric power generating industry in terms of evaluated pollutants, evaluated waterbody types, and evaluated environmental impacts.

Evaluated Pollutants

The EA quantitative analyses focused on the environmental impacts associated with discharges of toxic, bioaccumulative pollutants to surface waters. A key factor in determining the pollutants to include in the quantitative analyses was the potential for pollutant loadings to be diluted in the receiving waters following discharge. For example, EPA determined that the rivers and streams included in the IRW model had a median average annual flow of 2,808 cubic feet per second (cfs) and that 57 percent had an average annual flow greater than 1,000 cfs. Due to the potential for dilution, EPA focused the quantitative analyses on pollutants where the total mass loadings and not the concentration are critical factors in determining the potential for environmental impact. Section 5.1.2 lists the pollutants selected for quantitative analyses and how they were selected.

---

[27] The length of the immediate receiving water, as represented in the national-scale IRW model, ranges from between 1 to 5 miles from the steam electric power plant outfall. See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513) for details on the immediate discharge zone and length of stream reach represented.

The EA quantitative analyses did not focus on water quality impacts associated with discharges of nutrients (total nitrogen and total phosphorus).[28] While discharges of large amounts of nutrients to surface waters can cause environmental problems (*e.g.*, eutrophication), EPA focused the EA quantitative analyses on 10 toxic pollutants that can bioaccumulate in fish and impact wildlife and human receptors via fish consumption. Additionally, nutrient-related impacts tend to be site-specific depending on environmental factors (*e.g.*, water-body temperature, the limiting nutrient in the system, algal species in the waterbody, and availability of oxygen in the water).

While the EA quantitative analyses did not address nutrient-related impacts, EPA did include nutrient loadings in the Benefits and Cost Analysis. EPA estimated total nitrogen and total phosphorus concentrations in receiving waters using dilution equations as input values to analyze benefits related to improvements in water quality. EPA used the SPARROW (SPAtially Referenced Regressions On Watershed attributes) model to provide baseline concentrations, as well as concentrations under each regulatory option. EPA used these concentrations to develop subindices for a water quality index (WQI), a value that translates water quality measurements, gathered for multiple parameters that represent various aspects of water quality, into a single numerical indicator. Total nitrogen and total phosphorous are only two of the subindices included in the WQI; the others are dissolved oxygen, biochemical oxygen demand, fecal coliform, total suspended solids (TSS), and heavy metals. EPA then used the WQI as a basis for calculating a willingness to pay for an increase in water quality as a result of the different regulatory options. See the Benefits and Cost Analysis for further details on the analysis and the results.

EPA identified total dissolved solids (TDS) and chlorides as the pollutants with the largest loadings under baseline conditions (see Table 3-2); however, EPA did not perform quantitative analyses of these pollutants for several reasons. TDS from the evaluated wastestreams consists largely of dissolved metals that are already captured in the analysis. Therefore, estimates of potential environmental impacts from TDS would double-count many of the environmental impacts and potential improvements assessed. Chlorides lack partition coefficient data (which are necessary for the water quality modeling performed in this EA) and have limited numeric threshold criteria data for comparison.

Evaluated Waterbody Types

In selecting the appropriate methodologies for the quantitative analyses, EPA considered the types of receiving waters commonly impacted by steam electric power plants and the pollutants typically found in the evaluated wastestreams. The IRW model and the selected case study models quantify the environmental risks within rivers/streams and lakes/ponds (including reservoirs), based on the determination that 94 percent of the final outfall receiving water designations fell within these two categories.

The EA quantitative analyses did not evaluate pollutant concentrations in the Great Lakes and estuarine systems, which represented 6 percent of all final outfall receiving waters. The

---

[28] EPA evaluated the nutrient impacts to the Great Lakes and Chesapeake Bay systems from a total mass loadings perspective, discussed in Section 3.4.

specific hydrodynamics and scale of the analysis required to appropriately model and quantify receiving water concentrations in the Great Lakes and estuarine systems are more complex than the IRW model.[29] In selecting the receiving waters to evaluate in the case study analyses, EPA focused primarily on rivers and streams based on the following: 1) the determination that 82 percent of the final outfall receiving water designations fell within this category, and 2) the relative simplicity of the hydrodynamics in river and stream case study models. This allowed EPA to develop and execute a larger set of case studies. EPA also developed one case study to represent the impacts of steam electric discharges to a lake. Refer to Section 8 for discussion of the receiving waters selected for case study analyses.

Evaluated Environmental Impacts

EPA focused the evaluation of environmental impacts on four key areas resulting from discharges of harmful pollutants to surface waters (rivers, streams, lakes, ponds, and reservoirs):

- Water Quality 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.
- Wildlife Impacts: Potential toxic effects on benthic organisms based on changes in sediment quality within surface waters—specifically, exceedances of chemical stressor concentration limits (CSCL) for sediment biota.
- Wildlife Impacts: Bioaccumulaton of contaminants and potential toxic effects on wildlife from consuming contaminated aquatic organisms, specifically:
    - Risk of adverse reproductive impacts in fish and waterfowl that consume aquatic organisms with elevated levels of selenium (as determined by the ecological risk modeling methodology described in Section 5.2).
    - Potential risk of reduced reproduction rates in piscivorous wildlife, based on exceedances of no effect hazard concentration (NEHC) benchmarks.
- Human Health Impacts: Potential toxic effects to human health from consuming contaminated fish and water, specifically:
    - 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.
    - Exceedances of drinking water maximum contaminant levels (MCLs). Although MCLs apply to drinking water produced by public water systems and not surface waters themselves, EPA identified immediate receiving waters that exceeded a MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams.

---

[29] EPA evaluated the impacts to the Great Lakes and Chesapeake Bay systems from a total mass loadings perspective, discussed in Section 3.4. See the ERG memorandum “Site-Specific Estuary Dilution Analysis” (DCN SE02152) for details on EPA’s initial screening analysis of the modeled receiving water concentrations in the Great Lakes and estuary systems compared to water quality benchmarks.

- Risk of cancer and non-cancer threats (*e.g.*, reproductive or neurological impacts) due to consuming fish caught from contaminated receiving waters.

4.2 LEACHING TO GROUND WATER

Combustion residual landfills and surface impoundments can impact local ground water through leaching.[30] Once in ground water, pollutants can migrate from the site and contaminate public or private drinking water wells and surface waters [NRC, 2006]. Contamination of drinking water wells is of particular concern because more than one-third of the U.S. population relies on ground water for drinking water. According to the U.S. Geological Survey (USGS), one in every five samples of ground water used as a source for drinking contains at least one contaminant at a level of concern for human health [USGS, 2015].

The fate of pollutants that leach from combustion residuals to ground water is controlled by many biological and geochemical (*e.g.*, adsorption, desorption, and precipitation reactions with aquifer materials) processes that can vary over large spatial and temporal scales [NRC, 2006]. This section describes the pollutant concentrations, chemical characteristics (*e.g.*, solubility, leachability, persistence, and mobility), and fate and transport processes that influence the potential environmental impact of uncollected combustion residual leachate.

4.2.1 Factors Controlling Environmental Impacts to Ground Water

Environmental impacts to ground water are determined by the pollutant concentrations in the combustion residual leachate and the rate of pollutant transport in the ground water. The pollutant concentrations in the combustion residual leachate depend on factors such as characteristics of the combustion residuals, site conditions (*e.g.*, rainfall amount and pH of the pore water in the surface impoundment or landfill), and combustion residual residence time in the surface impoundment or landfill.[31] The rate of pollutant transport in ground water depends on factors such as the biogeochemical characteristics of the subsurface (*e.g.*, soil pH and oxidation-reduction potentials), local rates of ground water recharge, and unsaturated and saturated ground water flow velocities.

Pollutant Concentrations in Combustion Residual Leachate

Combustion residual characteristics include the mineralogy of the waste (*e.g.*, lime, gypsum, iron, and aluminum oxide content) and pollutant solubility in the pore water. The mobility of pollutants may be altered due to changes in pH, carbon and chloride content, and interaction with other wastes from steam electric power plants [Thorneloe *et.al.*, 2010]. The waste mineralogy can vary based on the chemical composition in the fuel source (*e.g.*, the

---

[30] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

[31] Leaching experiments indicate that the chemistry of leachates is based on both the chemical composition of the waste and other factors such as site conditions [Thorneloe *et al.,* 2010]. Thorneloe [2010] specifically looked at fly ash and bottom ash waste from coal-fired power plants.

specific coal seam and geographic location of the mine) and operational characteristics at the plant. Many laboratory investigations have examined the solubility characteristics of various pollutants associated with fly ash [Prasad *et al*., 1996; Thorneloe *et.al*., 2010]. The results of these investigations largely depend on multiple factors, and they tend to be more applicable qualitatively rather than quantitatively (*e.g.*, results from investigations can be used to determine the likelihood of a pollutant to dissolve in the combustion residual leachate, but not the amount). Concentrations of inorganic pollutants derived from calcium, sodium, magnesium, potassium, iron, sulfur, and carbon are relatively high in aqueous solution of fly ash because of their high total concentrations in the ash [Prasad *et al*., 1996].


The pH level of pore water in surface impoundments can strongly influence the concentration of pollutants in leachate from impoundments to ground water.

The pH of the pore water is a dominant factor in the leaching of pollutants from unlined surface impoundments and landfills. Because most pollutants in combustion residuals exhibit weak acidic or weak basic behavior in aqueous solution, the pore water pH strongly influences the concentrations of pollutants in the combustion residual leachate. Steam electric power plants generate combustion residuals in high-temperature processes, and many acids and acidic precursors (*e.g.*, carbon dioxide, hydrogen sulfide, hydrochloric acid) are volatilized prior to waste collection. Therefore, combustion residuals typically yield an alkaline reaction in water, but acidic reactions have also been observed [Theis and Gardner, 1990]. Acidic pore water allows pollutants from the combustion residuals to remain in solution, increasing their mobility and the potential for ground water contamination. The results of a study of three power plants in Turkey indicated that combustion residuals in the deeper layers of landfills and on the bottoms of the surface impoundments may continue to leach if the pH value drops in the surrounding environment [Baba and Kaya, 2004].[32]

Table 4-3 presents data collected by EPA's Steam Electric Survey regarding pollutant concentrations in the combustion residual leachate under acidic, neutral, and basic (or alkaline) conditions. Arsenic exceeded its MCL for more than 60 percent of the samples in both acidic and basic combustion residual leachate. Similarly, the majority of manganese samples exceeded its secondary MCL under all pH conditions, with 95 percent of the samples exceeding the MCL in

---

[32] This conclusion was based on a comparison of ash extraction procedures used. The study examined how the concentration of trace elements in the ash can vary based on the procedure used, comparing the EPA-developed EP (extraction procedure) and its replacement method, TCLP (toxicity characteristic leaching procedure), and the ASTM (American Society for Testing and Materials) Method D-3987. A comparison of the results revealed that the ASTM procedure indicated much lower dissolved metal concentrations than the EP and TCLP procedures. These results indicate that pH is an important parameter affecting the leaching rate of metals from ash deposits. The lower pH values in the EP and TCLP methods increase the leaching rate of inorganic constituents of fly ash and bottom ash [Fleming *et al*., 1996].

acidic conditions. Selenium had varying concentrations under all pH conditions, but exceeded its MCL more frequently under basic conditions. Overall, the results support the conclusion that pH levels influence the concentrations of pollutants in the combustion residual leachate.

Table 4-3. Exceedances of MCLs in Leachate Under Acidic, Neutral, and Basic Conditions

Pollutant	MCL (mg/L)	Total Number of Samples			Percentage of Total Samples Exceeding MCL		
		Acidic	Neutral	Basic	Acidic	Neutral	Basic
Arsenic	0.01	21	64	90	62%	30%	71%
Boron	7 [a]	21	64	91	14%	31%	31%
Cadmium	0.005	21	63	90	29%	3%	29%
Chromium	0.1	21	64	90	0%	0%	18%
Copper	1.3	21	64	91	0%	0%	0%
Lead	0.015	21	62	86	5%	0%	2%
Manganese	0.05 [b]	21	64	89	95%	81%	54%
Mercury	0.002	21	64	89	5%	16%	8%
Nickel	No MCL	21	64	87	NC	NC	NC
Selenium	0.05	21	64	90	14%	17%	31%
Thallium	0.002	21	62	86	52%	10%	14%
Zinc	5 [b]	21	63	86	0%	0%	0%

Source: ERG, 2015d.

Acronyms: mg/L (milligrams per liter); MCL (Maximum contaminant level); NC (not calculated; no MCL for comparison).

Note: Data are for untreated leachate collected in leachate collection systems at steam electric landfills and surface impoundments.

a – The drinking water equivalent level, used for noncarcinogenic endpoints, is listed rather than the MCL.

b – MCL is a secondary (nonenforceable) standard.

In addition to the pH of the pore water, amounts of precipitation can affect pollutant concentrations in the combustion residual leachate. Although landfills are dry disposal sites, rainfall and frozen precipitation infiltrate through the waste, dissolving pollutants that can then leach from the landfill. Landfills in drier climates generate less combustion residual leachate than landfills in wetter climates.

The last factor affecting pollutant concentrations in the combustion residual leachate is the combustion residual residence time in the surface impoundment or landfill. In a study of metals (calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc) leaching from fly ash and bottom ash, all pollutants decreased in concentration with time of leaching, except for calcium, which released at a constant rate [Kopsick and Angino, 1981]. The most commonly noted leachate release curve is an initial flush curve, where the highest concentrations of pollutants are released as the leachate initially forms, with rapidly decreasing concentrations over time. Therefore, active surface impoundments receiving fresh combustion residuals will produce a leachate with elevated concentrations of pollutants that have a greater potential to contaminate drinking water sources and surface waters. Most inactive surface impoundments where pollutants have initially already leached from the combustion residuals should produce a leachate with decreasing concentrations of pollutants [Kopsick and Angino, 1981].

Thorneloe *et al*. [2010] studied the leaching behavior of coal combustion residuals in landfills, performing tests using a range of pH conditions and liquid-solid ratios expected during management via landfills or beneficial use. Combustion residual leachate concentrations for most pollutants were variable over a range of coal types, plant configurations, and combustion residual types (*i.e.*, fly ash or flue gas desulfurization (FGD) gypsum). The study showed significantly different leaching results (liquid-solid partitioning [equilibrium] as a function of pH) for similar combustion residual types and plants. The variability in pollutant leaching results was several orders of magnitude higher than the variability in the pollutant concentrations in the combustion residuals; this indicates that the pollutant concentrations alone cannot predict the leaching of metals, as noted above. Table 4-4 presents pollutant concentrations in combustion residual samples across a pH range of 5.4 to 12.4 and the range of pollutant concentrations in the combustion residual leachate. The table also includes indicator values for each pollutant: toxicity characteristic (TC) values for Resource Conservation and Recovery Act (RCRA) hazardous waste regulatory determination and drinking water MCLs for combustion residual leachate concentrations. As shown in the table, the maximum combustion residual leachate pollutant concentrations:

Most surface impoundments are unlined, allowing pollutants to infiltrate into ground water and eventually into surface waters.

- Exceed the TC values for RCRA hazardous waste determinations for arsenic, barium, chromium, and selenium (in fly ash).
- Exceed the TC values for RCRA hazardous waste determinations for selenium (in FGD gypsum).
- Exceed the MCLs for nine metals (in fly ash and FGD gypsum): antimony, arsenic, barium (fly ash only), boron, cadmium, chromium, molybdenum, selenium, and thallium.

The higher pollutant concentrations in the combustion residual leachate indicate greater mobility of the pollutant from the solid/slurry residual to the liquid phase. The concentration of the pollutants in the combustion residual leachate can be hundreds to thousands of times greater than the MCL.

Table 4-4. Range of Fly Ash and FGD Gypsum Total Content and Combustion Residual Leaching Test Results (Initial Screening Concentrations) for Trace Metals

	Range of Combustion Residual Content		Range of Leaching Test Results: Concentration in the Combustion Residual Leachate		Indicator Values	
Pollutant	**Fly Ash (mg/kg)**	**FGD Gypsum (mg/kg)**	**Fly Ash (µg/L)**	**FGD Gypsum (µg/L)**	**TC Value for Hazardous Waste Designation (µg/L)**	**Drinking Water MCL (µg/L)**
Antimony	3.0-14	0.14-8.2	<0.3-11,000	<0.3-330	--	6
Arsenic	17-510	0.95-10	0.32-18,000	0.32-1,200	5,000	10
Barium	50-7,000	2.4-67	50-670,000	30-560	100,000	2,000
Boron	NA	NA	210-270,000	12-270,000	--	7,000 [a]
Cadmium	0.3-1.8	0.11-0.61	<0.1-320	<0.2-240	1,000	5
Chromium	66-210	1.2-20	<0.3-7,300	<0.3-240	5,000	100
Mercury	0.1-1.5	0.01-3.1	<0.01-0.50	<0.01-0.66	200	2
Molybdenum	6.9-77	1.1-12	<0.5-130,000	0.36-1,900	--	200 [a]
Selenium	1.1-210	2.3-46	5.7-29,000	3.6-16,000	1,000	50
Thallium	0.72-13	0.24-2.3	<0.3-790	<0.3-1,100	--	2

Source: Thorneloe *et al*., 2010.

Acronyms: Acronyms: MCL (maximum contaminant level); mg/kg (milligrams per kilogram); TC (Toxicity Characteristics); µg/L (micrograms per liter); NA (Not Available).

a – The drinking water equivalent level, used for noncarcinogenic endpoints, is listed rather than the MCL.

Transporting Pollutants in the Ground Water

Predicting the movement of combustion residual pollutants in ground water can be challenging due to the wide range of biogeochemical characteristics between sites and within a given site. Pollutant transport times can vary, and combustion residual pollutants can take many years to reach local drinking water wells and surface waters [NRC, 2006]. For example, in the damage case at the Virginia Power Yorktown Power Station Chisman Creek Disposal Site in Yorktown, Virginia, fly ash had been disposed of in abandoned, unlined sand and gravel pits at the site for almost 20 years, from 1957 to 1974. However, ground water contamination was not discovered until 1980, when nearby shallow residential wells became contaminated with nickel and vanadium. Sampling also showed elevated levels of other heavy metals and toxic pollutants: arsenic, beryllium, chromium, copper, molybdenum, and selenium [U.S. EPA, 2014b].

Natural mechanisms, such as soil buffering capacity, attenuation of trace pollutants in certain soil types, amount of organic matter, and low soil permeability, can limit the transport of combustion residual pollutants in the subsurface environment. The mobility of pollutants in the subsurface strongly depends on soil-specific characteristics. Soil can have a buffering influence over the leachate by raising or lowering the pH. As noted previously, the solubility of most trace pollutants (the notable exceptions being arsenic and selenium) tends to decrease with increased pH (*i.e.*, alkaline conditions). In general, trace pollutants are less mobile in alkaline soils because the pollutants will precipitate and/or adsorb onto hydrous iron and aluminum oxides. Theis and Richter [1979] attempted to assess the factors influencing the attenuation of trace metals in soil/ground water. Results show that the major solubility control for cadmium, nickel, and zinc is adsorption by iron and manganese oxides while chromium, copper, and lead are controlled by precipitation. In some cases, particles in leachate may seal a surface impoundment or landfill, reducing the amount of leachate entering the ground water. Simsiman *et al.* [1987] and Kopsick and Angino [1981] both reported evidence of some sealing and reduced permeability of combustion residual surface impoundments, reducing seepage.

4.2.2 Assessment of the Ground Water Exposure Pathway

The EA focused on the discharges of toxic, bioaccumulative pollutants to surface waters from the evaluated wastestreams. While Section 3.3 provides qualitative discussion of ground water impacts based on a review of damage cases and other documented site impacts, the EA did not quantify the environmental and human health impacts resulting from pollutants leaching into the ground water from combustion residual surface impoundments and landfills. Additionally, the models used for this EA did not consider pollutant loadings to surface waters caused by combustion residual pollutants migrating through the soil and into surface waters, even though this may be occurring at many of the plants. As shown in Tables A-4 and A-5 in Appendix A, several damage cases have documented impacts to surface waters due to ground water contamination from combustion residual surface impoundments and landfills. The EA may therefore underestimate the number of cases where water quality standards are being exceeded in immediate receiving waters (see Section 6).

On April 17, 2015, EPA published a RCRA rule that regulates the disposal of CCRs from steam electric power plants (80 FR 21302). As part of the final CCR rulemaking, EPA's Office of Solid Waste and Emergency Response (OSWER) evaluated ground water contamination associated with combustion residuals in surface impoundments and landfills. The ground water impact analysis for the CCR rule identified and quantified human health risks to private drinking water wells due to potential ground water contamination from current CCR management practices. The analysis determined that human health risks were primarily from exposures to arsenic and molybdenum in ground water used as a source of drinking water. EPA identified additional human health risks from exposures to boron, cadmium, cobalt, fluoride, mercury, lithium, and thallium in ground water used as drinking water at certain sites based on the CCR disposal practices. Refer to the Regulatory Impact Analysis: EPA's 2015 RCRA Final Rule Regulating Coal Combustion Residual (CCR) Landfills and Surface Impoundments at Coal-Fired Electric Utility Power Plants (EPA-HQ-RCRA-2009-0640-12034) for the results of the national-scale analysis of ground water impacts.

4.3 COMBUSTION RESIDUAL SURFACE IMPOUNDMENTS AS ATTRACTIVE NUISANCE

An "attractive nuisance" is an area or habitat that attracts wildlife and is contaminated with pollutants at concentrations high enough to potentially harm exposed organisms. Two methods of handling steam electric power plant wastewater, surface impoundments and constructed wetlands, are classified as lentic systems supporting aquatic vegetation and organisms. These methods have been known to attract wildlife from other terrestrial habitats and therefore can be considered attractive nuisances. As an attractive nuisance, a surface impoundment can impact local wildlife as well as transient species that might rely on them during critical reproduction periods such as seasonal breeding events [Rowe *et al.*, 2002].

Exposure to steam electric power plant wastewater during sensitive life cycle events is a concern given that it has been associated with complete reproductive failure in various vertebrate species [Cumbie and Van Horn, 1978; Gillespie and Baumann, 1986; Lemly, 1997a; Pruitt, 2000].

Organisms that frequent attractive nuisance sites at steam electric power plants, such as surface impoundments, risk exposure to elevated pollutant concentrations. Several studies have shown that terrestrial fauna nesting near combustion residual surface impoundments can have higher levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium than the same species at reference sites [Bryan *et al*., 2003; Burger *et al*., 2002; Hopkins *et al*., 1997, 1998, 2000, 2006; Nagle *et al*., 2001; Rattner *et al*., 2006]. Table A-8 in Appendix A summarizes documented examples of impacts to wildlife associated with attractive nuisances at steam electric power plants.

In several of these instances, histopathological effects (*i.e.*, changes in pollutant tissue concentrations) were observed. For example, birds nesting near a combustion residual surface impoundment produced eggs with higher selenium concentrations than eggs found at the reference site. Although egg selenium concentrations near combustion residual surface impoundments exceeded thresholds that signify adverse effects on reproduction, the study did not observe any reduction in reproductive success [Bryan *et al*., 2003]. In a study conducted by Hopkins *et al*. [1998], sediment from a contaminated combustion residual surface impoundment had arsenic levels more than 100 times higher than the levels found in reference site sediments. Adult toads captured in the contaminated surface impoundment reported a sevenfold difference in arsenic levels between those from reference sites [Hopkins *et al*., 1998]. Although the study did not measure any indicators of reduced survival or reproductive success in the toads, the results indicate that exposure to combustion residual surface impoundments are a potential threat [Hopkins *et al*., 1998].

Surface impoundments and constructed wetlands can act as attractive nuisances by attracting wildlife and exposing them to elevated pollutant levels.

Multiple studies have linked attractive nuisance areas at steam electric power plants to diminished reproductive success. Field studies have documented adverse effects on reproduction for turtles and toads living near selenium-laden combustion residual surface impoundments [Hopkins *et al*., 2006; Nagle *et al*., 2001]. In another study, an interior least tern *(Sternula antillarum),* an endangered migratory bird, began nesting at Gibson Lake, an artificial shallow pond that receives combustion residual surface impoundment effluent from the Gibson Generating Station in Indiana. Within several years, nearby combustion residual surface impoundments at the Gibson Generating Station were also attracting nesting least terns, placing these sensitive species in direct contact with steam electric power plant wastewater. To address the attractive nuisance problem presented by the surface impoundments, the Gibson Generating Station began a cooperative program with the Indiana Department of Natural Resources to protect the nesting birds by creating a nearby alternative habitat known as the Cane Ridge Wildlife Management Area (WMA) [Pruitt, 2000]. Cane Ridge WMA received water from Gibson Lake and, in 2008, the U.S. Fish and Wildlife Service became concerned about selenium levels in the water and fish present in the Cane Ridge WMA [USFWS, 2008]. Accordingly, the bottom of Cane Ridge was plowed to redistribute and bury the selenium in the soil and the water flowing from Gibson Lake into Cane Ridge was stopped and replaced with water piped from the Wabash River. Duke Energy paid to stock the Cane Ridge WMA ponds with fathead minnows to lure back migratory birds. As of June 2009, avocets, dunlins, black terns, Forster's terns, Caspian terns, and 50 endangered least terns have returned to Cane Ridge [USFWS, 2012].

Other well-documented cases of attractive nuisance settings with characteristics (*e.g.*, elevated concentrations of specific pollutants) similar to those associated with steam electric power plants provide further support that combustion residual surface impoundments have the potential to pose a threat to wildlife. For example, exposed organisms in attractive nuisance settings affected by urban and agricultural wastes have exhibited elevated tissue concentrations of pollutants, with some organisms experiencing a combination of reproductive or sublethal effects that adversely impact their survival [Clark, 1987; Hofer *et al*., 2010; King *et al*., 1994; Ohlendorf *et al*., 1986, 1988a, 1988b, 1989, 1990; Tsipoura *et al*., 2008]. Although these examples do not directly relate to steam electric power plants, they highlight the potential dangers of attractive nuisances and ability for pollutants to bioaccumulate in the surrounding wildlife [Ohlendorf *et al*., 1986, 1989, 1990]. Table A-9 in Appendix A summarizes documented examples of impacts to wildlife associated with attractive nuisances that are not specific to steam electric power plants.

SECTION 5
SURFACE WATER MODELING

Based on the documented environmental impacts discussed in the literature, EPA identified several key environmental and human health concerns and pathways of exposure to evaluate in the environmental assessment (EA). Environmental concerns include degradation of surface water, sediment, and ground water quality; toxic effects on aquatic and benthic organisms; bioaccumulation of contaminants and resultant toxic effects on wildlife; toxic effects on humans consuming contaminated fish; and contamination of drinking water resources.

EPA focused its quantitative analyses on discharges of the evaluated wastestreams to surface water – one of the primary exposure pathways of concern discussed in Section 4. To quantify baseline impacts and improvements under the final steam electric effluent limitations guidelines and standards (ELGs), EPA developed models to determine pollutant concentrations in the immediate receiving waters, pollutant concentrations in fish tissue, and exposure doses to ecological and human receptors from consuming aquatic organisms. This section describes the immediate receiving water (IRW) model and the ecological risk model used in developing this EA. Section 8 describes the development and execution of case study models using EPA's Water Quality Analysis Simulation Program (WASP) to supplement the results of the IRW model.

5.1 IMMEDIATE RECEIVING WATER (IRW) MODEL

EPA developed the IRW model[33] to quantify the environmental impacts to surface waters, wildlife, and human health from the wastestreams evaluated for the regulatory options. As part of this national assessment, EPA determined impacts in the immediate surface water where steam electric power generating industry discharges occur, between 1 and 5 miles from the outfall depending on the stream reach.[34] As part of the benefits and cost analysis, EPA also evaluated surface water concentrations downstream from steam electric discharges using EPA's Risk-Screening Environmental Indicators (RSEI) model; see the Benefits and Cost Analysis (EPA-821-R-15-005). The IRW model framework focused on four key areas of impacts:

- Impacts to aquatic life based on reduction in water quality from discharges of the evaluated wastestreams.
- Impacts to aquatic life based on reduction in sediment quality from discharges of the evaluated wastestreams.
- Impacts to wildlife from the bioaccumulation of contaminants in aquatic organisms and fish, including piscivorous (fish-eating) wildlife.
- Impacts to human health from consuming contaminated fish.

---

[33] The IRW model is the same model that EPA used for the national-scale analyses in support of the proposed ELGs. EPA assigned the "IRW model" label to help distinguish the national-scale model from the case study models developed in support of the final ELGs.

[34] See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513) for details on the immediate discharge zone and length of stream reach represented.

As discussed in Section 4.1.2, EPA considered the type of receiving waters commonly impacted by steam electric power plants and the pollutants typically found in the evaluated wastestreams in selecting the appropriate methodologies for the quantitative analysis. The IRW model quantified the environmental risks within rivers/streams and lakes/ponds/reservoirs, and evaluated impacts from 10 toxic, bioaccumulative pollutants: arsenic, cadmium, copper, hexavalent chromium (chromium VI), lead, mercury, nickel, selenium, thallium, and zinc. EPA's IRW model includes three interrelated modules:

- Water quality module—calculates immediate-receiving-water-specific pollutant concentrations in the water column and sediment and evaluates the impacts that receiving water concentrations pose to aquatic life and human health.
- Wildlife module—evaluates the impact that sediment concentrations pose to aquatic life, calculates the pollutant concentrations in exposed fish populations, and evaluates the potential adverse effects to minks and eagles from consuming fish.
- Human health module—calculates non-cancer and cancer risks to human populations from consuming fish.

Additionally, EPA used the selenium outputs from the IRW water quality module to evaluate the risks to fish and waterfowl that consume aquatic organisms with elevated levels of selenium (see Section 5.2). This ecological risk analysis expands on the results of the IRW wildlife module described in this section.

The IRW water quality module uses plant-specific input data (plant-specific pollutant loadings and cooling water flow rate),[35] surface-water-specific characteristic data (*e.g.*, receiving water flow rate, lake volume), and representative environmental parameters (*e.g.*, partition coefficients) to quantify the environmental impacts of the evaluated wastestreams to surface waters. The module calculates pollutant concentrations in the surface water and sediment. These concentrations are inputs to the IRW wildlife module, which calculates the bioaccumulation of pollutants in fish tissue and determines impacts to wildlife. The fish tissue concentration calculated in the IRW wildlife module becomes an input to the IRW human health module. This section provides overviews of each module. Appendices C through E describe the IRW model equations, input data, and assumed environmental parameters in further detail. The appendices also describe the limitations and assumptions of the IRW model.

Figure 5-1 provides an overview of the IRW model inputs and the connections among the three modules to support EPA's national-scale modeling framework.

---

[35] EPA calculated annual pollutant loadings for the evaluated wastestreams and excluded any pollutants discharged with other wastewaters (*e.g.*, coal pile runoff). EPA incorporated cooling water flow rates into the IRW water quality module on a site-by-site basis. EPA assumed no pollutant loadings were associated with cooling water discharges to surface waters and used cooling water flow rates only to evaluate dilution effects.

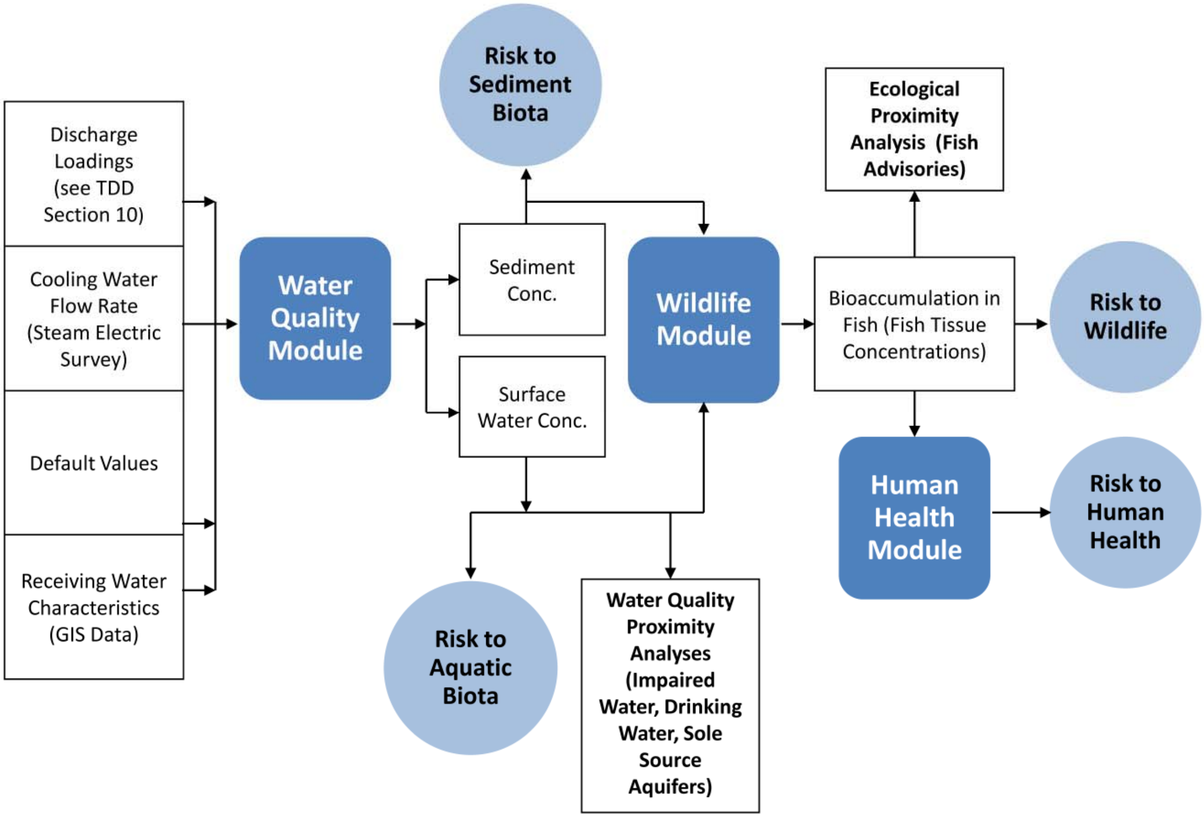


Figure 5-1. Overview of IRW Model

5.1.1 Water Quality Module

EPA selected the steady-state equilibrium-partitioning model described in EPA's *Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions* (EPA 600-R-98-137) for the IRW water quality module. This selection was based on three factors: 1) the model's ability to represent pollutants in the aquatic environment; 2) the model's complexity, which EPA judged to be appropriate for a national-scale evaluation;[36] and 3) the level of previous Agency and external peer reviews performed on the modeling methodology. An equilibrium-partitioning model assumes that dissolved and sorbed pollutants in a receiving water will quickly attain equilibrium in the immediate vicinity of the discharge point because they dissolve or sorb in the surface water faster than they can be transported or dispersed outside that area. The model also assumes that the equilibrium state for each pollutant can be represented by a partition coefficient that divides the total mass of a pollutant in the waterbody into four compartments:

- Constituents dissolved in the water column.
- Constituents sorbed onto suspended solids in the water column.

---

[36] For a national-scale environmental assessment of over 200 receiving waters, data limitations inhibit the feasibility of using more complex fate and transport receiving water models (dynamic or hydrodynamic) to estimate surface water concentrations.

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

Table 5-1 lists the pollutants commonly found in the evaluated wastestreams with known environmental impacts (see Section 3.1, Table 3-1). EPA selected a subset of these pollutants for the water quality model based on the following criteria:

- The pollutant is known to be present in the evaluated wastestreams (*i.e.*, identified as a pollutant of concern).
- Scientific literature documents elevated levels observed in surface waters or wildlife from exposure to steam electric power plant wastewater.
- Partition coefficient data are available for the water quality model.
- Benchmarks are available to evaluate potential threats to wildlife or human health.

For the immediate receiving water quality analysis, EPA modeled 10 of the pollutants shown in Table 5-1: arsenic, cadmium, chromium VI, copper, lead, mercury, nickel, selenium, thallium, and zinc.

Table 5-1. Pollutants Considered for Analysis in the Immediate Receiving Water Model

Pollutant	POC [a]	Literature Review [b]	Partition Coefficient [c]	NRWQC [d]	Maximum Contaminant Level (MCL)	Wildlife Benchmark [e]	Human Health Benchmark [f]	Included in Modeling Analysis [g]
Aluminum	✓			✓			✓	
Arsenic [h]	✓	✓	✓	✓	✓	✓	✓	✓
Boron	✓			✓			✓	
Cadmium	✓	✓	✓	✓	✓	✓	✓	✓
Chromium [i]	✓	✓	✓	✓	✓	✓	✓	✓
Copper	✓	✓	✓	✓	✓	✓	✓	✓
Iron	✓			✓			✓	
Lead	✓		✓	✓	✓	✓		✓
Manganese	✓			✓			✓	
Mercury [j]	✓	✓	✓	✓	✓	✓	✓	✓
Nickel	✓	✓	✓	✓		✓	✓	✓
Selenium [k]	✓	✓	✓	✓	✓	✓	✓	✓
Thallium	✓		✓	✓	✓		✓	✓
Vanadium	✓	✓	✓				✓	
Zinc	✓		✓	✓		✓	✓	✓

a – A check mark indicates that the pollutant is a pollutant of concern (POC) for one or more of the evaluated wastestreams (see Section 6 of the Technical Development Document (TDD) (EPA-821-R-15-007)).

b – Literature review identified documented cases of elevated pollutant levels in surface waters or wildlife near steam electric power plants [ERG, 2013b; ERG, 2015m].

c – Partition coefficients for modeling analysis identified in U.S. EPA, 1999, and U.S. EPA, 2005a.

d – National Recommended Water Quality Criteria (NRWQC) are available at http://water.epa.gov/scitech/swguidance/standards/current/index.cfm.

e – No effect hazard concentration (NEHC) identified in USGS, 2008, for minks and bald eagles.

f – Reference dose (RfD) identified in EPA's Integrated Risk Information System (IRIS) for all pollutants except copper and thallium (available at http://www.epa.gov/iris/); RfD for copper is the intermediate oral minimal risk level (MRL) [ATSDR, 2010a]; and RfD for thallium is the value for thallium chloride provided in U.S. EPA, 2010a. Cancer slope factor for arsenic identified in EPA's Integrated Risk Information System (IRIS) database [2011].

g – Pollutant is included in the quantitative modeling analysis discussed in this section.

h – Arsenic exists in two primary forms: arsenic III (arsenite) and arsenic V (arsenate). A check mark indicates that total arsenic, arsenite, and/or arsenate satisfied the criterion in the table header.

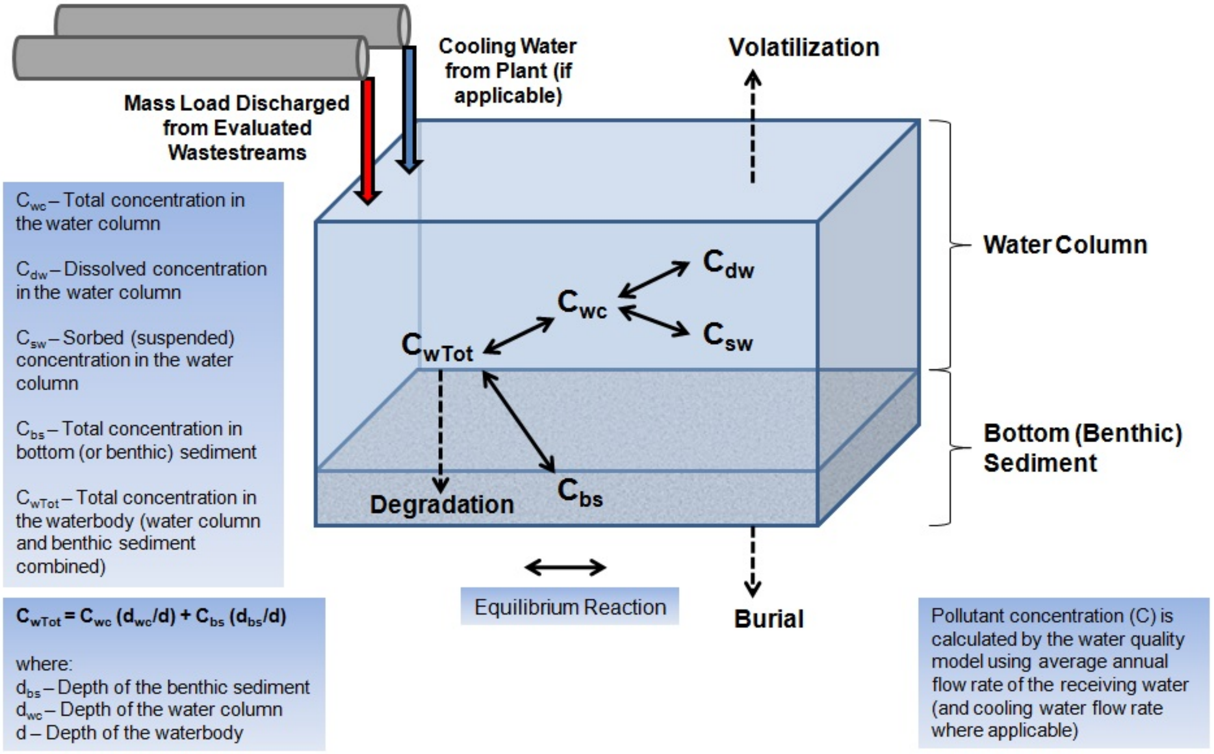
i – Chromium exists in two primary forms: chromium III and chromium VI. A check mark indicates that total chromium and/or chromium VI satisfied the criterion in the table header.

j – A check mark indicates that mercury and/or methylmercury satisfied the criterion in the table header.

k – Selenium exists in two primary forms: selenium IV (selenite) and selenium VI (selenate). A check mark indicates that total selenium, selenite, and/or selenate satisfied the criterion in the table header.

EPA developed the IRW water quality module in Microsoft Access™ using the equilibrium-partition equations presented in Appendix C. The IRW water quality module is a mathematical model used to represent the partitioning of pollutants through the surface water after the wastestream has been discharged. The module output provides site-specific pollutant concentrations in the water column (total, dissolved, and suspended) and sediment for 188 steam electric power plants located across the United States that discharge to a river or stream or to a lake, pond, or reservoir. Figure 5-2 depicts the pollutant concentrations calculated in the IRW water quality module. EPA implemented this modeling approach through the following steps:

1. Characterize the immediate receiving water characteristics (*e.g.*, depth of water column, depth of waterbody, receiving water width, and flow independent mixing value) using site-specific inputs. See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513).
2. Using the immediate receiving water characteristics, determine the fraction of pollutant in the benthic sediment and in the water column and determine fraction of pollutant in the water column that is dissolved.
3. Using the immediate receiving water characteristics and assumed input values, calculate the water column volatilization rate constant, for volatile pollutants only (*i.e.*, mercury).
4. Calculate the water concentration dissipation rate (zero for nonvolatile pollutants).
5. Based on site-specific pollutant loadings (converting annual loadings to an average daily loading), cooling water flow rates (for a subset of plants), and immediate receiving water characteristics, calculate the total pollutant concentrations (*e.g.*, total arsenic) in the immediate receiving water, including the concentration in the water column and in the benthic sediment.
6. Calculate the concentration of dissolved pollutant in the water column. Section 10 of the TDD details the pollutant loadings methodology; the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE004513) describes the use of cooling water flow rates. Note that the pollutant loadings included in the module do not represent the total pollutant loadings from steam electric power plants; several wastestreams were not evaluated (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). In addition, the module uses an annual average discharge rate, assuming no seasonal or daily variation.
7. Quantify the number of sites that exceed the NRWQC and drinking water maximum contaminant levels (MCLs) to evaluate the potential exposure of ecological receptors (*i.e.*, aquatic biota) and human receptors to toxic pollutants in the environment from the evaluated wastestreams.



Source: Adapted from U.S. EPA, 1998b.

Figure 5-2. Water Quality Module: Pollutant Fate in the Waterbody

As an indicator of potential impacts, EPA compared the immediate receiving water concentrations (under baseline and regulatory options) to the following NRWQCs:

- Freshwater acute and chronic aquatic life NRWQC.
- Human health NRWQC for the consumption of water and organisms.
- Human health NRWQC for the consumption of organisms.

EPA also compared immediate receiving water concentrations to drinking water MCLs. EPA identified immediate receiving waters that exceeded a NRWQC or MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams. Section 6.3 summarizes the NRWQC and MCL exceedances under baseline pollutant loadings. Section 7.2 presents the percent reduction in number of immediate receiving waters that potentially impact water quality under the final rule.

As with any modeling, EPA recognizes that model limitations exist and certain assumptions need to be made. EPA used average annual pollutant loadings and normalized effluent flow rates, which do not take into account temporal variability (*e.g.*, variable plant operating schedules, storm flows, low-flow events, catastrophic events). The IRW water quality module does not account for ambient background pollutant concentrations or contributions from other point and nonpoint sources, and assumes a constant flow rate in the receiving water based on the annual average reported in National Hydrography Dataset Plus (NHDPlus). Appendix C discusses these and additional module-specific limitations and assumptions and Section 6 and

Section 7 present the results of the IRW water quality module under baseline and regulatory options.

5.1.2 Wildlife Module

As shown in Figure 5-1, the IRW wildlife module builds off the IRW water quality module by using the calculated immediate receiving water and sediment concentrations to calculate pollutant concentrations in fish populations exposed to the evaluated wastestreams and to assess the potential to impact wildlife for the following categories:

- Impact to aquatic organisms from contact with sediment contaminated by the evaluated wastestreams. To do this, the model quantifies the number of sites with potential exposure of ecological receptors (*i.e.*, sediment biota) to the pollutant in the environment.
- Impact to piscivorous wildlife (*i.e.*, wildlife that habitually feeds on fish) from consuming fish impacted by the evaluated wastestreams. To do this, the model quantifies the number of sites with potential exposure of ecological receptors (*i.e.*, piscivorous wildlife) to the pollutant in the environment.

EPA developed the wildlife model in Microsoft Access^{TM} to calculate pollutant concentrations in fish populations exposed to the evaluated wastestreams and estimate daily contaminant dose for wildlife receptors (*i.e.*, minks and eagles) using equations presented in Appendix D. EPA determined potential impacts to wildlife by comparing the concentration in the contaminated media (*i.e.*, water, sediment, or fish) to concentrations known to be protective of negative impacts (*i.e.*, benchmark). Benchmarks, which are pollutant- and endpoint-specific and sometimes are species-specific, are an expression of the concentration level in contaminated media that is protective against a specific endpoint (*e.g.*, mortality). Endpoints frequently reflected in benchmark values include sublethal effects (*e.g.*, reduced reproduction, neurological effects) and lethal effects. EPA implemented the wildlife modeling approach through the following steps:

1. Compare the concentration of the contaminant in benthic sediment to the benchmark for sediment biota.
2. Calculate the pollutant concentration in fish for trophic level three (T3) or trophic level four (T4),[37] using the calculated pollutant concentration in the water column and the bioaccumulation factor (BAF) or bioconcentration factor (BCF).[38] For mercury, calculate the concentration of methylmercury in the fish. See Appendix D for details on the IRW wildlife module and calculation of methylmercury concentration in fish.
3. Compare the concentration of the contaminant in the fish to the wildlife benchmarks for ecological receptors (*i.e.*, mink and eagle).

---

[37] 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.

[38] BCFs are more appropriate for use with pollutants where the primary pathway entering fish tissue is via the water, whereas BAFs are more appropriate for pollutants where the primary pathway entering fish tissue is through a food source (takes into account both water and diet). Where available, EPA used pollutant-specific BAFs.

4. Compare the baseline and regulatory option results (*i.e.*, number of sites with potential exposure of ecological receptors to concentrations above protective benchmarks).

Adverse Effects to Aquatic Organisms from Contact with Sediment

EPA compared the concentration in the benthic sediment to benchmarks protective of benthic organisms. EPA used threshold effects level (TEL) benchmarks provided in the National Oceanic and Atmospheric Administration (NOAA) 2008 Screening Quick Reference Tables (SQuiRTs), referred to as the chemical stressor concentration limit (CSCL), for the sediment biota adverse impacts analysis. The CSCL is a chemical-specific media concentration that is protective of ecological receptors of concern. The CSCL benchmark is species-specific, but can be used to represent a community of organisms, such as amphibians or fish. Usually the most sensitive (or lowest) CSCL for a species is used to represent the community. Table D-1 in Appendix D presents the benchmarks used for sediment exposure analysis. Section 6.2 discusses the results of this analysis for baseline pollutant loadings.

Assessment of Pollutant Bioconcentration in Fish

EPA calculated fish tissue concentrations based on the following: 1) total water column concentrations (*i.e.*, dissolved plus sorbed) calculated in the IRW water quality module, and 2) trophic-level-specific BAFs or BCFs. BAFs and BCFs are based on field and laboratory study results compiled to develop a single factor or ratio for estimating the amount of pollutant transferred into fish tissue at a given trophic level (*i.e.*, rank in the food chain) based on the pollutant concentration in the waterbody. EPA estimated fish tissue concentrations in milligrams per kilogram (mg/kg) for T3 and T4 fish to account for the variability in fish likely consumed by both wildlife and human receptors included in the IRW model.

Although using the total water column concentration in the bioaccumulation analysis may overestimate the level of pollutants in the fish, it provides for a more environmentally protective estimate of risk in the subsequent human health model because it assumes that all pollutants within the waterbody (both dissolved and sorbed) are bioavailable to the exposed fish. The exception to this methodology is mercury, where EPA based the fish tissue concentration calculation on the dissolved concentration of methylmercury in the waterbody [U.S. EPA, 2005b]. Appendix D presents the BCFs and model equations for the analysis of pollutant bioconcentration in fish tissue for T3 and T4 fish. EPA used the fish tissue concentrations to evaluate impacts to piscivorous wildlife (see next section) and impacts to human health receptors (see Section 5.1.3).

Impact to Piscivorous Wildlife

EPA based the piscivorous wildlife impact analysis on the methodology outlined in the 2008 U.S. Geological Survey (USGS) study *Environmental Contaminants in Freshwater Fish and Their Risk to Piscivorous Wildlife Based on a National Monitoring Program*. The study examined the impacts to minks and eagles from eating contaminated fish. Minks and eagles are commonly used in ecological risk assessments as indicator species for potential impacts to fish-eating mammals and birds in areas contaminated with bioaccumulative pollutants [USGS, 2008]. Minks and eagles are appropriate receptors for the steam electric power plant wildlife impact analysis because their habitats span most of the country and their diet largely consists of adult fish from the two trophic levels (*i.e.*, T3 and T4 fish) included in the IRW wildlife module. According to the literature [U.S. EPA, 1998a], minks consume mostly T3 fish, while eagles consume mostly T4 fish. EPA evaluated the potential adverse effects to minks and eagles for nine pollutants commonly found in the wastestreams of interest: arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium, and zinc.[39] The USGS method [USGS, 2008] is a wildlife impact analysis using NOAELs (no-observed-adverse-effect levels), which were derived from adult dietary exposure or tissue concentration studies based primarily on reproductive endpoints. The study calculated a NEHC benchmark, which is based on the NOAEL, the food consumption rate, and/or the biomagnification factor of each receptor. The report states that piscivorous wildlife may be at an elevated risk for reduced reproduction rates if the measured pollutant concentration in fish exceeds the NEHC. Therefore, EPA compared the mink-specific and eagle-specific NEHC values from the USGS study with the T3 and T4 fish tissue concentrations, respectively, to identify potential adverse impacts to the ecological receptors. In the piscivorous wildlife analysis, a benchmark exceedance indicates that piscivorous mammals or birds exposed to fish in the immediate receiving water of interest are at an elevated risk for reduced reproduction rates or other health effects.

Table D-3 in Appendix D presents the NEHC values used to evaluate potential adverse effects to wildlife. The text of Appendix D presents the equations used to compare model outputs to benchmarks (NEHCs), along with model-specific limitations and assumptions. The results of the IRW wildlife module under baseline conditions and the final rule are included in Section 6 and Section 7, respectively.

5.1.3 Human Health Module

As shown in Figure 5-1, the IRW human health module builds off the IRW wildlife module, using the calculated T3 and T4 fish tissue concentrations. Its purpose is to evaluate the cancer risk and potential to cause non-cancer health effects from consuming fish within the following age and consumption categories:

- Child recreational fishers (six cohorts covering different age ranges).[40]
- Child subsistence fishers (six cohorts covering different age ranges).
- Adult recreational fishers.
- Adult subsistence fishers.

In addition, EPA evaluated potential impacts to different race populations using these same cohorts as part of its environmental justice analysis. See the *Regulatory Impact Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA) (EPA-821-R-15-004).

---

[39] Because there are no benchmarks for chromium VI or methylmercury, EPA used the total chromium and total mercury benchmarks, respectively, which may underestimate the risk to wildlife.

[40] The child cohort age ranges correspond to the ranges provided in the 2008 *Child-Specific Exposure Factors Handbook* (EPA-600-R-06-096F) for body weights.

EPA developed the IRW human health module in Microsoft Access^{TM} to estimate the daily pollutant doses for human receptors as a result of eating T3 and T4 contaminated fish. EPA used a mathematical model to estimate the potential threats to human receptors from pollutant exposure. EPA estimated the average concentration of pollutants in a fish fillet consumed by humans based on a consumption diet of 36 percent T3 and 64 percent T4 fish (see Appendix E). The IRW human health module then calculates the daily dose of pollutants from fish consumption for each cohort included in the analysis. EPA varied the fish consumption rate based on the specific cohort using two factors: 1) type of fisher (recreational or subsistence) and 2) age (adult and six child cohorts). EPA first evaluated human health impacts based on type of fisher and age of cohort using national-level consumption rates. For the environmental justice analysis, EPA determined fish consumption rates using the race population in addition to the other two factors. See Appendix E for further details. Using the fish consumption rate, EPA determined an average daily pollutant dose for each human cohort evaluated. Table E-2 in Appendix E presents the cohorts included in the IRW human health module and the corresponding fish consumption rates used in the module. EPA implemented the human health modeling approach through the following steps:

1. Calculate the pollutant concentration in a fish fillet.
2. Calculate the average daily dose of pollutant from fish consumption by each receptor cohort (used for comparison to reference dose [RfD] values).
3. Calculate the lifetime average daily dose (LADD) for carcinogenic pollutants only, by each receptor cohort (used to determine cancer risk).
4. Calculate the lifetime excess cancer risk (LECR) for carcinogenic pollutants only, by each receptor cohort, using the LADD.
5. Compare the exposure doses of human receptor cohorts to appropriate benchmarks (RfD and selected cancer benchmark: 1-in-a-million).
6. Compare the baseline and regulatory option results: reduction in the number of immediate receiving waters with exposure doses from consuming fish that pose a potential threat to human receptors.

Non-Cancer Threat to Human Receptors

EPA evaluated the non-cancer threat (*e.g.*, reproductive or neurological impacts) to each cohort by comparing the pollutant-specific average daily dose values for fish consumption to the corresponding RfDs. EPA evaluated non-cancer risks for the following pollutants: inorganic arsenic,[41] cadmium, chromium VI, copper, methylmercury, nickel, selenium, thallium, and zinc. Table E-3 in Appendix E presents the RfD values used in the non-cancer threat analysis. RfD values are an expression of the consumption dose that is protective against a specific endpoint.

---

[41] For this analysis, EPA used only the concentration of inorganic arsenic for the human health impact assessment. Based on the literature review, arsenic in fish is mostly in the organic form and is not considered harmful. The wildlife model calculates a total arsenic fish tissue concentration. To convert this number to inorganic arsenic, EPA assumed that 4 percent of the total arsenic is inorganic based on EPA's 1997 document *Arsenic and Fish Consumption* (EPA-822-R-97-003). The 1997 document reported that the inorganic arsenic concentration in fish is between 0.4 and 4 percent of the total arsenic accumulating in fish [U.S. EPA, 1997b].

Endpoints frequently reflected in RfDs include various immunological, reproductive, neurological, and other non-cancer effects. In the IRW human health module, when the RfD is exceeded, it indicates a potential threat to humans for the endpoint associated with the RfD. For example, exceeding the RfD for selenium indicates that the exposure dose from fish consumption can cause non-cancer health effects, such as selenium-induced liver dysfunction or selenosis (hair or nail loss, morphological changes of the nails, etc.) [U.S. EPA, 2011c].

Cancer Risk to Human Receptors

Arsenic is the only pollutant included in the IRW model for which EPA has derived a cancer slope factor for ingestion exposures.[42] The IRW human health module calculates the LADD for each receptor cohort based on an exposure duration (*i.e.*, length of time a receptor is in contact with the carcinogen) averaged over a lifetime (*i.e.*, 70 years). For this analysis, EPA assumed the exposure duration to be equal to the number of years represented by each cohort. Using these exposure durations is appropriate for screening-level estimates of cancer risk and for comparing changes between baseline and regulatory options.[43] The model then multiplies the LADD by the cancer slope factor to calculate the LECR from arsenic. LECR is an estimate of the increase in cancer risk resulting from an exposure (*i.e.*, consumption of contaminated fish). EPA used the benchmark value for evaluating cancer risk of 1-in-a-million people. Therefore, a calculated LECR greater than 1×10^{-6} indicates an increased cancer risk for humans that consume fish exposed to discharges of evaluated wastestreams.

5.2 ECOLOGICAL RISK MODELING

Selenium bioaccumulation in aquatic organisms occurs primarily from ingesting food rather than through direct exposure to dissolved selenium in the water column [Fan *et al.*, 2002; Ohlendorf *et al.*, 1986; Saiki and Lowe, 1987; Presser and Ohlendorf, 1987; Luoma *et al.*, 1992; Presser *et al.*, 1994; Chapman *et al.*, 2009]. Unlike other bioaccumulative contaminants such as mercury, the single largest step in selenium accumulation in aquatic environments occurs in aquatic organisms at the base of the food web; algae, particulates, and microorganisms can accumulate selenium to levels far greater than the concentration in the water column. Bioaccumulation and transfer through aquatic food webs constitute the major selenium exposure pathway in aquatic ecosystems.

Macrophytes, algae, phytoplankton, zooplankton, and macroinvertebrates at the base of the food web easily bioaccumulate selenite and selenate and incorporate selenium in tissues as selenomethionine, an organo-selenide. This selenomethionine is then released back to the water

---

[42] Although EPA determined that lead and lead compounds can be "reasonably anticipated to be human carcinogens," no numeric value has been determined to quantify the cancer risk. As stated on the IRIS website, "quantifying lead's cancer risk involves many uncertainties, some of which may be unique to lead. Age, health, nutritional state, body burden, and exposure duration influence the absorption, release, and excretion of lead. In addition, current knowledge of lead pharmacokinetics indicates that an estimate derived by standard procedures would not truly describe the potential risk. Thus, the Carcinogen Assessment Group recommends that a numerical estimate not be used." (See http://www.epa.gov/iris/subst/0277.htm#reforal.)

[43] To completely assess risk to an individual, EPA recommends that risks should be calculated by integrating exposures throughout all life stages (*i.e.*, adding multiple cohort risks from screening analysis). For example, the exposure duration may be equal to the length of time a person lives in an area [U.S. EPA, 2011b].

column as these plants and organisms die or are consumed [U.S. EPA, 2014f]. In general, selenium concentrations in particulates (*e.g.*, sediment, detritus, and primary producers such as algae and biofilm) are 100 to 500 times higher than dissolved concentrations in selenate-dominated environments such as streams and rivers. Where selenite or organo-selenide is proportionately more abundant, such as in lakes, wetlands, some estuaries, and oceans, the ratio can be much higher (1,000 to 10,000 times higher than dissolved concentrations). This variability of particulate concentrations relative to dissolved concentrations across different aquatic environments makes it difficult to develop a simple relationship between the concentration of selenium in water and the concentration of selenium in organisms [Presser and Luoma, 2010].

The scientific community has devoted significant effort to understanding the mechanisms of selenium bioaccumulation. The preferred approach, as described in Presser and Luoma [2010], accounts for the variability in particulate concentrations described above by applying site-specific enrichment factors (EFs) that represent the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water. Subsequent bioaccumulation by aquatic organisms is described through a series of empirically derived, species-specific trophic transfer factors (TTFs) that link the selenium concentrations in particulates and invertebrates to higher trophic-level organisms such as fish and birds. TTFs can be derived from laboratory experiments or from field data. TTFs differ from traditional BCFs (described in Section 5.1.2) in that they are the ratio of the selenium concentration in each animal to the selenium concentration in its food, whereas BCFs represent the ratio of the selenium concentration in an animal to the selenium concentration in the water of its environment. Using TTFs therefore more accurately predicts selenium bioaccumulation in aquatic organisms because it accounts for the significant role of dietary exposure.

Selenium toxicity among exposed fish and birds primarily is transferred to the eggs and demonstrated via subsequent reproductive effects. Many studies and expert panels have shown that reproductive effects, linked to egg-ovary selenium concentrations, are of greatest concern and likely have led to observed reductions in sensitive fish species populations in waterbodies having excessive selenium concentrations [Chapman *et al.*, 2009].

EPA developed and applied a probabilistic ecological risk model, based on the bioaccumulation concepts described above, to assess the risk of adverse reproductive impacts among fish and birds exposed to selenium in waterbodies that receive discharges of the evaluated wastestreams. Figure 5-3 provides a general schematic of the approach, which follows these general steps:

1. Apply a distribution of site-specific EFs (with separate distributions for lentic and lotic systems) to the predicted dissolved selenium concentration from the IRW water quality module, resulting in a distribution of predicted selenium concentrations in particulates and primary producers for each receiving water.
2. Apply a TTF distribution for invertebrates ($\mathrm{TTF}_{\mathrm{invert}}$) to the outputs from Step 1, resulting in a distribution of predicted selenium concentrations in invertebrates that inhabit each receiving water.
3. To predict the bioaccumulation and reproductive risk among fish:

    a. Apply a TTF distribution for fish (TTF_{fish}) to the outputs from Step 2, resulting in a distribution of predicted selenium concentrations in the eggs and ovaries of fish that inhabit each receiving water (some of the TTFs incorporate tissue conversion factors to translate the outputs from whole body or muscle concentrations into fish egg-ovary concentrations).

    b. Apply an exposure-response function for fish (ER_{fish}) to the outputs from Step 3a, resulting in a distribution showing the probability of a decline in reproductive success across exposed fish populations.

4. To predict the bioaccumulation and reproductive risk among birds (specifically, mallards):

    a. Apply a TTF distribution for mallards ($TTF_{mallard}$) to the outputs from Step 2, resulting in a distribution of predicted selenium concentrations in the eggs of mallards that forage and/or breed in each receiving water.

    b. Apply an exposure-response function for mallards ($ER_{mallard}$) to the outputs from Step 4a, resulting in a distribution showing the probability of a decline in reproductive success across exposed mallard populations.

This modeling approach is consistent with the approach taken in developing the External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2014f] (referred to as the external peer review draft selenium criterion) and is based on the same data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish}. For this EA, EPA expanded the model to include data sets for $TTF_{mallard}$ and $ER_{mallard}$ and to include several additional data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish} that were eventually incorporated into the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2015b].

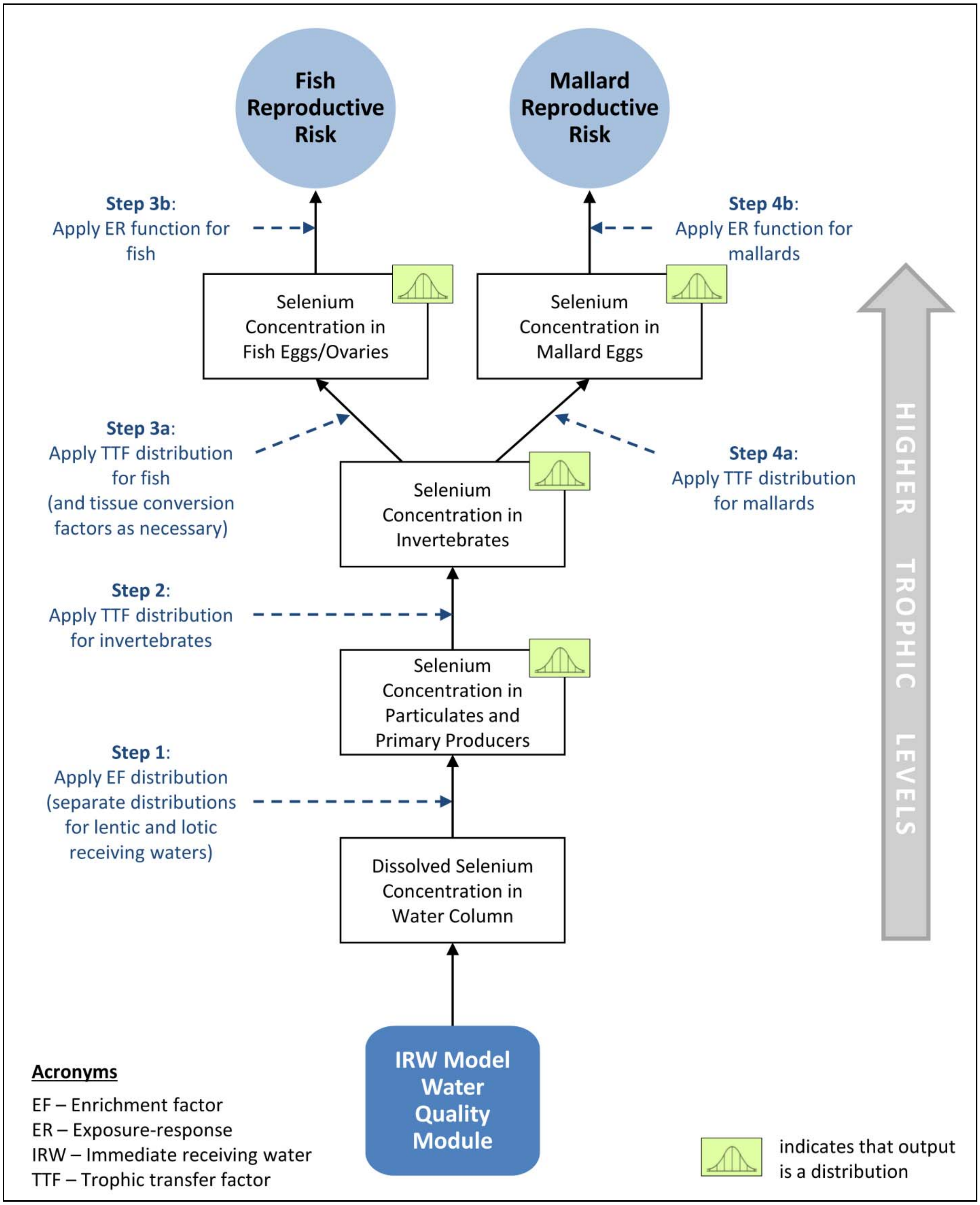


Figure 5-3. Flowchart of Selenium Ecological Risk Model

Detailed information for some of the factors that influence selenium bioaccumulation at a particular site, such as the form of selenium in the environment (*e.g.*, selenate, selenite, and organo-selenide) and the structure of the aquatic food web, is not available across the 209 immediate receiving waters modeled in this EA. The ecological risk model accounts for these unknowns by applying distributions of EFs and TTFs based on data representing a wide variety of lentic and lotic waterbodies and freshwater invertebrate and fish species, rather than relying on a single statistical measure (*e.g.*, mean or median) for those parameters. This approach accounts for the variability across aquatic systems and captures the full range of food web constructs that could occur in these receiving waters.

The remainder of this section further discusses EPA's development of the EFs, TTFs, and ER functions in the ecological risk model and use of those functions to calculate risk of adverse reproductive effects (performed using Oracle Crystal Ball software). Appendix F provides additional details regarding data sources, data acceptance criteria, statistical methods, and assumptions and limitations of the ecological risk model.

Enrichment Factors

EPA compiled a database of empirical measurements of selenium concentration (water, sediment, biofilm, algae, phytoplankton, and detritus) from relevant field studies across a range of aquatic systems. EPA then calculated EFs for a set of aquatic systems and applied statistical methods to distinguish categories with similar bioaccumulation characteristics, consistent with the approach followed in developing the external peer review draft selenium criterion [U.S. EPA, 2014f]. The key factor distinguishing EFs across systems is whether the data were collected from lentic systems (*e.g.*, lakes, reservoirs, and ponds) or lotic systems (*e.g.*, rivers, creeks, and streams). Therefore, the EPA developed EF distributions separately for lentic and lotic systems.

This effort produced EF distributions for both systems that are well described by lognormal distributions with means (standard deviations) of 1,738 (2,499)[44] for lentic systems and 692 (787) for lotic systems.

Trophic Transfer Factors for Invertebrates and Fish

EPA compiled a database of empirical measurements of selenium concentration in particulates, invertebrates, and fish from relevant field studies. EPA arranged the data by developing data pairs representing the concentration in the consumer organism (invertebrate or fish) and the concentration in the consumed material or lower-trophic-level organism (particulate or invertebrate). The ratio between these two values defines the TTF for the consumer organism. EPA limited these data pairs to measurements collected from the same aquatic site. EPA further limited the data pairs by excluding measurements of material or lower-trophic-level organisms deemed unlikely to be ingested by the higher-trophic-level organism. Many of the fish concentration measurements required a further conversion to the concentration of selenium in eggs, requiring a whole-body-to-egg/ovary conversion factor. This factor (egg/ovary concentration = whole body concentration × 1.9) is based on paired measurements from

---

[44] The EF incorporates a multiplier of 1,000. A mean EF of 1,738 for lentic systems indicates that, on average, the concentration of selenium at the base of the food web is 1.738 times greater than the dissolved concentration in water.

individual fish and is consistent with the value used to develop the external peer review draft selenium criterion [U.S. EPA, 2014f].

This effort resulted in a TTF_{invert} distribution with a mean (standard deviation) of 2.84 (2.49) and a TTF_{fish} distribution with a mean (standard deviation) of 1.6 (1.08).

Trophic Transfer Factors for Mallards

EPA selected the mallard (*Anas platyrhynchos*) as the representative bird species for the ecological risk analysis. The mallard has been extensively evaluated in both field and laboratory studies and has been shown to be relatively sensitive to selenium. Mallards are ubiquitous, occurring in every state at specific times during the year, and are the species with the highest probability of being found at any of the 209 modeled receiving waters. Dabbling ducks such as mallards contribute important ecosystem services, such as transferring eggs and seeds of aquatic organisms between isolated wetlands and maintaining the biodiversity of other organisms [Bengtsson *et al.*, 2014; Green and Elmberg, 2014].

Based on a review of Ohlendorf [2003], EPA developed a database of field measurements of mallards and their likely food sources, expressed as a ratio of measured egg concentrations to dietary concentrations. Many studies across a wide variety of species have shown that selenium concentrations in bird eggs range from roughly equal to or three or four times the concentrations in the diet of the female at the time of egg-laying [Ohlendorf and Heinz, 2011]. The resulting $TTF_{mallard}$ distribution is best described by a triangular distribution, with a likeliest value of 2.5, a minimum value of 0.4, and a maximum value of 4.1.

Exposure-Response Function for Fish

Larval mortality and reproductive teratogenesis (*i.e.*, deformities in offspring) from maternal transfer of selenium to eggs represent the most sensitive endpoints in fish. Deformities in fish that affect feeding or respiration can be lethal shortly after hatching. Deformities that are not directly lethal, but that distort the spine and fins, can affect larval survival by reducing swimming ability and overall fitness. EPA therefore selected larval mortality and deformities as the target endpoints for this analysis.

This approach is consistent with the approach taken to develop the external peer review draft selenium criterion, and used the same extensively peer-reviewed exposure-response function (*i.e.,* curve) as was used in that analysis [U.S. EPA, 2014f]. Appendix F provides the exposure-response function for fish, which translates the modeled egg-ovary concentration into the probability of adverse reproductive effects.

Exposure-Response Function for Mallards

To derive the exposure-response function for mallards, EPA used the same set of six progressive studies used to develop the $TTF_{mallard}$ distribution [Ohlendorf, 2003]. This approach ensures consistency in the predicted bioaccumulation and reproductive response across different selenium exposure levels.

The mallard exposure-response function in Ohlendorf [2003] is based on a regression meta-analysis of six different laboratory studies that evaluated the effect of selenium on mallard egg hatchability [Heinz *et al.,* 1987, 1989; Heinz and Hoffman, 1996, 1998; Stanley *et al.,* 1994, 1996]. This function formed the basis of the water quality criterion adopted by the Utah Water Quality Board for Lake Gilbert, and underwent peer review by EPA Region 8. For this analysis, EPA fit a logistic curve to the combined, control normalized data from the six mallard studies. Appendix F provides the resulting exposure-response function for mallards.

Calculation of Reproductive Risk

In this analysis, risk is defined as the probability of a percentage reduction in reproductive capacity based on larval mortality and deformity in fish and hatching success in mallards. For any given exposure concentration to selenium predicted from the EF-TTF model, the exposure-response function provides the probability of the effect occurring, termed a joint probability model.

The EF-TTF models provide the predicted exposure distributions in fish and mallard eggs. For each concentration, the probability of exposure occurring is compared to the probability of effect at that exposure level. The resulting functions provide the probability of larval mortality and deformities in fish and hatching failure in mallards.

SECTION 6
CURRENT IMPACTS FROM STEAM ELECTRIC POWER GENERATING INDUSTRY

EPA developed the immediate receiving water (IRW) model and ecological risk model described in Section 5 to quantify the current national-scale environmental impacts of direct surface water discharges of the evaluated wastestreams (*i.e.*, flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate) from steam electric power plants. This section presents the baseline results of the modeled pollutant concentrations in surface waters and fish tissue and their potential impacts to aquatic life, wildlife, and human health.

6.1 WATER QUALITY IMPACTS

The quality of a surface water is defined by its chemical, physical, and biological characteristics and is measured to evaluate a water's potential to harm aquatic life and human health. EPA assessed the quality of surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the water column to the National Recommended Water Quality Criteria (NRWQC) and drinking water maximum contaminant levels (MCLs). Based on the modeling results for surface water quality impacts, approximately 62 percent of the lakes, ponds, and reservoirs (16 out of 26) and 43 percent of the rivers and streams (78 out of 183) that receive discharges of the evaluated wastestreams have estimated pollutant concentrations that exceed these water quality benchmarks and may have quantifiably impaired water quality due to those discharges. Based on the modeling results, human health criteria exceedances are more prevalent among the immediate receiving waters than aquatic life criteria exceedances. Approximately 17 to 45 percent of the immediate receiving waters had modeled pollutant concentrations that exceed a human health criterion, while approximately 4 to 17 percent of the immediate receiving waters had modeled pollutant concentrations that exceed an aquatic life criterion. The difference between exceedances for human health and aquatic life criteria is due to the human health criteria for arsenic and thallium, which are significantly lower than the aquatic life criteria for most of the modeled pollutants.

Due to data limitations at the national scale, EPA did not include other pollutant sources (*e.g.*, naturally -occurring pollutants, nonpoint source discharges, or other point source discharges) in the IRW model. Quantified exceedances estimated by the IRW model represent environmental impacts due entirely to the pollutant loadings in discharges of the evaluated wastestreams from steam electric power plants. Table 6-1 presents the number and percentage of immediate receiving waters with estimated pollutant concentrations that exceed each water quality criterion under baseline conditions.

EPA identified arsenic, thallium, cadmium, and selenium as the primary pollutants contributing to the water quality exceedances, as shown in Table 6-1. Humans are primarily at risk for exposure to arsenic and thallium. Out of the 209 modeled immediate receiving waters:

- 94 exceed the human health NRWQC for the consumption of arsenic-contaminated water and organisms (0.018 micrograms per liter (µg/L)).

- 65 exceed the arsenic NRWQC for consumption of organisms only (0.14 µg/L).
- 49 exceed the human health NRWQC for the consumption of thallium-contaminated water and organisms (0.24 µg/L).
- 45 exceed the thallium NRWQC for consumption of organisms only (0.47 µg/L).

Therefore, humans consuming water and/or organisms inhabiting these waters are more at risk of arsenic-related effects (skin damage, cardiovascular disease, and cancer in the skin, lungs, bladder, and kidney) and thallium-related effects (changes in blood chemistry; damage to liver, kidney, and intestinal and testicular tissues; hair loss; and reproductive and developmental damage).

Aquatic organisms are primarily at risk due to exposure to cadmium and selenium. Estimated pollutant concentrations in approximately 15 percent of the immediate receiving waters (29 and 33 out of 209, respectively) exceed the aquatic life criterion for chronic exposure to cadmium- and selenium-contaminated waters (0.25 and 5 µg/L, respectively). Therefore, aquatic organisms inhabiting these waters are under a greater threat for cadmium-related effects (tissue damage and organ abnormalities) and selenium-related effects (reproductive failure, deformities, reduced growth, increased metabolic rates, and death). Sublethal and lethal impacts from chronic selenium exposure are frequently cited in literature. For more information on these impacts, refer to Section 3.1.1.

Table 6-1. Number and Percentage of Immediate Receiving Waters with Estimated Water Concentrations that Exceed the Water Quality Criteria at Baseline

Evaluation Criterion		Number of Immediate Receiving Waters Exceeding a Criterion [a]			
		Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters [b]	
				Number Exceeding	Percentage Exceeding
Aquatic Life Criteria	Freshwater Acute NRWQC	9	0	9	4%
	Freshwater Chronic NRWQC	30	5	35	17%
Human Health Criteria	Human Health Water and Organism NRWQC	78	16	94	45%
	Human Health Organism Only NRWQC	55	11	66	32%
	Drinking Water MCL	31	5	36	17%
Total Number of Unique Immediate Receiving Waters [c]		78	16	94	45%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NRWQC (National Recommended Water Quality Criteria); MCL (maximum contaminant level).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceeded at least one criterion.

Table H-1 in Appendix H presents additional details on the number and percentage of immediate receiving waters that are exceeding each water quality criterion by pollutant. For more detailed information on the modeled immediate receiving water concentrations under baseline conditions, see Figures H-1 to H-10 and Tables H-2 to H-11 in Appendix H.

6.2 WILDLIFE IMPACTS

As part of the national-scale wildlife impacts analysis, EPA assessed the impacts of the evaluated wastestreams on the following categories:

- Impacts to wildlife indicator species (*i.e.*, mink and eagle) due to consuming contaminated fish (using the wildlife component of the IRW model).
- Impacts to fish and waterfowl due to dietary exposure and trophic transfer of selenium (using the ecological risk model in combination with the water quality component of the IRW model).
- Impacts to benthic organisms due to contact with contaminated sediment (using the wildlife component of the IRW model).

The results of these analyses are described in the following sections.

6.2.1 Impacts to Wildlife Indicator Species

As described in Section 5.1.2, EPA assessed the potential impact to piscivorous wildlife from the evaluated wastestreams by modeling fish tissue pollutant concentrations and comparing these concentrations to no effect hazard concentrations (NEHC) for minks and eagles developed by the U.S. Geological Survey (USGS). Based on the estimated fish tissue concentrations, approximately 34 percent (71 out of 209) and 28 percent (58 out of 209) of the immediate receiving waters pose a potential threat to eagles and minks, respectively, through the consumption of contaminated fish. This result demonstrates that estimated pollutant concentrations in fish that inhabit receiving waters immediately downstream from steam electric power plant wastewater discharges pose a potential reproductive threat to surrounding minks and eagles and indicates the potential broader impacts that steam electric power plant wastewater discharges may pose to the greater environment as pollutants transfer from the aquatic environment and begin to accumulate in terrestrial food webs.

As expected, based on documented environmental impacts, modeling results indicate that pollutant concentrations in fish inhabiting lakes, ponds, and reservoirs are more likely to exceed the NEHC benchmarks than pollutant concentrations in fish inhabiting rivers and streams. The estimated fish tissue pollutant concentrations pose a potential reproductive threat to minks and eagles in approximately 46 percent of modeled lakes, ponds, and reservoirs (12 out of 26) and in 32 percent of rivers and streams (59 out of 183) that were evaluated. These results are expected, since fish populations inhabiting lake environments cannot travel to uncontaminated waters and therefore continue to bioaccumulate pollutants.

Table 6-2 presents the number and percentage of immediate receiving waters that exceed the USGS wildlife fish consumption NEHC for minks and eagles.

Table 6-2. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Waterbody Type) at Baseline

Evaluation Criterion	Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [a,b]	
			Number Exceeding	Percentage Exceeding
Mink fish consumption NEHC	47	11	58	28%
Eagle fish consumption NEHC	59	12	71	34%
Total Number of Unique Immediate Receiving Waters [c]	59	12	71	34%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NEHC (No Effect Hazard Concentration).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceed a criterion.

The pollutants found to present the greatest threat to minks and eagles from fish consumption were mercury and selenium. The modeled concentrations of mercury in fish tissue exceeded the NEHC benchmarks for minks and eagles in 26 and 34 percent of the modeled immediate receiving waters, respectively. Approximately 20 percent of the immediate receiving waters contained fish with modeled selenium concentrations exceeding a fish consumption NEHC benchmark for minks and eagles.

Table 6-3 presents the number and percentage of immediate receiving waters that exceed a USGS wildlife fish consumption NEHC for minks and eagles by pollutant.

6.2.2 Impacts to Fish and Waterfowl due to Dietary Selenium Exposure

As discussed in Section 5.2, EPA expanded upon the piscivorous wildlife benchmark analysis to include ecological risk modeling of the reproductive risks among fish and waterfowl that consume aquatic organisms contaminated with elevated levels of selenium. Selenium is of particular concern in aquatic environments because it can accumulate in sediment and biomagnify to toxic levels in fish inhabiting selenium-contaminated waters (even at relatively low concentrations), potentially eliminating piscivorous (fish-eating) wildlife higher in the food chain [Ohlendorf *et al.*, 1988a]. Impacts to fish populations are well documented in the literature [Garrett and Inman, 1984; Lemly, 1985a; Sorensen *et al.*, 1982]. While exposed fish populations may not experience lethal impacts, the sublethal damage to their reproductive systems can eventually impact the survivability of fish populations near steam electric power plants. The documented impacts at Belews Lake illustrate this is especially an issue in lakes, ponds, and reservoirs, where healthy fish populations cannot migrate and seek out alternative food sources. Decreased fish populations may cause cascading effects within the food web that can adversely affect other organisms in the ecosystem.

Table 6-3. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Pollutant) at Baseline

Pollutant	Mink			Eagle		
	Fish Consumption NEHC (µg/g) [a]	Immediate Receiving Waters		Fish Consumption NEHC (µg/g) [a]	Immediate Receiving Waters	
		Number Exceeding [b]	Percentage Exceeding		Number Exceeding [b]	Percentage Exceeding
Arsenic	7.65	0	0%	22.4	0	0%
Cadmium	5.66	6	3%	14.7	4	2%
Chromium VI	17.7 [c]	0	0%	26.6 [c]	0	0%
Copper	41.2	1	<1%	40.5	1	<1%
Lead	34.6	1	<1%	16.3	2	1%
Mercury	0.37	55	26%	0.5	71	34%
Nickel	12.5	0	0%	67.1	0	0%
Selenium	1.13	42	20%	4	42	20%
Thallium	ID	NC	NC	ID	NC	NC
Zinc	904	1	<1%	145	5	2%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified in the wildlife analysis for thallium); NC (Not calculated); NEHC (No Effect Hazard Concentration); µg/g (micrograms/gram).

a – The wildlife fish consumption NEHC represents the maximum pollutant concentration in the fish that will result in no observable adverse effects in wildlife (*i.e.*, minks or eagles) [USGS, 2008].

b – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

c – An NEHC benchmark is not available for chromium VI; therefore, EPA used the total chromium benchmark.

The results of the ecological risk model indicate that, under baseline conditions, discharges of selenium from steam electric power plants elevate the risk of adverse reproductive impacts among fish and mallards that inhabit, forage, or breed in the immediate receiving waters. These reproductive impacts include larval mortality and deformities among fish and reduced egg hatchability among mallards.

The ecological risk modeling results indicate that 15 percent of the lakes, ponds, and reservoirs (four out of 26) and 11 percent of the rivers and streams (20 out of 183) that receive discharges of the evaluated wastestreams present an elevated risk of negative reproductive impacts to fish. For mallards, the counts are slightly higher, with 19 percent of the lakes, ponds, and reservoirs (five out of 26) and 14 percent of the rivers and streams (26 out of 183) presenting these risks. These results support the conclusion that lentic systems, which have higher potential for pollutant retention due to longer residence times, are more likely to experience ecological impacts due to discharges from steam electric power plants.

The results described above represent those immediate receiving waters whose median modeled egg/ovary concentration is predicted to impact reproduction among at least 10 percent of the exposed fish or mallard population. As described below, however, adjusting these criteria reveals additional perspective regarding the prevalence of immediate receiving waters that may be causing reproductive impacts due to selenium exposure.

Selecting the 90th percentile modeled egg/ovary concentration, meaning there is a 10 percent probability that the egg/ovary concentrations are greater than the selected concentration, reveals that 20 percent of the immediate receiving waters (42 out of 209) present reproductive risks to at least 10 percent of the exposed fish population. The results for mallards (21 percent) are very similar. These counts are considerably higher than the results obtained using the median modeled egg/ovary concentration, indicating the potential for more widespread ecological impacts among those waterbodies and food webs that tend to experience higher bioaccumulation of selenium.

The results of the ecological risk model indicate that sublethal effects from dietary exposure to selenium (from discharges of the evaluated wastestreams) can lead to hidden population-level effects among exposed fish and waterfowl by reducing reproductive success. The results for mallards illustrate the broader effects throughout the food web that can result from exposure to waterbodies contaminated with selenium. These results also indicate that impacts to aquatic-dependent wildlife are not limited to piscivorous wildlife such as mink and eagles.

The ecological risk model accounts only for those reproductive effects associated with exposure to selenium. There might be more immediate receiving waters whose pollutant levels result in elevated reproductive risk because they contain other pollutants at concentrations that are harmful to wildlife.

For more information on the potential environmental impacts from selenium exposure, refer to the selenium discussion in Section 3.1. For more detailed information on baseline modeled fish tissue concentrations in the immediate receiving water for selenium and other pollutants evaluated in the EA, see Figures H-11 to H-21 and Tables H-12 to H-22 in Appendix H.

6.2.3 Impacts to Benthic Organisms

EPA also assessed the potential impact to wildlife exposed to sediments in surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the sediment to chemical stressor concentration limit (CSCL) benchmarks for sediment biota published by MacDonald, *et. al.* (2000) in *Archives of Environmental Contamination and Toxicology*. Table 6-4 presents the number and percentage of immediate receiving waters with sediment pollutant concentrations that exceed a CSCL. EPA calculated that 22 percent of rivers and streams (40 out of 183) and 35 percent of lakes, ponds, and reservoirs (9 out of 26) had estimated sediment pollutant concentrations that may be toxic to wildlife.

Benthic organisms are at risk primarily due to exposure to mercury, nickel, and cadmium. Estimated sediment pollutant concentrations in 13 to 23 percent of the immediate receiving waters (27 to 49 out of 209) exceed the sediment biota CSCL benchmarks for exposure to cadmium-contaminated, nickel-contaminated, and mercury-contaminated waters. Therefore, benthic organisms inhabiting these waters are under a greater threat for sublethal effects such as skeletal malformation and reduced growth and reproductive success. For more information on these impacts, refer to Section 3.1.1.

As expected, based on documented environmental impacts, modeling results indicate that pollutant concentrations in the benthic sediment in lakes, ponds and reservoirs are more likely to exceed the sediment biota CSCL benchmarks than pollutant concentrations in the benthic sediment of rivers and streams. Several publications in the literature confirm that sediment impacts are more likely to occur in lakes where pollutants can accumulate in sediments over time [Hopkins *et al*., 2000, 2003; Lemly, 1997a].

Table 6-4. Number and Percentage of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding CSCLs for Sediment Biota at Baseline

Pollutant	Sediment Benchmark (mg/kg)	Number of Immediate Receiving Waters Exceeding CSCLs for Sediment Biota			
		Rivers and Streams	Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters	
				Number [a]	Percent
Arsenic	5.90	7	0	7	3%
Cadmium	0.596	22	5	27	13%
Chromium VI [b]	37.3	0	0	0	0%
Copper	35.7	6	1	7	3%
Lead	35	5	1	6	3%
Mercury	0.174	40	9	49	23%
Nickel	18.0	29	5	34	16%
Selenium	ID	NC	NC	NC	NC
Thallium	ID	NC	NC	NC	NC
Zinc	123	14	1	15	7%
Total Number of Unique Immediate Receiving Waters		**40**	**9**	**49**	**23%**

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); ID (Insufficient data; no benchmarks were identified); NC (Not calculated).a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.

6.3 HUMAN HEALTH IMPACTS

In addition to assessing water quality impacts on human health as discussed in Section 3.3.2, EPA expanded the analysis to evaluate human health impacts from consuming fish in immediate receiving waters downstream from discharges of the evaluated wastestreams. The purpose of this analysis was to evaluate the broader bioaccumulative effects of pollutants in steam electric power plant discharges to see whether average daily doses of pollutants from fish consumption could potentially exceed human health thresholds where water concentrations may not indicate an issue. EPA evaluated multiple human cohorts (*i.e.*, recreational and subsistence fishers, children and adults) by calculating the average daily dose of pollutants from fish consumption using the estimated fish tissue concentrations calculated in the model. EPA varied the fish consumption rate of each cohort (based on age) to determine the average and long-term daily doses for each pollutant. EPA calculated the lifetime excess cancer risk (LECR) based on estimated fish tissue concentrations of inorganic arsenic and calculated non-cancer threats by comparing the average daily doses to threshold values for all pollutants with published reference doses. EPA first evaluated human health impacts based on type of fisher and age of cohort using national-level consumption rates. For the environmental justice analysis, EPA determined fish consumption rates using the race population in addition to the other two factors. For more information on how EPA identified potential impacts to human receptors, see Section 5.1.3 and Appendix E.

The human health module presents the risk results for each age group individually to allow for further manipulation in the benefits analysis. The true cancer risk to a child would depend on the amount of time the child consumed fish from locations downstream from steam electric power plant discharges. For example, the cancer risk for a 6-year-old child who was born and raised in the same place would be the sum of the LECRs from the 1 to <2 years, 2 to <3 years, and 3 to <6 years cohort groups.

A limitation of the national-scale IRW modeling that may underestimate the cancer risk is the use of an average annual pollutant loading rate as the basis for the risk estimation; as described earlier, the model does not consider the potential for pollutants to accumulate over time in the environment. The model estimates a minimal cancer risk from consuming fish in lakes, ponds, and reservoirs that receive discharges of the evaluated wastestreams. The cancer risk is likely greater in a lake, where fish are limited in their food sources and can bioaccumulate pollutants over a longer exposure period than is represented in the model.

6.3.1 National-Scale Cohort Analysis

Table 6-5 presents the number and percentage of immediate receiving waters where the estimated LECR for the national-scale human receptor exceeds the selected threshold, 1-in-a-million cancer risk for arsenic. Inorganic arsenic concentrations in fish result in an estimated cancer risk greater than 1-in-a-million to adult subsistence fishers in approximately 12 percent of the immediate receiving waters (25 out of 209) and to adult recreational fishers in approximately 6 percent of the immediate receiving waters (12 out of 209). Cancer risks for the child cohorts are lower, with LECRs exceeding the cancer risk threshold in 2 to 4 percent of the immediate receiving waters. Even given the limitations of the modeling framework discussed in Section 6.3, the inorganic arsenic concentrations in fish can pose a cancer risk to adult subsistence fishers in 12 percent of the lakes and to adult recreational fishers in 8 percent of the lakes.

Table 6-5. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic at Baseline

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [c]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	6	0	6	3%
	6 to <11 years	5	6	0	6	3%
	11 to <16 years	5	6	0	6	3%
	16 to <21 years	5	6	0	6	3%
Adult recreational fisher		49	10	2	12	6%
Child subsistence fisher	1 to <2 years	1	6	0	6	3%
	2 to <3 years	1	6	0	6	3%
	3 to <6 years	3	7	0	7	3%
	6 to <11 years	5	8	1	9	4%
	11 to <16 years	5	6	0	6	3%
	16 to <21 years	5	6	0	6	3%
Adult subsistence fisher		49	22	3	25	12%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

c – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Based on the estimated fish tissue concentrations and average daily pollutant doses by cohort, subsistence fishers (adults and children) have the greatest threat for non-cancer health effects. This is because the average daily doses (for one or more pollutant) exceed the oral reference dose values in 49 to 56 percent of the immediate receiving waters, depending on the age group evaluated. Recreational fishers (adult or child) have less of a threat, with average daily doses exceeding oral reference doses in 41 to 48 percent of the immediate receiving waters. These results suggest that fish downstream from discharges of the evaluated wastestreams pose a non-cancer health threat to surrounding fisher populations. Given the modeling limitations described above, these results may underestimate these non-cancer health impacts.

Table 6-6 presents the number and percentage of immediate receiving waters where the average daily dose of one or more pollutant exceeds an oral reference dose for non-carcinogens.

Table 6-6. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [b]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	82	18	100	48%
	2 to <3 years	1	82	18	100	48%
	3 to <6 years	3	80	18	98	47%
	6 to <11 years	5	76	16	92	44%
	11 to <16 years	5	72	14	86	41%
	16 to <21 years	5	72	14	86	41%
Adult recreational fisher		49	72	14	86	41%
Child subsistence fisher	1 to <2 years	1	98	20	118	56%
	2 to <3 years	1	98	20	118	56%
	3 to <6 years	3	92	19	111	53%
	6 to <11 years	5	87	19	106	51%
	11 to <16 years	5	84	18	102	49%
	16 to <21 years	5	84	18	102	49%
Adult subsistence fisher		49	85	18	103	49%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

According to the exposure doses calculated from the estimated fish tissue concentrations, methylmercury poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Mercury concentrations in fish pose a non-cancer threat to humans in approximately 52 percent of the immediate receiving waters. Therefore, humans who consume fish inhabiting these waters are at risk for developing mercury-related effects, which could include neurological symptoms (*e.g.*, affecting fine motor function, language skills, verbal memory) and cardiovascular disease if exposed at high enough doses. In addition, thallium concentrations in fish pose a non-cancer threat to humans in approximately 45 percent of immediate receiving waters.[45] Therefore, humans who consume thallium-contaminated fish inhabiting these waters are more likely to develop neurological symptoms (*e.g.*, weakness, sleep disorders, muscular problems), alopecia (*i.e.*, loss of hair from the head and body), and gastrointestinal effects (*e.g.*, diarrhea and vomiting).

Table 6-7 presents the number and percentage of immediate receiving waters where average daily doses exceed an oral reference dose for non-carcinogens by pollutant.

---

[45] EPA used the chronic oral exposure value cited in U.S. EPA, 2010a for thallium chloride as the reference dose.

Table 6-7. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline by Pollutant

Pollutant	Oral Reference Dose (mg/kg/day)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]	
		Number Exceeding	Percentage Exceeding
Inorganic arsenic	0.0003 [b]	3	1%
Cadmium	0.001 [b]	32	15%
Chromium VI	0.003 [b]	0	0%
Copper	0.01 [c]	6	3%
Lead	ID	NC	NC
Mercury (as methylmercury)	0.0001 [b]	109	52%
Nickel (soluble salts)	0.02 [b]	0	0%
Selenium	0.005 [b]	55	26%
Thallium (soluble salts)	0.00001 [d]	94	45%
Zinc	0.3 [b]	9	4%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NC (Not calculated); ID (Insufficient data; there is no current reference dose for lead).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – U.S. EPA, 2011c.

c – ATSDR, 2010a.

d – U.S. EPA, 2010a.

States, territories, and authorized tribes have the primary responsibility to protect residents from the health risks of consuming contaminated noncommercially caught fish. They inform the general population, including recreational and subsistence fishers, typically by issuing advisories that notify the public that chemical contamination found in local fish may present a public health hazard.

EPA modeled concentrations in T4 fish tissue and compared them 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 hazard. Based on the modeling results, up to 48 percent of the immediate receiving waters evaluated may contain fish with contamination levels that could trigger advisories for recreational and subsistence fishers. Mercury and selenium are the pollutants most likely to exceed screening values. This result indicates that steam electric power plants are contributing to the already widespread concentrations of mercury and selenium in fish throughout the country.

Table 6-8 presents the number and percentage of immediate receiving waters where the modeled T4 fish tissue concentrations exceed screening values used for fish advisories.

Table 6-8. Comparison of T4 Fish Tissue Concentrations at Baseline to Fish Advisory Screening Values

Pollutant	Recreational Fishers			Subsistence Fishers		
	Screening Value (ppm)[a]	Number Exceeding [b]	Percentage Exceeding	Screening Value (ppm) [a]	Number Exceeding [b]	Percentage Exceeding
Inorganic arsenic (noncarcinogen)	1.2	0	0%	0.147	3	1%
Inorganic arsenic (carcinogen)	0.026	4	2%	0.00327	9	4%
Cadmium	4.0	8	4%	0.491	22	11%
Mercury (as methylmercury)	0.4	76	36%	0.049	101	48%
Selenium	20	22	11%	2.457	46	22%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ppm (parts per million).

a – Screening values are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as threshold values against 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 risk should be conducted [U.S. EPA, 2000a, Table 5-3].

b – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

6.3.2 Environmental Justice Analysis

As part of the EA, EPA evaluated whether the impacts from steam electric power plant wastewater discharges disproportionately impact minority groups. This environmental justice (EJ) analysis included looking at impacts based on race or Hispanic origin. Table 6-9 presents the number and percentage of immediate receiving waters where the estimated LECR for the human receptor exceeds the selected threshold, 1-in-a-million cancer risk for arsenic. Inorganic arsenic concentrations in fish result in an estimated cancer risk greater than 1-in-a-million to adult subsistence, minority fishers in approximately 12 to 15 percent of the immediate receiving waters (26 to 32 out of 209) and to adult recreational fishers in approximately 7 to 9 percent of the immediate receiving waters (14 to 19 out of 209). Cancer risks for the child cohorts are lower. The estimated cancer risk among adult minority fishers is higher than the risk among adult nonminority fishers (especially among the recreational fisher population).

Table 6-9. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic at Baseline, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,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	3	3	4	6	6	6	12
	Non-Hispanic Black	3	3	5	6	6	6	14
	Mexican-American	4	4	6	6	6	6	18
	Other Hispanic	4	4	6	6	6	6	16
	Other, including Multiple Races	4	4	6	6	6	6	19
Subsistence	Non-Hispanic White	4	4	6	7	7	7	25
	Non-Hispanic Black	5	5	6	7	7	7	26
	Mexican-American	6	6	6	8	8	8	28
	Other Hispanic	6	6	6	7	7	7	28
	Other, including Multiple Races	6	6	7	10	10	10	32

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

Based on the estimated fish tissue concentrations and average daily pollutant doses by cohort, subsistence fishers (adults and children) have the greatest threat for non-cancer health effects. This is because the average daily doses (for one or more pollutant) exceed the oral reference dose values in 49 to 56 percent of the immediate receiving waters, depending on the age group evaluated. Recreational fishers (adult or child) have less of a threat, with average daily doses exceeding oral reference doses in 41 to 48 percent of the immediate receiving waters. These results suggest that fish downstream from discharges of the evaluated wastestreams pose a non-cancer health threat to surrounding fisher populations. Given the modeling limitations described above, these results may underestimate these non-cancer health impacts.

Table 6-10 presents the number and percentage of immediate receiving waters where the average daily dose of one or more pollutant exceeds an oral reference dose for non-carcinogens.

Table 6-10. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Pollutant Exceeds a Non-Cancer Reference Dose [a]						
		Inorganic Arsenic	Cadmium	Copper	Mercury [b]	Selenium	Thallium [c]	Zinc
Recreational, Child Fisher	Non-Hispanic White	0 (0%)	10 (5%)	3 (1%)	81 (39%)	32 (15%)	55 (26%)	4 (2%)
	Non-Hispanic Black	0 (0%)	12 (6%)	4 (2%)	84 (40%)	33 (16%)	58 (28%)	4 (2%)
	Mexican-American	0 (0%)	14 (7%)	4 (2%)	86 (41%)	33 (16%)	63 (30%)	4 (2%)
	Other Hispanic	0 (0%)	13 (6%)	4 (2%)	84 (40%)	33 (16%)	60 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	14 (7%)	4 (2%)	88 (42%)	34 (16%)	63 (30%)	4 (2%)
Subsistence, Child Fisher	Non-Hispanic White	3 (1%)	21 (10%)	5 (2%)	98 (47%)	42 (20%)	76 (36%)	5 (2%)
	Non-Hispanic Black	3 (1%)	22 (11%)	5 (2%)	98 (47%)	43 (21%)	78 (37%)	5 (2%)
	Mexican-American	3 (1%)	25 (12%)	6 (3%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other Hispanic	3 (1%)	25 (12%)	5 (2%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other, including Multiple Races	3 (1%)	29 (14%)	6 (3%)	104 (50%)	48 (23%)	89 (43%)	6 (3%)
Recreational, Adult Fisher	Non-Hispanic White	0 (0%)	10 (5%)	3 (1%)	81 (39%)	32 (15%)	55 (26%)	4 (2%)
	Non-Hispanic Black	0 (0%)	12 (6%)	4 (2%)	84 (40%)	33 (16%)	58 (28%)	4 (2%)
	Mexican-American	0 (0%)	14 (7%)	4 (2%)	86 (41%)	33 (16%)	63 (30%)	4 (2%)
	Other Hispanic	0 (0%)	13 (6%)	4 (2%)	84 (40%)	33 (16%)	60 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	14 (7%)	4 (2%)	88 (42%)	34 (16%)	63 (30%)	4 (2%)
Subsistence, Adult Fisher	Non-Hispanic White	3 (1%)	21 (10%)	5 (2%)	98 (47%)	42 (20%)	76 (36%)	5 (2%)
	Non-Hispanic Black	3 (1%)	22 (11%)	5 (2%)	98 (47%)	43 (21%)	78 (37%)	5 (2%)
	Mexican-American	3 (1%)	25 (12%)	6 (3%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other Hispanic	3 (1%)	25 (12%)	5 (2%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other, including Multiple Races	3 (1%)	29 (14%)	6 (3%)	104 (50%)	48 (23%)	89 (43%)	6 (3%)

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Mercury, as methylmercury.

c – Reference dose based on thallium (soluble salts).

SECTION 7
ENVIRONMENTAL IMPROVEMENTS UNDER THE FINAL RULE

In Section 6, EPA presented the environmental impacts to surface water quality, wildlife, and human health estimated with EPA's immediate receiving water (IRW) model and ecological risk model resulting from baseline discharges of the evaluated wastestreams. Under the final steam electric effluent limitations guidelines and standards (ELGs), EPA evaluated six regulatory options (Options A, B, C, D, E, and F). As part of this quantitative environmental assessment (EA), EPA evaluated the environmental improvements associated with the reduction in pollutant loadings from the evaluated wastestreams (*i.e.*, flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate) under Options A, B, C, D, and E, described in Table 7-1.[46]

In the remainder of this document, EPA presents the results only for Options A through E for existing sources. During development of the final rule, EPA decided not to base the final rule on Option F for existing sources due primarily to the high cost of that Option, particularly in light of the costs associated with other rulemakings expected to impact the steam electric industry (see Section VIII.C.1 of the preamble). As a result, EPA chose not to conduct particular analyses for Option F to the same extent that it did for some of the other options considered. Section 8 of the Technical Development Document (TDD) (EPA-821-R-15-007) details the technology options for all wastestreams evaluated under each regulatory option for the final rule. As described in Section 8 of the TDD, EPA selected Option D as the technology basis for the best available technology economically achievable (BAT) and for pretreatment standards for existing sources (PSES). See Section 12 of the TDD for further information on the limitations and standards of the final rule. This section presents the improvements to surface water quality, wildlife, and human health under the final rule as quantified by EPA's IRW model and ecological risk model.

Based on the quantitative and qualitative analyses performed for the EA, EPA estimated that a variety of environmental improvements would result from the pollutant loading removals associated with the regulatory options. In particular, the EA evaluated the following: 1) improvements in water quality, 2) reduction in threats to wildlife, 3) reduction in human health cancer risks, 4) reduction in threats for non-cancer human health effects, and 5) other unquantified environmental improvements. Table 7-2 lists the quantified and unquantified environmental improvements estimated to result from the final rule's regulatory options and designates which quantified improvements were monetized in the benefits analysis described in the Benefits and Cost Analysis (EPA-821-R-15-005).

---

[46] In addition to the wastestreams listed in Table 7-1, EPA evaluated technology options associated with flue gas mercury control (FGMC) wastewater, gasification wastewater, and nonchemical metal cleaning wastes as part of the regulatory options. However, no plants currently discharge FGMC wastewater, all existing gasification plants are operating the technology used as the basis for the regulatory option, and EPA will continue to reserve BAT/NSPS/PSES/PSNS for nonchemical metal cleaning wastes, as previously established regulations do. Therefore, EPA estimated zero compliance costs and zero pollutant reductions associated with these wastestreams and did not include these three wastestreams in the EA.

Table 7-1. Regulatory Options for the Wastestreams Evaluated in the EA

Evaluated Wastestream [a]	Option A	Option B	Option C	Option D	Option E
FGD wastewater	Chemical precipitation	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment
Fly ash transport water	Dry handling	Dry handling	Dry handling	Dry handling	Dry handling
Bottom ash transport water	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Dry handling/ closed loop (for units >400 MW); impoundment (equal to BPT) for units ≤400 MW	Dry handling/ closed loop	Dry handling/ closed loop
Combustion residual leachate	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Chemical precipitation

Acronyms: BPT (Best practicable control technology currently available); MW (Megawatt).

a – The evaluated wastestreams and regulatory options listed in the table are a subset of regulatory options for the steam electric ELGs. See Section 8 of the TDD for the full list of regulatory options.

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
Water Quality	Reduced number of immediate receiving waters exceeding an acute or chronic aquatic life NRWQC	✓		Section 7.2 Section 7.3
	Reduced number of immediate receiving waters exceeding a human health NRWQC	✓		Section 7.2 Section 7.3
	Reduced number of immediate receiving waters exceeding MCLs	✓		Section 7.2 Section 7.3
	Increased aesthetic benefits, such as enhancement of adjoining site amenities (*e.g.*, residing, working, traveling, and owning property near water)	✓	✓	Benefits and Cost Analysis [a]
	Improved water-based recreation, including swimming, fishing, boating, and near-water activities from improved water quality	✓	✓	Benefits and Cost Analysis [a]
	Improved quality of source water used for drinking, irrigation, and industrial use			Qualitative Discussion (Benefits and Cost Analysis)
	Increased property values from water quality improvements			Qualitative Discussion (Benefits and Cost Analysis)
	Increased tourism and participation in water-based recreation			Qualitative Discussion (Benefits and Cost Analysis)
	Pollutant removals to impaired waters	✓		Section 7.4
	Pollutant removals to the Great Lakes and Chesapeake Bay	✓		Section 7.5
	Pollutant removals of toxic contaminants, chlorides, and TDS to receiving waters	✓		Section 7.1
	Nutrient removals to receiving waters	✓	✓	Section 7.1 and Benefits and Cost Analysis [a]
	Reduced risk of surface impoundment failures	✓	✓	Benefits and Cost Analysis [a]
	Reduced sediment contamination			Qualitative Discussion (Benefits and Cost Analysis)
	Increased availability of ground water resources	✓	✓	Benefits and Cost Analysis [a]

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
Wildlife	Reduced exposure among minks to pollutants that bioaccumulate in fish	✓		Section 7.2 Section 7.3
	Reduced exposure among eagles to pollutants that bioaccumulate in fish	✓		Section 7.2 Section 7.3
	Reduced selenium concentrations in fish and waterfowl and associated reduced reproductive risk	✓		Section 7.2 Section 7.3
	Improved aquatic and wildlife habitat and improved protection of threatened and endangered species	✓	✓	Section 7.4 and Benefits and Cost Analysis [a]
	Improved commercial fisheries yield due to aquatic habitat improvement			Qualitative Discussion (Benefits and Cost Analysis)
	Enhanced existence, option, and bequest values from improved ecosystem health	✓	✓	Benefits and Cost Analysis [a]
	Reduced risks to aquatic life from exposure to steam electric pollutants		✓	Benefits and Cost Analysis [a]
	Reduced exposure to pollutants associated with the wastestreams of concern in surface impoundments that serve as attractive nuisances			Qualitative Discussion (Section 7.7)
Human Health	Reduced exposure to non-cancer pollutants for recreational and subsistence fishers	✓		Section 7.2 Section 7.3 Benefits and Cost Analysis [a]
	Reduced cancer risk in recreational and subsistence fishers	✓	✓	Section 7.2 Section 7.3 Benefits and Cost Analysis [a]
	Reduced incidences of cardiovascular disease from reduced arsenic and lead exposure	✓	✓	Benefits and Cost Analysis [a]
	Reduced adverse health effects from reduced in-utero mercury exposure from maternal fish consumption	✓	✓	Benefits and Cost Analysis [a]
	Reduced IQ loss and specialized education from reduced childhood exposure to lead from fish consumption	✓	✓	Benefits and Cost Analysis [a]
	Reduced adult mortality from air pollutant emissions	✓	✓	Benefits and Cost Analysis [a]
	Avoided climate change impacts from carbon dioxide emissions	✓	✓	Benefits and Cost Analysis [a]
	Reduced exposure to pollutants from recreational water uses			Qualitative Discussion (Benefits and Cost Analysis)

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
	Reduced injury associated with impoundment failures			Qualitative Discussion (Benefits and Cost Analysis)
	Reduced number of immediate receiving waters exceeding fish consumption advisory screening values	✓		Section 7.4

Acronyms: MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria); TDS (total dissolved solids).

a – The Benefits and Cost Analysis quantifies and monetizes individual environmental improvements for Options A, B, C, D, and E. See Benefits and Cost Analysis for more detail.

7.1 POLLUTANT REMOVALS UNDER THE REGULATORY OPTIONS

EPA estimates that the regulatory options would significantly reduce pollutant loadings to receiving waters for the 10 pollutants modeled in the EA and for other pollutants that can adversely affect surface waters, such as boron, manganese, nutrients, chlorides, and TDS. Table 7-3 and Table 7-4 present the pollutant removals under the regulatory options for the evaluated wastestreams.

Under the final rule (Option D), EPA estimates that pollutant loadings from existing sources will decrease by over 95 percent for copper, lead, mercury, nickel, selenium, thallium, and zinc and over 90 percent for arsenic and cadmium. In turn, these pollutant removals will reduce the negative impacts on the environment as well as the potential exposure of these contaminants to ecological and human receptors. The selenium removals will significantly improve the water quality around the steam electric power plant discharge locations. Mercury removals will improve human health as mercury has been linked to decreased IQs in children whose pregnant mothers have been exposed to mercury by consuming fish.

Manganese and boron, while not generally considered toxic at levels seen in the aquatic environment, have the highest and third highest toxic-weighted pound equivalents (TWPEs), respectively, under baseline conditions for pollutants evaluated in the EA (see Section 3.2). As discussed in Section 3, boron can negatively impact fish and ducks and manganese can be toxic to humans at high levels. Under the final rule, the pollutant loadings for manganese and boron will decrease by 80 and 15 percent, respectively.

As discussed in Section 3, nutrients (*i.e.*, nitrogen and phosphorus) in excess quantities can adversely affect surface waters by causing oxygen-consuming harmful algae blooms and creating “dead zones” where fish and shellfish cannot survive. Under the final rule, EPA calculated that nitrogen loadings will decrease by 16.8 million pounds per year (99 percent) and phosphorus loadings will decrease by 174,000 pounds per year (81 percent). The nutrient removals will improve hypoxic areas (*i.e.*, low-oxygen surface waters) such as the Chesapeake Bay and the Gulf of Mexico (via reduced loadings to the Mississippi River Basin).

Excess chlorides levels in wastewater discharges can be harmful to animals and plants in nonmarine surface waters and can disrupt ecosystem structure. Under the final rule, annual chlorides loadings to surface waters will decrease by 21.8 million pounds (two percent).

The pollutant parameter, TDS, comprises dissolved solids such as chloride and metals. Under the final rule, EPA calculated that annual TDS loadings to surface waters will decrease by more than 1.32 billion pounds (31 percent). This decrease is at least partially due to the reduction in total and dissolved metals discharged to receiving waters.[47]

---

[47] EPA's estimated TDS removals do not account for additional removals that may be achieved as a result of steam electric power plants opting to participate in the voluntary incentives program, in which they would be subject to effluent limitations based on evaporation technology, including for TDS.

Table 7-3. Steam Electric Power Generating Industry Pollutant Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	**Pollutant Removals, lbs/yr (Percent Reduction) [a]**				
	Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	15,700 (53%)	15,700 (53%)	23,200 (78%)	27,900 (94%)	28,500 (96%)
Boron	4,230,000 (14%)	4,230,000 (14%)	4,480,000 (14%)	4,630,000 (15%)	4,630,000 (15%)
Cadmium	9,020 (68%)	9,020 (68%)	11,200 (84%)	12,500 (94%)	12,600 (95%)
Chromium VI	131 (84%)	131 (84%)	147 (95%)	156 (>99%)	156 (>99%)
Copper	14,300 (46%)	14,300 (46%)	24,300 (78%)	30,500 (98%)	30,600 (98%)
Lead	7,670 (39%)	7,670 (39%)	14,800 (75%)	19,200 (98%)	19,200 (98%)
Manganese	5,120,000 (68%)	5,120,000 (68%)	5,650,000 (75%)	5,990,000 (80%)	5,990,000 (80%)
Mercury	858 (58%)	868 (58%)	1,230 (83%)	1,450 (97%)	1,470 (99%)
Nickel	62,300 (52%)	62,600 (52%)	96,200 (80%)	117,000 (98%)	118,000 (99%)
Selenium	29,300 (21%)	130,000 (93%)	134,000 (96%)	136,000 (97%)	136,000 (97%)
Thallium	7,180 (11%)	7,180 (11%)	40,900 (64%)	62,300 (98%)	62,300 (98%)
Zinc	120,000 (69%)	120,000 (69%)	148,000 (85%)	166,000 (95%)	169,000 (97%)
Nitrogen, total [b]	1,980,000 (12%)	12,300,000 (73%)	15,100,000 (89%)	16,800,000 (99%)	16,800,000 (99%)
Phosphorus, total	43,100 (20%)	43,100 (20%)	123,000 (57%)	174,000 (81%)	174,000 (81%)
Chlorides	4,160,000 (<1%)	4,160,000 (<1%)	14,900,000 (2%)	21,800,000 (2%)	21,800,000 (2%)
TDS	849,000,000 (20%)	849,000,000 (20%)	1,130,000,000 (27%)	1,320,000,000 (31%)	1,320,000,000 (31%)

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); lbs/yr (pounds per year).

Note: Pollutant removals are rounded to three significant figures.

a – .>0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table 7-4. Steam Electric Power Generating Industry TWPE Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	**Pollutant Removals, TWPE/year (Percent Reduction) [a]**				
	Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	54,600 (53%)	54,600 (53%)	80,400 (78%)	96,700 (94%)	98,900 (96%)
Boron	35,300 (13%)	35,300 (13%)	37,300 (14%)	38,600 (15%)	38,600 (15%)
Cadmium	205,000 (68%)	205,000 (68%)	254,000 (84%)	285,000 (94%)	287,000 (95%)
Chromium VI	6\7.5 (84%)	67.5 (84%)	76.1 (94%)	80.4 (>99%)	80.4 (>99%)
Copper	8,890 (46%)	8,890 (46%)	15,100 (78%)	19,000 (98%)	19,100 (98%)
Lead	17,200 (39%)	17,200 (39%)	33,100 (75%)	43,100 (98%)	43,100 (98%)
Manganese	526,000 (68%)	526,000 (68%)	580,000 (75%)	615,000 (80%)	615,000 (80%)
Mercury	94,400 (58%)	95,500 (58%)	136,000 (83%)	160,000 (97%)	162,000 (99%)
Nickel	6,790 (52%)	6,820 (52%)	10,500 (80%)	12,800 (98%)	12,900 (99%)
Selenium	32,900 (21%)	146,000 (93%)	150,000 (96%)	152,000 (97%)	152,000 (97%)
Thallium	20,500 (11%)	20,500 (11%)	117,000 (64%)	178,000 (98%)	178,000 (98%)
Zinc	5,650 (69%)	5,650 (69%)	6,950 (85%)	7,770 (95%)	7,940 (97%)
Nitrogen, total	N/A	N/A	N/A	N/A	N/A
Phosphorus, total	N/A	N/A	N/A	N/A	N/A
Chlorides	101 (<1%)	101 (<1%)	364 (2%)	531 (2%)	531 (2%)
TDS	N/A	N/A	N/A	N/A	N/A

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); TWPE (Toxic Weighted Pound Equivalents).

Note: Pollutant removals are rounded to three significant figures.

N/A – The TWPE/year is not provided for total nitrogen, total phosphorus, and TDS because EPA has not established a toxic weighting factor (TWF) for these pollutants.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.2 KEY ENVIRONMENTAL IMPROVEMENTS

As part of this EA, EPA conducted modeling of the expected environmental improvements under Options A through E. EPA estimates the environmental improvements under Option F, which were not modeled, to be incrementally greater than those under Option E based on the pollutant reductions calculated.

Table 7-5 summarizes the key environmental improvements within the immediate receiving waters due to the pollutant removals under the final rule (Option D) and other evaluated regulatory options. The numbers of immediate receiving waters with water quality, wildlife, and human health exceedances would:

- Decrease under Options A and B by no more than 33 percent, with most exceedances being reduced by less than 15 percent.
- Decrease under Option C by 17 to 56 percent, with most exceedances being reduced by less than 40 percent.
- Decrease under Option D by 45 to 83 percent, with most exceedances being reduced by at least 56 percent.
- Decrease under Option E by 51 to 84 percent, with most exceedances being reduced by at least 61 percent.

The final rule (Option D) will substantially improve water quality, wildlife, and human health. Under the final rule, EPA estimates that:

- Receiving water exceedances of the NRWQC will decrease by 45 to 67 percent.
- Receiving water exceedances of the MCL benchmarks will decrease by 83 percent.
- The number of receiving waters with fish tissue concentrations exceeding the no effect hazard concentration (NEHC) for selenium for eagles and minks will decrease by 63 and 62 percent, respectively.
- Human exposures via fish consumption to pollutants with the potential to cause non-cancer health effects will decrease by up to 56 percent.
- Human exposures to pollutants that present a cancer risk will decrease by up to 75 percent.

Results for the final rule are discussed in further detail in the sections following Table 7-5.

7.2.1 Improvements in Water Quality Under the Final Rule

EPA estimates that pollutant removals to surface waters associated with the final rule will significantly improve water quality by reducing exceedances of the NRWQC and MCLs by up to 83 percent. The largest reductions in NRWQC exceedances are attributed to reduced loadings of cadmium, selenium, arsenic, and thallium. Due to the substantial pollutant removals, EPA projects that aquatic organisms will be less susceptible to chronic impacts such as:

- Skeletal malformations;
- Organ damage;
- Developmental abnormalities;
- Behavioral impairments;
- Reproductive failure;
- Metabolic failure;
- Neurological effects;
- Gastrointestinal effects; and
- Fish kills.[48]

EPA estimates that up to 45 percent of the 209 evaluated immediate receiving waters currently exceed NRWQC for the protection of human health, primarily due to arsenic and thallium. EPA estimates that these arsenic and thallium removals will lower the number of immediate receiving waters that exceed NRWQC designed to protect public health by 45 to 50 percent. By reducing MCL exceedances by 83 percent, the final rule will improve the quality of source water available to drinking water treatment plants downstream from steam electric power plants.

In addition to reducing NRWQC and MCL exceedances, the final rule will quantifiably improve overall water quality – in the immediate receiving waters and downstream from steam electric power plants. EPA calculates that, on average, receiving water concentrations of the 10 toxic, bioaccumulative pollutants evaluated in the EA will decrease by 57 percent.

---

[48] Impacts documented in ATSDR, 2008a; Coughlan and Velte, 1989; Lemly, 1985b; Nagle *et al*., 2001; NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2009a; and U.S. EPA, 2011f.

Table 7-5. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	9	4%	6 (33%)	6 (33%)	6 (33%)	3 (67%)	2 (78%)
Freshwater Chronic NRWQC	35	17%	34 (3%)	27 (23%)	21 (40%)	17 (51%)	17 (51%)
Human Health Water and Organism NRWQC	94	45%	90 (4%)	90 (4%)	69 (27%)	52 (45%)	43 (54%)
Human Health Organism Only NRWQC	66	32%	62 (6%)	62 (6%)	46 (30%)	33 (50%)	26 (61%)
Drinking Water MCL	36	17%	34 (6%)	33 (8%)	16 (56%)	6 (83%)	6 (83%)
Wildlife Results							
Fish Ingestion NEHC for Minks	58	28%	57 (2%)	51 (12%)	32 (45%)	22 (62%)	21 (64%)
Fish Ingestion NEHC for Eagles	71	34%	65 (8%)	61 (14%)	44 (38%)	26 (63%)	23 (68%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	100	48	92 (8%)	90 (10%)	68 (32%)	47 (53%)	38 (62%)
Non-Cancer Reference Dose for Adult (recreational)	86	41%	77 (10%)	74 (14%)	56 (35%)	38 (56%)	28 (67%)
Non-Cancer Reference Dose for Child (subsistence)	118	56%	107 (9%)	104 (12%)	79 (33%)	52 (56%)	46 (61%)
Non-Cancer Reference Dose for Adult (subsistence)	103	49%	94 (9%)	93 (10%)	71 (31%)	49 (52%)	39 (62%)

Table 7-5. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	**Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions** [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Arsenic Cancer Risk for Adult (recreational)	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Arsenic Cancer Risk for Child (subsistence)	8	4%	7 (13%)	7 (13%)	6 (25%)	3 (63%)	2 (75%)
Arsenic Cancer Risk for Adult (subsistence)	25	12%	23 (8%)	23 (8%)	15 (40%)	11 (56%)	4 (84%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.2.2 Reduced Threat to Wildlife Under the Final Rule

In the EA, EPA evaluated multiple threats to wildlife, including impacts to wildlife indicator species by consuming contaminated fish; impacts to fish and waterfowl due to dietary exposure to selenium; and exposure of benthic aquatic organisms to contaminated sediments. The combination of lethal and sublethal effects (*e.g.*, changes to morphology, behavior, and metabolism) of exposure to steam electric power plant wastewater can cause cascading effects through the food web.

As discussed in Section 7.2.1, the number of immediate receiving waters that can potentially pose an acute or chronic threat to wildlife will decrease under the final rule, improving wildlife populations and communities surrounding steam electric power plants (*e.g.*, reduced impacts to population density and species diversity as discussed in Section 3). EPA estimates that average fish tissue concentrations of the pollutants evaluated in the EA will decrease by an average of 57 percent. EPA projects that these lower pollutant concentrations will significantly improve the health of fish populations and the quality of fish available for consumption by both humans and wildlife near steam electric power plants.

Based on the threats to minks and eagles from consuming fish contaminated by steam electric power plant wastewater, pollutants can bioaccumulate and impact higher order species in the food chain. Under the final rule, EPA estimates that exceedances of the NEHC for eagles and minks will decrease by approximately 70 percent. See Section 7.3.3 for discussion of the reduced risk of adverse reproductive effects among aquatic wildlife (fish and mallards) resulting from dietary exposure to selenium.

EPA estimates that pollutant removals to surface waters associated with the final rule will decrease the exposure of aquatic organisms to pollutants in the sediment, as shown in Table 7-6. As discussed in Section 6.2.3, benthic organisms are at risk primarily due to exposure to mercury, nickel, and cadmium. Under the final rule, the number of immediate receiving waters with pollutant concentration in the sediment above chemical stressor concentration limits (CSCL) will decrease by over 60 percent.

Table 7-6. Number of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding CSCLs for Sediment Biota Under the Regulatory Options

Pollutant	**Modeled Immediate Receiving Waters Exceeding CSCLs Under Baseline Conditions** [a]	**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	7 (3%)	6 (14%)	6 (14%)	6 (14%)	3 (57%)	2 (71%)
Cadmium	27 (13%)	21 (22%)	21 (22%)	14 (48%)	10 (63%)	8 (70%)
Chromium VI [c]	0 (0%)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Copper	7 (3%)	5 (29%)	5 (29%)	5 (29%)	2 (71%)	2 (71%)
Lead	6 (3%)	4 (33%)	4 (33%)	4 (33%)	1 (83%)	1 (83%)
Mercury	49 (23%)	45 (8%)	44 (10%)	26 (47%)	19 (61%)	7 (86%)
Nickel	34 (16%)	28 (18%)	28 (18%)	16 (53%)	11 (68%)	4 (88%)
Selenium	NC	NC	NC	NC	NC	NC
Thallium	NC	NC	NC	NC	NC	NC
Zinc	15 (7%)	9 (40%)	9 (40%)	9 (40%)	6 (60%)	2 (87%)
Total	**49 (23%)**	**45 (8%)**	**44 (10%)**	**27 (45%)**	**20 (59%)**	**8 (84%)**

Source: ERG, 2015d;ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NC (Not calculated; no benchmark for comparison).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – EPA used the total chromium benchmark for this analysis.

7.2.3 Reduced Human Health Cancer Risk Under the Final Rule

Under baseline conditions, EPA estimates that 25 immediate receiving waters (12 percent) could contain fish contaminated with inorganic arsenic that present cancer risks above the 1-in-a-million threshold for the most sensitive, national-scale cohort. EPA calculates that the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by at least 56 percent for all national-scale cohorts under the final rule.

7.2.4 Reduced Threat of Non-Cancer Human Health Effects Under the Final Rule

Chronic exposure to toxic, bioaccumulative pollutants in steam electric power plant wastewater can potentially compromise neurological and developmental functions and affect the circulatory, respiratory, and digestive systems of exposed populations. EPA estimates that the number of immediate receiving waters whose fish pose non-cancer health risks will decrease by at least 52 percent for all national-scale cohorts under the final rule. As discussed in Section 7.2.2, EPA found that the pollutant concentrations in fish tissue will decrease, improving the quality of fish available to recreational and subsistence fishers and subsequently lowering exposures to toxic, bioaccumulative pollutants and the potential for humans to develop non-cancer health effects (*e.g.*, nausea, abdominal pain, sleep disorders, muscular problems, and cardiovascular disease).

The pollutants that cause the potential for non-cancer health effects are selenium, cadmium, mercury (as methylmercury), and, to a lesser degree, thallium. EPA calculates that the final rule will decrease the number of immediate receiving waters with fish that, if consumed, would exceed the reference doses for these pollutants, by the following amounts:

- Selenium: decrease by at least 51 percent for all national-scale cohorts.
- Cadmium: decrease by at least 53 percent for all national-scale cohorts.
- Methylmercury: decrease by at least 52 percent for all national-scale cohorts.
- Thallium: decrease by at least 62 percent for all national-scale cohorts.

Although the EA did not directly assess the potential non-cancer health effects posed by lead,[49] the final rule will lower the total annual loadings of lead to the environment by 19,000 pounds (98 percent), thus reducing the potential threat of hypertension, coronary heart disease, and impaired cognitive function in exposed populations. For children in particular, lead exposure can cause additional negative impacts, such as hyperactivity, behavioral and attention difficulties, delayed mental development, and motor and perceptual skill deficits. The benefits to adults and children from the reduced lead discharges are discussed in the Benefits and Cost Analysis.

7.2.5 Reduced Human Health Risk for Environmental Justice Analysis

As discussed in Section 6.3.2, EPA evaluated the impacts that steam electric power plant discharges have on environmental justice (EJ) cohorts in addition to the national-scale cohorts. Under baseline conditions, EPA estimates that 32 immediate receiving waters (15 percent) could

---

[49] Currently, there is no reference dose for lead—there is no safe level for ingestion of lead (see EPA's Integrated Risk Information System (IRIS) website: http://www.epa.gov/IRIS/).

contain fish contaminated with inorganic arsenic that present cancer risks above the 1-in-a-million threshold for the most sensitive minority cohort. EPA estimates that the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by at least 46 percent for the average recreational fisher minority cohort and at least 51 percent for the average subsistence fisher minority cohort under the final rule.[50] These improvements are similar to those for non-minority recreational and subsistence fisher cohorts (at least 33 and 50 percent, respectively) under the final rule.

EPA estimates that the number of immediate receiving waters whose fish pose non-cancer health risks will decrease by 56 percent for all recreational fisher minority cohorts and 53 percent for all subsistence fisher minority cohorts under the final rule. These improvements are similar to those for non-minority recreational and subsistence fisher cohorts (56 and 52 percent, respectively) under the final rule. The pollutants that cause the potential for non-cancer health effects are selenium, cadmium, mercury (as methylmercury), and, to a lesser degree, thallium.

7.3 POLLUTANT-SPECIFIC IMPROVEMENTS

EPA identified several key pollutants (*i.e.*, arsenic, mercury, selenium, cadmium, and thallium) whose pollutant removals would primarily be responsible for the improvements in water quality, wildlife, and human health attributed to the final rule. This section highlights the environmental improvements associated with these five pollutants.

7.3.1 Arsenic

Under the final rule, EPA estimates 27,900 pounds per year of arsenic removals from steam electric power plant discharges – a 94 percent reduction in annual loadings. The final rule will decrease the number of immediate receiving waters exceeding human health NRWQC for arsenic by up to 49 percent. The arsenic removals will reduce negative effects on aquatic organisms, such as liver tissue death, developmental abnormalities, behavioral impairments, metabolic failure, growth reduction, and appetite loss [NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2011f]. As a result, the final rule will decrease human exposure to arsenic through fish consumption and thus lower the potential for exposed populations to develop arsenic-related cancer and non-cancer health effects such as dermal, cardiovascular, and respiratory effects. The final rule will decrease the number of immediate receiving waters exceeding the human health cancer risk threshold for arsenic by up to 75 percent, depending on the evaluated cohort. Table 7-7 presents the key environmental improvements resulting from arsenic removals under the regulatory options evaluated in the EA.

EPA did not see a reduction in the number of immediate receiving waters exceeding the arsenic NEHCs for minks or eagles because there are no exceedances modeled at baseline. The final rule, however, will still reduce the bioaccumulation of arsenic in the food web.

---

[50] These values represent the average percentage improvements across the four race populations that comprise the minority cohorts.

Table 7-7. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Freshwater Chronic NRWQC	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	1 (75%)
Human Health Water and Organism NRWQC	94	45%	90 (4%)	90 (4%)	69 (27%)	52 (45%)	43 (54%)
Human Health Organism Only NRWQC	65	31%	61 (6%)	61 (6%)	45 (31%)	33 (49%)	26 (60%)
Drinking Water MCL	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Wildlife Results							
Fish Ingestion NEHC for Minks	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Fish Ingestion NEHC for Eagles	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	2	1%	1 (50%)	1 (50%)	1 (50%)	1 (50%)	0 (100%)
Non-Cancer Reference Dose for Adult (recreational)	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Non-Cancer Reference Dose for Child (subsistence)	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Non-Cancer Reference Dose for Adult (subsistence)	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)

Table 7-7. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Arsenic Cancer Risk for Adult (recreational)	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Arsenic Cancer Risk for Child (subsistence)	8	4%	7 (13%)	7 (13%)	6 (25%)	3 (63%)	2 (75%)
Arsenic Cancer Risk for Adult (subsistence)	25	12%	23 (8%)	23 (8%)	15 (40%)	11 (56%)	4 (84%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.3.2 Mercury

Under the final rule, EPA estimates 1,450 pounds per year of mercury removals from steam electric power plant discharges – a 97 percent reduction in annual loadings. As discussed in Section 6.2, estimated fish tissue concentrations for mercury (and selenium) exceed levels that can affect reproduction in exposed mink and eagle populations. EPA estimates that the final rule will decrease the number of immediate receiving waters with fish tissue concentrations that exceed the mercury NEHC for eagles and minks by 62 and 64 percent, respectively. These reductions also represent the potential improvement in exposure to mercury above effects thresholds in other wildlife that consume fish from these receiving waters.

Under baseline pollutant loadings, EPA estimates that fish methylmercury concentrations pose a non-cancer threat to subsistence fishers and recreational fishers in up to 52 and 46 percent, respectively, of immediate receiving waters. EPA calculates that fish tissue concentrations of methylmercury will decrease under the final rule and, as a result, the number of immediate receiving waters with exposure doses from fish consumption that exceed the methylmercury reference dose will decrease by up to 57 percent. Because there are over 80 addressed by this final rule discharge to receiving waters that are under a fish advisory for mercury (see Section 3.4.4), the final rule will reduce mercury loadings to those receiving waters (see Section 7.4). Table 7-8 presents the key environmental improvements resulting from mercury removals under the regulatory options.

Table 7-8. Key Environmental Improvements for Mercury Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	1	0%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Freshwater Chronic NRWQC	1	0%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	5	2%	4 (20%)	4 (20%)	4 (20%)	2 (60%)	1 (80%)
Wildlife Results							
Fish Ingestion NEHC for Minks	55	26%	50 (9%)	49 (11%)	30 (45%)	20 (64%)	8 (85%)
Fish Ingestion NEHC for Eagles	71	34%	61 (14%)	61 (14%)	44 (38%)	27 (62%)	18 (75%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	96	46%	87 (9%)	84 (13%)	63 (34%)	44 (54%)	35 (64%)
Non-Cancer Reference Dose for Adult (recreational)	82	39%	71 (13%)	69 (16%)	52 (37%)	35 (57%)	24 (71%)
Non-Cancer Reference Dose for Child (subsistence)	109	52%	97 (11%)	96 (12%)	75 (31%)	52 (52%)	46 (58%)
Non-Cancer Reference Dose for Adult (subsistence)	99	47%	89 (10%)	87 (12%)	66 (33%)	46 (54%)	36 (64%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.3.3 Selenium

Under the final rule, EPA estimates 136,000 pounds per year of selenium removals from steam electric power plant discharges – a 97 percent reduction in annual loadings. Selenium is one of the primary pollutants identified in the literature and by EPA as causing documented environmental impacts to fish and wildlife from steam electric power plant discharges. EPA estimates that immediate receiving water concentrations of total selenium will decrease under the final rule by 71 percent on average, decreasing the amount of selenium that would bioaccumulate or persist in the aquatic environment. Under the final rule, the number of immediate receiving waters exceeding chronic aquatic life NRWQC will decrease by 55 percent and the number of immediate receiving waters exceeding a drinking water MCL for selenium will decrease by 75 percent.

Reducing selenium loadings and subsequent bioaccumulation will decrease by 52 percent the number of immediate receiving waters with fish tissue concentrations exceeding the NEHC for selenium for both eagles and minks. These reductions also represent the potential health improvements in other wildlife that consume fish from these receiving waters, as well as the potential decrease in bioaccumulation of toxic pollutants in the broader food web near steam electric power plants.

Selenium is known to cause fish deformities at high levels, such as these from Belews Lake, NC.

The results of the ecological risk model further support these predicted reductions in the bioaccumulative impact of selenium throughout the food web. Under the final rule, the ecological risk modeling results indicate that:

- The risk of negative reproductive impacts among fish and/or mallards will be reduced to less than one percent in each of the 26 modeled lentic immediate receiving waters.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 10 percent of the exposed population will be reduced by 67 percent (for fish) and 61 percent (for mallards).
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 50 percent of the exposed population will be reduced by 70 percent (for fish) and 74 percent (for mallards).

These results are based on the median modeled egg/ovary selenium concentration in exposed fish and mallards. Use of the 90th percentile modeled egg/ovary concentration, which results in a higher predicted risk of reproductive impacts, shows similar improvements under the final rule:

- The risk of negative reproductive impacts among fish will be reduced to less than one percent in all but one of the 26 modeled lentic immediate receiving waters.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 10 percent of the exposed population will be reduced by 55 percent (for fish) and 52 percent (for mallards). Under the final rule, none of the lentic immediate receiving waters will pose this reproductive risk to fish or mallards.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 50 percent of the exposed population will be reduced by 53 percent (for fish) and 59 percent (for mallards).

Under the final rule, EPA estimates that fish selenium concentrations that pose a non-cancer threat to subsistence fishers and recreational fishers will decrease in up to 53 and 56 percent of immediate receiving waters, respectively. This reduces the risk of developing non-cancer health effects associated with selenium, such as pulmonary edema and lesions of the lung; cardiovascular effects such as tachycardia; gastrointestinal effects including nausea, vomiting, diarrhea, and abdominal pain; effects on the liver; and neurological effects such as aches, irritability, chills, and tremors [U.S. EPA, 2000b]. Table 7-9 presents the key environmental improvements resulting from selenium removals under the regulatory options.

Table 7-9. Key Environmental Improvements for Selenium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC [d]	33	16%	30 (9%)	20 (39%)	18 (45%)	15 (55%)	15 (55%)
Human Health Water and Organism NRWQC	8	4%	7 (13%)	3 (63%)	3 (63%)	2 (75%)	2 (75%)
Human Health Organism Only NRWQC	1	0%	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Drinking Water MCL	12	6%	10 (17%)	5 (58%)	5 (58%)	3 (75%)	3 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	42	20%	40 (5%)	29 (31%)	23 (45%)	20 (52%)	20 (52%)
Fish Ingestion NEHC for Eagles	42	20%	40 (5%)	29 (31%)	23 (45%)	20 (52%)	20 (52%)
Negative Reproductive Effects in Fish [c]	24	11%	19 (21%)	10 (58%)	10 (58%)	8 (67%)	8 (67%)
Negative Reproductive Effects in Mallards [c]	31	15%	26 (16%)	16 (48%)	14 (55%)	12 (61%)	12 (61%)

Table 7-9. Key Environmental Improvements for Selenium Under the Regulatory Options

Evaluation Benchmark	**Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions** [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	41	20%	39 (5%)	29 (29%)	23 (44%)	20 (51%)	20 (51%)
Non-Cancer Reference Dose for Adult (recreational)	32	15%	29 (9%)	18 (44%)	17 (47%)	14 (56%)	14 (56%)
Non-Cancer Reference Dose for Child (subsistence)	55	26%	51 (7%)	39 (29%)	33 (40%)	27 (51%)	27 (51%)
Non-Cancer Reference Dose for Adult (subsistence)	43	21%	40 (7%)	30 (30%)	23 (47%)	20 (53%)	20 (53%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.

d – The EA analyses use the EPA recommended water quality criteria for selenium in the water column of 5 µg/L -- in effect at the time of the modeling done, both for the proposed rule in 2012, and the final rule in 2015. EPA used this criterion in its modeling for the final rule to allow for consistent comparisons between the modeling done for the proposed rule and that done for the final rule. All modeling was done prior to EPA publishing new final draft criteria for selenium on July 27, 2015. The new final draft criteria, which EPA now recommends, of 3.1 µg/L in freshwater flowing systems (rivers, streams) and 1.2 µg/L in lakes and reservoirs, are lower than the criteria EPA used in these analyses. Had EPA conducted the modeling with these new recommended criteria, it would have resulted in slightly greater estimated impacts (more exceedances of the new selenium criteria) than that revealed using the old criteria. As a result, this would have led to slightly greater potential improvements due to control of selenium discharges under the final rule. Therefore, the estimates of the modeled selenium impacts, and potential improvements of the final ELG, are conservative and tend, if anything, to underestimate both the impacts and the benefits.

7.3.4 Cadmium

Under the final rule, EPA estimates 9,020 pounds per year of cadmium removals from steam electric power plant discharges – a 68 percent reduction in annual loadings. At baseline conditions, discharges of cadmium are the second largest toxic-weighted pollutant discharges from the steam electric power generating industry among those pollutants evaluated in the EA (see Section 3.2). The final rule will decrease the number of immediate receiving waters that exceed acute and chronic NRWQC by up to 67 and 59 percent, respectively. The number of immediate receiving waters with fish tissue concentrations that exceed NEHCs for minks and eagles will decrease by 67 and 50 percent, respectively. Under the final rule, the number of immediate receiving waters with fish containing cadmium concentrations that pose a risk of non-cancer health effects will decrease by 53 to 70 percent, depending on the cohort. Table 7-10 presents the key environmental improvements resulting from cadmium removals under the regulatory options.

7.3.5 Thallium

Under the final rule, EPA estimates 62,300 pounds per year of thallium removals from steam electric power plant discharges – a 98 percent reduction in annual loadings. EPA estimates that the final rule will decrease the number of immediate receiving waters exceeding human health NRWQC and MCLs for thallium by up to 85 percent. Under the final rule, the number of immediate receiving waters with fish containing thallium concentrations that can potentially cause non-cancer health effects in humans (*e.g.*, neurological symptoms, alopecia, gastrointestinal effects, and reproductive and developmental damage) will decrease by up to 69 percent, depending on the cohort. Table 7-11 presents the key environmental improvements resulting from thallium removals under the regulatory options.

Table 7-10. Key Environmental Improvements for Cadmium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	9	4%	6 (33%)	6 (33%)	6 (33%)	3 (67%)	2 (78%)
Freshwater Chronic NRWQC	29	14%	23 (21%)	23 (21%)	16 (45%)	12 (59%)	9 (69%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	11	5%	7 (36%)	7 (36%)	6 (45%)	3 (73%)	2 (82%)
Wildlife Results							
Fish Ingestion NEHC for Minks	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Fish Ingestion NEHC for Eagles	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	16	8%	12 (25%)	12 (25%)	9 (44%)	5 (69%)	3 (81%)
Non-Cancer Reference Dose for Adult (recreational)	10	5%	7 (30%)	7 (30%)	6 (40%)	3 (70%)	2 (80%)
Non-Cancer Reference Dose for Child (subsistence)	32	15%	26 (19%)	26 (19%)	19 (41%)	15 (53%)	10 (69%)
Non-Cancer Reference Dose for Adult (subsistence)	22	11%	17 (23%)	17 (23%)	11 (50%)	7 (68%)	4 (82%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table 7-11. Key Environmental Improvements for Thallium Under the Regulatory Options

Evaluation Benchmark	**Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions** [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Water and Organism NRWQC	49	23%	46 (6%)	46 (6%)	27 (45%)	13 (73%)	13 (73%)
Human Health Organism Only NRWQC	45	22%	42 (7%)	42 (7%)	23 (49%)	8 (82%)	8 (82%)
Drinking Water MCL	34	16%	32 (6%)	32 (6%)	15 (56%)	5 (85%)	5 (85%)
Wildlife Results							
Fish Ingestion NEHC for Minks	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Fish Ingestion NEHC for Eagles	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	74	35%	73 (1%)	73 (1%)	46 (38%)	27 (64%)	27 (64%)
Non-Cancer Reference Dose for Adult (recreational)	54	26%	51 (6%)	51 (6%)	31 (43%)	17 (69%)	17 (69%)
Non-Cancer Reference Dose for Child (subsistence)	94	45%	90 (4%)	90 (4%)	63 (33%)	35 (63%)	35 (63%)
Non-Cancer Reference Dose for Adult (subsistence)	77	37%	76 (1%)	76 (1%)	49 (36%)	29 (62%)	29 (62%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.4 IMPROVEMENTS TO SENSITIVE ENVIRONMENTS

As discussed in Section 3.4, EPA evaluated pollutant discharges to sensitive environments (*i.e.*, impaired waters, threatened and endangered species, and fish consumption advisory waters) and sensitive watersheds (the Great Lakes and Chesapeake Bay). The purpose was to assess if steam electric power plants discharge to receiving waters with existing impairments or fish advisories and assess if discharges of the evaluated wastestreams increase stress on threatened and endangered species. This section presents EPA's estimated pollutant removals under five regulatory options to the evaluated sensitive environments.

The final rule will decrease pollutant loadings to sensitive environments, which will help impaired waters to recover; decrease the bioaccumulation of toxic pollutants in fish, thereby reducing the number of fish advisories; and reduce stress on threatened and endangered species and sensitive watersheds such as Chesapeake Bay and the Great Lakes (see Section 7.5).

7.4.1 Impaired Waters

EPA determined that 59 of the immediate receiving waters are 303(d)-listed waterbodies, designated as impaired for one or more pollutants found in the evaluated wastestreams.[51] Mercury (30 immediate receiving waters), nutrients (19 immediate receiving waters), and phosphorus (11 immediate receiving waters) are the most frequently identified impairment categories among the surface waters that directly receive the evaluated wastestreams. Table 7-12 presents the pollutant removals to impaired waters (by impairment category) as a result of the regulatory options.

Under the final rule, EPA estimates the following pollutant removals:

- Mercury removals of 168 pounds per year to mercury-impaired waters (decrease of 99 percent).
- Phosphorus removals of 4,100 pounds per year to nutrient-impaired waters (decrease of 78 percent).
- Nitrogen removals of 471,000 pounds per year to nutrient-impaired waters (decrease of 96 percent).
- Pollutant removals to receiving waters impaired for a metal (except mercury) include 4,100 pounds per year of arsenic (decrease of 95 percent); 1,770 pounds per year of cadmium (decrease of 93 percent); 2,630 pounds per year of lead (decrease of 97 percent); 21,500 pounds per year of selenium (decrease of 97 percent); and 7,130 pounds per year of thallium (decrease of 97 percent).[52]

---

[51] The count of impaired waters excludes the general impairment category "metals (not mercury)" and includes receiving waters impaired for arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, selenium, zinc, phosphorous, nutrients, TDS, or chlorides.

[52] EPA presents pollutant loadings and removals for metals, other than mercury, for immediate receiving waters designated as impaired for the general impairment category "metals (not mercury)" to protect confidential business information. See all results in Table 7-12.

Table 7-12. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Mercury-Impaired Receiving Waters							
30	Mercury	170	89.7 (53%)	90.2 (53%)	139 (81%)	168 (99%)	169 (99%)
Metals (Not Mercury)-Impaired Receiving Waters							
28	Arsenic	4,320	2,800 (65%)	2,800 (65%)	3,690 (85%)	4,110 (95%)	4,160 (96%)
	Boron	4,900,000	316,000 (6%)	316,000 (6%)	349,000 (7%)	361,000 (7%)	361,000 (7%)
	Cadmium	1,900	1,380 (73%)	1,380 (73%)	1,650 (87%)	1,770 (93%)	1,780 (94%)
	Chromium VI	27.2	23.4 (86%)	23.4 (86%)	26.9 (99%)	27.2 (>99%)	27.2 (>99%)
	Copper	4,420	2,490 (56%)	2,490 (56%)	3,790 (86%)	4,320 (98%)	4,320 (98%)
	Lead	2,700	1,360 (50%)	1,360 (50%)	2,240 (83%)	2,630 (97%)	2,630 (97%)
	Manganese	1,080,000	718,000 (66%)	718,000 (66%)	780,000 (72%)	810,000 (75%)	810,000 (75%)
	Nickel	15,600	9,270 (59%)	9,320 (60%)	13,300 (85%)	15,200 (97%)	15,300 (98%)
	Selenium	22,100	3,320 (15%)	20,900 (94%)	21,300 (96%)	21,500 (97%)	21,500 (97%)
	Thallium	7,330	1,260 (17%)	1,260 (17%)	5,220 (71%)	7,130 (97%)	7,130 (97%)
	Zinc	24,700	18,600 (75%)	18,600 (75%)	21,900 (89%)	23,500 (95%)	23,800 (96%)

Table 7-12. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Nutrient-Impaired Receiving Waters							
19	Total Nitrogen	492,000	7,250 (1%)	341,000 (69%)	395,000 (80%)	471,000 (96%)	471,000 (96%)
	Total Phosphorous	5,280	406 (8%)	406 (8%)	1,930 (37%)	4,090 (78%)	4,090 (78%)
TDS and Chlorides-Impaired Receiving Waters							
4	Chlorides	CBI	CBI	CBI	CBI	CBI	CBI
	TDS	CBI	CBI	CBI	CBI	CBI	CBI

Source: ERG, 2015c.

Acronyms: CBI (Confidential business information); lbs/yr (pounds per year).

Note: Loadings and pollutant reductions are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – For the impaired waters proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams.

c – The EPA impaired water database listed 28 immediate receiving waters as impaired based on the “metal, other than mercury” impairment category. Of those 28 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals (arsenic, cadmium, chromium, copper, lead, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

d – Total phosphorous and total nitrogen loadings are presented with this impairment category. Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

7.4.2 Threatened and Endangered Species

As discussed in Section 3.4.5, EPA identified 138 threatened and endangered species whose habitats overlap with, or are located within, surface waters that exceeded NRWQC for the protection of aquatic life under baseline conditions.[53] To assess the potential improvements to threatened and endangered species under the final rule, EPA initially selected only those species identified as highly vulnerable to changes in water quality (75 of the 138 species) for evaluation. EPA further excluded species from the analysis based on the following criteria: the species is already presumed extinct, species habitat is unlikely to be affected by discharges of the evaluated wastestreams (*e.g.*, isolated headwaters), species listing status is due to habitat destruction unrelated to steam electric power plant discharges (*e.g.*, damming, stream channelization), and other criteria. Based on the analysis, EPA identified 15 species out of the 75 that are highly vulnerable to changes in water quality and whose recovery may be enhanced by the final rule. Four of these 15 species inhabit waters that will no longer exceed NRWQC for the protection of aquatic life following implementation of the final rule. The species may therefore experience increases in population growth rates as a result of the final rule. See the Benefits and Cost Analysis for further details on the methodology and results of EPA's threatened and endangered species analysis.

7.4.3 Fish Advisory Waters

States, territories, and authorized tribes issue fish advisories to notify the public (including recreational and subsistence fishers) of waterbodies containing fish with elevated and potentially unhealthy contamination levels. Mercury is the most common pollutant found in steam electric power plant wastewater for which fish advisories are issued to the surface waters that receive the evaluated wastestreams (see Section 3.4.4). EPA determined that 88 of the 222 immediate receiving waters included in the EA are under a fish advisory for mercury. Under the final rule, the number of immediate receiving waters with fish that exceed EPA's mercury screening value for recreational fishers (based on steam electric power plant discharges only) will decrease by 63 percent, thereby reducing the potential threat to human health from consuming contaminated fish.

7.5 IMPROVEMENTS TO WATERSHEDS

As discussed in Section 3.4, both the Great Lakes and Chesapeake Bay watersheds have a history of receiving pollutant discharges that negatively affect water quality, wildlife, and human health. Both are well-studied, sensitive environments that are affected by pollutants commonly found in steam electric power plant wastewater. Mercury is one of the primary pollutants of concern in the Great Lakes,[54] and nutrients are the primary pollutants of focus in the Chesapeake Bay.

EPA identified 23 steam electric power plants that discharge into the Great Lakes watershed. Table 7-13 presents the pollutant reductions to the Great Lakes watershed under the

---

[53] The habitat locations evaluated for this analysis include waters downstream from steam electric power plant discharges and reflect changes in the industry as a result of the Clean Power Plan [Clean Air Act Section 111(d)].

[54] One of the main environmental pathways for mercury in the Great Lakes is from atmospheric deposition, which is not in the scope of the final rule.

regulatory options considered by EPA. Under the final rule, EPA estimates the following pollutant removals to the Great Lakes watershed:

- 2,070 pounds of arsenic annually (96 percent reduction).
- 612 pounds of cadmium annually (95 percent reduction).
- 1,880 pounds of lead annually (99 percent reduction).
- 80.6 pounds of mercury annually (97 percent reduction).
- 4,800 pounds of selenium annually (96 percent reduction).
- 9,510 pounds of thallium annually (99 percent reduction).
- 1.15 million pounds of total nitrogen annually (>99 percent reduction).
- 21,800 pounds of total phosphorus annually (94 percent reduction).

EPA identified nine steam electric power plants that discharge to the Chesapeake Bay watershed. Under the final rule, EPA estimates the following pollutant removals to the Chesapeake Bay watershed:

- 2,430 pounds of arsenic annually (97 percent reduction).
- 476 pounds of cadmium annually (93 percent reduction).
- 1,540 pounds of lead annually (99 percent reduction).
- 87.1 pounds of mercury annually (98 percent reduction).
- 6,380 pounds of selenium annually (97 percent reduction).
- 5,220 pounds of thallium annually (99 percent reduction).
- 990,000 pounds of total nitrogen annually (>99 percent reduction).
- 14,900 pounds of total phosphorus annually (89 percent reduction).

Table 7-13. Pollutant Removals to the Great Lakes Watershed Under the Regulatory Options

Pollutant	Baseline Loadings to the Great Lakes Watershed (lbs/yr)	Pollutant Removals (lbs/yr) to Great Lakes Watershed Under the Regulatory Options (Percent Reduction) [a]				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	2,170	47.5 (2%)	47.5 (2%)	513 (24%)	2,070 (96%)	2,130 (98%)
Boron	997,000	9,190 (1%)	9,190 (1%)	22,600 (2%)	66,800 (7%)	66,800 (7%)
Cadmium	648	53.6 (8%)	53.6 (8%)	183 (28%)	612 (95%)	623 (96%)
Chromium VI	0.548	0.471 (86%)	0.471 (86%)	0.548 (>99%)	0.548 (>99%)	0.548 (>99%)
Copper	2,550	34.5 (1%)	34.5 (1%)	608 (24%)	2,510 (99%)	2,520 (99%)
Lead	1,900	19.4 (1%)	19.4 (1%)	449 (24%)	1,880 (99%)	1,880 (99%)
Manganese	242,000	35,500 (15%)	35,500 (15%)	70,500 (29%)	188,000 (77%)	188,000 (77%)
Mercury	82.8	4.56 (6%)	4.91 (6%)	22.6 (27%)	80.6 (97%)	82.2 (99%)
Nickel	9,840	402 (4%)	413 (4%)	2,550 (26%)	9,720 (99%)	9,790 (99%)
Selenium	5,020	126 (3%)	3,780 (75%)	4,010 (80%)	4,800 (96%)	4,800 (96%)
Thallium	9,570	23.5 (<1%)	23.5 (<1%)	2,200 (23%)	9,510 (95%)	9,510 (99%)
Zinc	8,730	658 (8%)	658 (8%)	2,410 (28%)	8,270 (95%)	8,600 (99%)
Nitrogen, total [b]	1,150,000	2,420 (<1%)	380,000 (33%)	556,000 (48%)	1,150,000 (>99%)	1,150,000 (>99%)
Phosphorus, total	23,100	135 (1%)	135 (1%)	5,110 (22%)	21,800 (94%)	21,800 (94%)
Chlorides	31,900,000	11,400 (<1%)	11,400 (<1%)	698,000 (2%)	3,000,000 (9%)	3,000,000 (9%)
TDS	186,000,000	3,890,000 (2%)	3,890,000 (2%)	22,300,000 (12%)	83,900,000 (45%)	83,900,000 (45%)

Source: ERG, 2015a; ERG, 2015c.

Acronyms: lbs/yr (pounds per year).

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

7.6 ENVIRONMENTAL AND HUMAN HEALTH IMPROVEMENTS IN DOWNSTREAM SURFACE WATER

EPA estimates that the environmental and human health improvements in the immediate receiving waters expected from the final rule will translate into considerable improvements in water quality further downstream from steam electric power plant discharges. EPA calculated downstream receiving water pollutant concentrations using EPA's Risk-Screening Environmental Indicators (RSEI) model[55] and compared these concentrations to the same NRWQC and MCL water quality benchmarks used in the IRW model national-scale analysis. EPA also evaluated the wildlife (mink and eagle NEHC benchmarks) and human health (cancer and non-cancer) improvements in downstream surface waters using a simplified version of the IRW model national-scale analysis. This approach involved calculating the water pollutant concentrations that would result in exceedances if used as inputs to the wildlife and human health modules in the IRW model; EPA then compared the downstream receiving water pollutant concentrations in RSEI to these "threshold" concentrations to identify the downstream reaches that would have at least one exceedance of a particular wildlife or human health benchmark.[56] EPA used this approach to estimate the extent (in river miles) of environmental and human health impacts in downstream surface waters under baseline conditions and the improvements under the modeled regulatory options (Options A, B, C, D, and E). Table 7-14 presents the results of this downstream analysis.

Based on the results of the downstream modeling, thousands of downstream river miles are impacted by steam electric power plant discharges. Pollutant concentrations exceed NRWQC for human health (water and organism) in 4,400 river miles downstream from immediate receiving waters. However, under the final rule, this drops by 2,390 river miles (54 percent). The final rule reduces the number of downstream exceedances for each of the NRWQCs and MCLs evaluated. This reduction improves the water quality and aquatic habitats available to wildlife and human populations located outside of the immediate vicinity of steam electric power plants. In addition, pollutant removals under the final rule also reduce impacts to wildlife that rely on downstream aquatic habitats as a food source. Up to 1,040 miles of surface waters downstream from steam electric power plant discharges will no longer contain fish populations that exceed an NEHC benchmark for minks or eagles. The final rule also decreases potential exposure of humans to pollutants that can cause non-cancer health effects from consumption of contaminated fish in up to 5,470 river miles. These results demonstrate that steam electric power plant discharges are impacting surface waters beyond the immediate receiving waters. Pollutant removals associated with the final rule will substantially improve the environmental and human health for communities beyond the area immediately surrounding steam electric power plants.

---

[55] EPA used pollutant loadings discharged to each receiving reach by steam electric power plants to estimate concentrations in downstream reaches. The RSEI model uses a simple dilution and first-order decay equation to calculate receiving water concentrations (metals are treated as conservative substances). The RSEI model assumes that the plant's annual discharge is released at a constant rate throughout the year. In addition, EPA included pollutant loadings from EPA's Toxics Release Inventory (TRI) database for other industries to represent background pollutant concentrations in the downstream receiving waters. For further details on the RSEI model methodology and assumptions, see the Benefits and Cost Analysis.

[56] See the ERG memorandum "Downstream EA Modeling Methodology and Supporting Documentation" (DCN SE04455) regarding the calculation of these water pollutant concentration thresholds.

Table 7-14. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Water Quality Results						
Freshwater Acute NRWQC	417	396 (5%)	396 (5%)	394 (5%)	390 (7%)	390 (7%)
Freshwater Chronic NRWQC	628	612 (3%)	569 (9%)	547 (13%)	518 (18%)	518 (18%)
Human Health Water and Organism NRWQC	4,400	3,670 (17%)	3,670 (17%)	2,620 (40%)	2,010 (54%)	1,760 (60%)
Human Health Organism-only NRWQC	1,560	1,300 (16%)	1,300 (16%)	1,070 (31%)	782 (50%)	713 (54%)
Drinking Water MCL	759	731 (4%)	726 (4%)	630 (17%)	487 (36%)	487 (36%)
Wildlife Results						
Fish Ingestion NEHC for Minks	1,180	917 (23%)	892 (25%)	723 (39%)	527 (56%)	504 (57%)
Fish Ingestion NEHC for Eagles	2,000	1,730 (13%)	1,720 (14%)	1,390 (30%)	959 (52%)	901 (55%)
Human Health Results—Non-Cancer						
Non-cancer reference dose for child (recreational)	6,350	4,900 (23%)	4,890 (23%)	3,130 (51%)	2,310 (64%)	2,150 (66%)
Non-cancer reference dose for adult (recreational)	3,760	2,960 (21%)	2,950 (21%)	2,050 (46%)	1,470 (61%)	1,380 (63%)
Non-cancer reference dose for child (subsistence)	10,100	8,380 (17%)	8,350 (17%)	6,150 (39%)	4,630 (54%)	4,240 (58%)
Non-cancer reference dose for adult (subsistence)	7,110	5,580 (22%)	5,570 (22%)	3,720 (48%)	2,770 (61%)	2,540 (64%)

Table 7-14. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	**Number of River-Miles Exceeding Criteria Under Baseline Conditions**	**Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]**				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer						
Cancer risk for child (recreational)	231	216 (7%)	216 (7%)	211 (9%)	210 (9%)	207 (10%)
Cancer risk for adult (recreational)	286	263 (8%)	263 (8%)	251 (12%)	246 (14%)	245 (14%)
Cancer risk for child (subsistence)	262	241 (8%)	241 (8%)	239 (9%)	235 (10%)	231 (12%)
Cancer risk for adult (subsistence)	446	383 (14%)	383 (14%)	358 (20%)	328 (27%)	304 (32%)

Source: ERG, 2015i; ERG, 2015l.

Note: River miles are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – EPA evaluated a total of 73,000 river-miles in the downstream receiving water analysis for toxic, bioaccumulative pollutants. Downstream receiving water concentrations are calculated until one of three conditions occurs: 1) the discharge travels 300 kilometers (km) downstream; 2) the discharge travels downstream for a week; or 3) the concentration reaches 1 x 10^{-9} milligrams per liter (mg/L).

7.7 ATTRACTIVE NUISANCES

EPA projects that the final rule will also decrease the environmental impact to wildlife exposed to pollutants through direct contact with surface impoundments and constructed wetlands at steam electric power plants. Multiple studies show that wildlife living near steam electric surface impoundments exhibit elevated levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium [Burger *et al*., 2002; Bryan *et al*., 2003; Hopkins *et al*., 1997, 1998, 2000, 2002, 2006; Nagle *et al*., 2001; Rattner *et al*., 2006]. Multiple studies have linked attractive nuisance areas at steam electric power plants to diminished reproduction [Hopkins *et al*., 2002, 2006; Nagle *et al*., 2001]. While the final rule does not control pollutants within surface impoundments or constructed wetlands prior to their discharge to surface waters, EPA estimates that the final rule will decrease pollutant loadings to these waterbodies (*e.g.*, through plants converting to dry handling their fly ash). These pollutant removals will decrease the exposure of wildlife populations to toxic pollutants and decrease the threat that combustion residual surface impoundments pose to surrounding wildlife.

7.8 OTHER SECONDARY IMPROVEMENTS

In addition to the improvements discussed above, other secondary, or ancillary, other resources will see improvements that are associated directly or indirectly with the final rule. Pollutant removals not only improve water quality in surface waters but enhances their aesthetic (*e.g.*, by improving clarity and decreasing odor and discoloration). Cleaner surface water improves the source of drinking water for both surface water treatment plants and wells that are influenced by surface water; water used for irrigation; and water used for industrial uses (less contaminants). Recreational benefits from water quality improvements include more enjoyment from swimming, fishing, and boating and potentially increased revenue from more people partaking of recreational activities. The final rule may also reduce economic impacts such as clean-up and treatment costs for contamination or impoundment failures, reduced injury associated with surface impoundment failures, reduced water usage, reduced potential for algal blooms, and decreased air emissions.

The Benefits and Cost Analysis monetizes benefits of implementing the final rule (increased aesthetics, recreational improvements, increased availability of ground water resources, reduced risk of surface impoundment failures, and air quality improvements). In addition, the document also qualitatively discusses improvements to the quality of source water for drinking, irrigation, and industrial use; quantity and quality of recreational opportunities; improved commercial fisheries yields; increased property values; and reduced sediment contamination within receiving waters.

While the final rule does not control pollutants leaching to ground water from surface impoundments and landfills containing combustion residuals, EPA estimates that the final rule will decrease pollutant loadings to surface impoundments (*e.g.*, through plants converting to dry handling their fly ash). These pollutant removals will decrease pollutants leaching from combustion residual surface impoundments to ground water and decrease the potential human health impacts associated with exposure to contaminated drinking water wells (see Section 3.3.4). EPA, however, did not quantify or monetize the benefits associated with this improvement to ground water quality.

7.9 UNRESOLVED DRINKING WATER IMPACTS DUE TO BROMIDE DISCHARGES

As discussed in Section 3.1.3, bromide in water can form brominated disinfection by-products (DBPs), some potentially carcinogenic, when drinking water plants use certain processes including chlorination and ozonation to disinfect the incoming source water. The national effluent limitations guidelines and standards under the final rule (regulatory Option D) do not directly control TDS levels (including bromides) in FGD wastewater discharges from all steam electric power plants.[57] Coal-fired steam electric power plants can discharge bromide due to its natural presence in coal (which is released when burned and/or captured in particulates by baghouses and FGD controls) or through bromide addition to flue gas control processes to reduce mercury emissions. Steam electric power plant discharges occur close to more than 100 public drinking water intakes on rivers and other waterbodies and there is evidence that bromide discharges are already having adverse effects on the quality of drinking water sources.

While bromide itself is not thought to be toxic at levels present in the environment, its reaction with other constituents in water may be of concern now and into the future. Drinking water utilities should be concerned about bromides affecting drinking water sources, as bromide loadings into surface waters could potentially increase in the future as more coal-fired steam electric power plant operators add bromide to help control mercury emissions. Although EPA decided not to finalize BAT requirements based on evaporation for treating FGD wastewater at all steam electric power plants in the final rule, evaporation technology is potentially available and may be appropriate for achieving water quality-based effluent limitations, depending on site-specific conditions, where drinking water supplies need to be protected.

---

[57] They do, however, directly control TDS in cases where steam electric power plants opt into the voluntary incentives program, in which they would be subject to effluent limitations based on evaporation technology.

SECTION 8
CASE STUDY MODELING

EPA developed dynamic water quality models of selected case study locations to supplement the water quality component of the national-scale immediate receiving water (IRW) model. EPA performed the case study modeling to provide additional resolution regarding the baseline impacts and the expected environmental and human health improvements under the final rule, while encompassing a broader temporal and spatial scope than what is included in the IRW model. The case study models also validate and provide additional perspective on the results of the IRW model for those waterbodies included in both models. The case study modeling improves upon the IRW model in the following ways:

- Accounts for long-term pollutant loadings from steam electric power plants (under both baseline conditions and the final rule) and estimates the resultant accumulation of pollutants within the water column and sediments of the receiving water. These models can more accurately assess baseline pollutant concentrations and the time frame and magnitude of environmental improvements associated with the final rule.
- Accounts for fluctuations in receiving water flow rates by using daily stream flow monitoring data instead of one annual average flow rate for the receiving water. This approach better reflects the varying influence of dilution (or lack thereof) within the receiving water during high-flow and low-flow conditions.
- Accounts for pollutant transport and accumulation within receiving water reaches that are downstream from the discharge location. This approach can more accurately estimate the river distance showing environmental impacts under baseline conditions and improvements under the final rule.[58]
- Accounts for pollutant contributions from other point, nonpoint, and background sources, to the extent practical, using available data sources. Incorporating non-steam-electric pollutant sources and available water quality data provides a more complete illustration of the compounding impacts of background pollutant concentrations, steam electric power plant pollutant loadings, and other point source dischargers.

This section describes EPA’s methodology for developing and running the case study models (Section 8.1); presents the results of the case study models for the selected case study locations (Section 8.2); and compares the case study and IRW model results (Section 8.3).

---

[58] The case study downstream modeling described in this section is separate from the downstream modeling EPA performed using the Risk-Screening Environmental Indicators (RSEI) model and the SPARROW (SPAtially Referenced Regressions On Watershed attributes) model. EPA used the national-scale RSEI and SPARROW models to quantify changes in water quality in support of the benefits analysis for the final rule. See the *Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-15-005).

8.1 CASE STUDY MODELING METHODOLOGY

The case studies use EPA's Water Quality Analysis Simulation Program (WASP), a dynamic compartment-modeling program for aquatic systems that simulates pollutant fate and transport within both the water column and the benthic sediment. The WASP model helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollutant management decisions. EPA's approach also relies on U.S. Geological Survey (USGS) daily stream flow data downloaded through EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) interface to provide input time series flow data for use in the WASP model.

This section is organized as follows:

- Section 8.1.1 discusses EPA's approach for selecting case study locations (*i.e.*, steam electric power plants and receiving waters) for case study modeling, including the differences in selection criteria for lotic, lentic, and estuarine water systems.
- Section 8.1.2 summarizes the scope and general technical approach for the case study modeling, including the selection of pollutants and wastestreams for modeling; the data sources evaluated for non-steam-electric pollutant contributions; and approaches for modeling pollutant levels before and after the assumed final rule compliance date.
- Section 8.1.3 explains the development and execution of the case study models using WASP. Appendix G provides additional information regarding the specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data) and model settings (*e.g.*, solids transport parameters) for each of the WASP models. For additional documentation regarding the selection and calculation of the input parameters and settings, refer to the ERG memorandum, "Technical Approach for Case Study Water Quality Modeling of Aquatic Systems in Support of the Final Steam Electric Power Generating Industry Environmental Assessment" (DCN SE05570) (*Case Study Water Quality Modeling Memorandum*).
- Section 8.1.4 describes the use of the case study model outputs to determine impacts to aquatic life based on changes in water quality; impacts to aquatic life based on changes in sediment quality; impacts to wildlife from consuming contaminated aquatic organisms; and impacts to human health from consuming contaminated fish.
- Section 8.1.5 lists some of the limitations and assumptions involved with EPA's case study modeling.

8.1.1 Selection of Case Study Locations for Modeling

To select locations for detailed case study modeling, EPA developed site-selection criteria to identify a collection of steam electric power plants and receiving waters that, when evaluated as a group:

- Represent a reasonable cross-section of the range of receiving waters evaluated in the environmental assessment (EA).
- Illustrate pollutant removals across the regulatory options evaluated by EPA.

- Encompass discharges of all four wastestreams evaluated in the EA.
- Demonstrate pollutant loadings that are representative of those discharged by steam electric power plants evaluated in the EA (*i.e.*, discharges are typical of steam electric power plants and not outlier values).

EPA evaluated 195 steam electric power plants that discharge directly to aquatic systems with lotic characteristics (rivers and streams), lentic characteristics (lakes, ponds, and reservoirs), or that are estuarine systems. Through the site-selection process described below, EPA identified six representative case study locations (five lotic sites and one lentic site) that capture improvements across multiple regulatory options, represent all four evaluated wastestreams (flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate), and represent both lentic and lotic aquatic environments. Figure 8-1 and Table 8-1 present the six receiving waters that EPA selected for case study modeling.

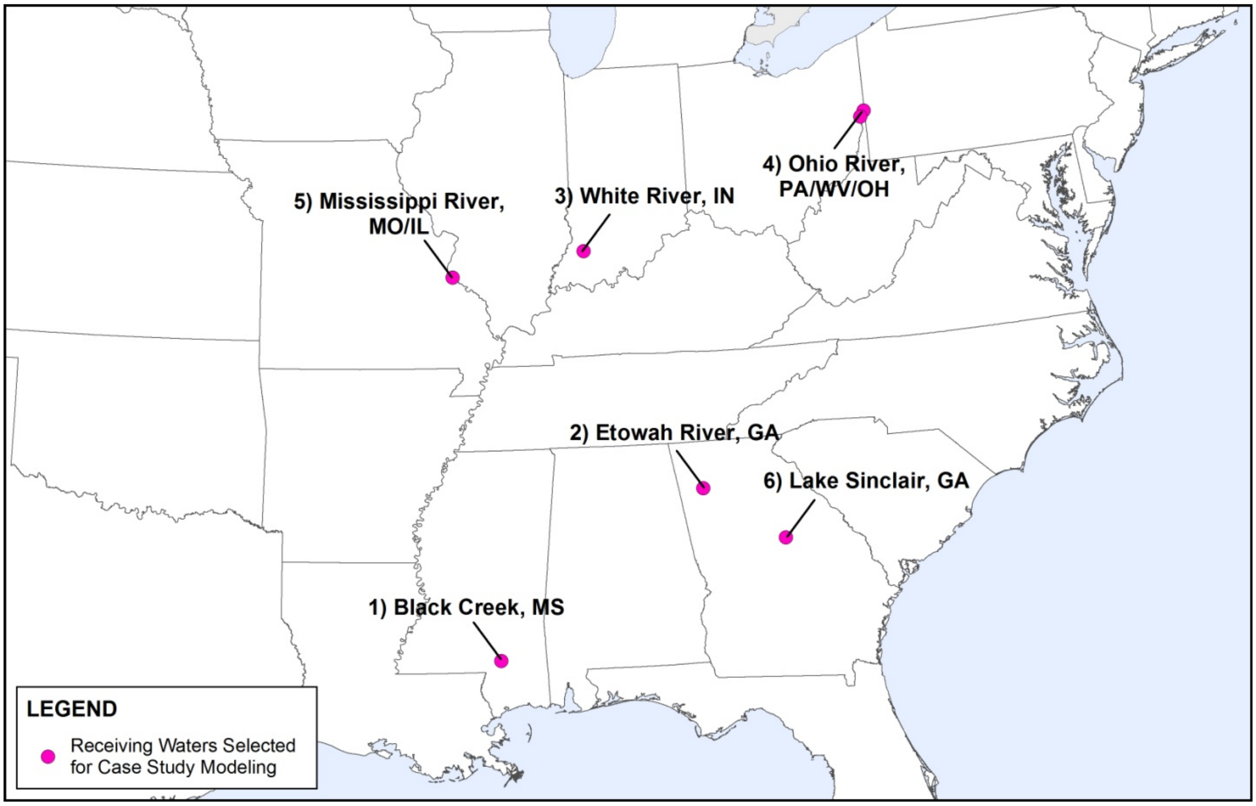


Figure 8-1. Overview of Case Study Modeling Locations

Table 8-1. Locations Selected for Case Study Modeling

Case Study Location	Water-body Type	Steam Electric Power Plant(s) Modeled	Evaluated Wastestreams Discharged				Regulatory Options Demonstrating Removals				Model Length (river-miles)	Modeling Period [a]
			FGD	**Fly Ash**	**Bottom Ash**	**Leachate**	**A**	**B**	**C**	**D**		
Black Creek, MS	Lotic	R.D. Morrow Sr. Generating Site	✓		✓	✓	✓	✓		✓	97	1982-2036 (55 years)
Etowah River, GA	Lotic	Plant Bowen	✓		✓		✓	✓	✓		35	1982-2032 (51 years)
Lick Creek & White River, IN	Lotic	Petersburg Generating Station	✓		✓			✓	✓	✓	53	1986-2034 (49 years)
Ohio River, PA/WV/OH	Lotic	Bruce Mansfield Plant & W.H. Sammis Plant	✓		✓	✓	✓	✓	✓	✓	44	1982-2036 (55 years)
Mississippi River, MO/IL	Lotic	Rush Island [b]		✓	✓		✓		✓		65	1982-2036 (55 years)
Lake Sinclair, GA	Lentic	Plant Harllee Branch [c]	✓	✓	✓		✓	✓	✓	✓	N/A	2012-2025 (14 years)

Acronym: FGD (flue gas desulfurization); N/A (Not applicable).

a – The modeling periods start at 1982 (the year of the last revision to the steam electric effluent limitations guidelines and standards (ELGs) or the date of installation of the most recent generating unit impacted by the final rule (if after 1982). The duration of the modeling period is influenced by the available time periods covered by USGS time series flow data and by the assumed date upon which the steam electric power plant would achieve the limitations under the final rule, as determined based on the plant's National Pollutant Discharge Elimination System (NPDES) permitting cycle.

b – EPA identified another steam electric power plant, Meramec, that discharges upstream of the Rush Island plant. EPA incorporated the pollutant loadings of the Meramec plant to account for the upstream pollutant contributions. EPA did not evaluate the water quality, wildlife, or human health impacts associated with discharges from the Meramec plant because this plant was not selected using the case study selection methodology described in this section.

c – This steam electric power plant has decertified and retired all of its steam electric generating units. EPA selected this plant to represent the potential impacts of discharges of the evaluated wastestreams to lentic waterbodies because it meets all of the case study selection criteria.

Selection of Lotic Case Study Locations

To select lotic receiving waters to model using WASP, EPA reviewed all combinations of steam electric power plants and their receiving waters evaluated in the EA for factors that would negatively influence the ability to use WASP for case study water quality modeling or the ability to discuss the case study modeling results in a public document. EPA completed an assessment using industry responses to the 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (the Steam Electric Survey), EPA's BASINS tool, National Hydrography Dataset Plus (NHDPlus Version 1) hydrography layers, and USGS National Water Information System (NWIS) data sources to identify and eliminate the lotic receiving waters that met one or more of the following criteria from consideration for case study modeling:

- Confidential Business Information (CBI). EPA identified and eliminated steam electric power plants with CBI claims on discharge flow rate data for any of the four evaluated wastestreams. EPA eliminated these plants as potential case study locations because CBI data, including modeled water concentrations based on CBI data, cannot be discussed in a public document such as this EA report.
- Stream gage flow data. EPA identified and eliminated receiving waters that lack sufficient stream gage flow data. Availability of a long-term, continuous stream flow record for both the receiving water being modeled and any significant downstream tributaries was a major factor in selecting case study locations because these data are needed to construct the hydrodynamics in WASP. The primary considerations when reviewing the sufficiency of stream gage flow data for use in WASP were the following:
    - Location of USGS stream gage stations (the ideal location is within the vicinity of the immediate receiving water being evaluated, plus additional locations within the model area).
    - A continuous stream flow record covering a time period that matches or exceeds the length of the desired modeling period.
    - Age of the stream gage flow data (data sets without data from within the previous 30 years were considered potentially unrepresentative of current flow conditions).
- Downstream waterbody characteristics. WASP's ability to accurately model water quality using USGS stream gage flow data can be affected by flow control structures such as dams that affect the linear flow and circulation of water, and thus influence the transport of pollutants. EPA identified and eliminated receiving waters whose downstream waterbodies exhibit these characteristics, unless the areas of concern were sufficiently downstream to allow for modeling of a reasonable distance (*i.e.*, at least 25 miles) before encountering the area of concern.
- Influence by other point source dischargers that could not be modeled. EPA identified receiving waters that could be significantly influenced by discharges from other point sources (including other steam electric power plants) and evaluated whether those point sources would meet the criteria listed above for case study modeling. If EPA determined that a receiving water would be significantly influenced by other point source discharges that could not be modeled (*e.g.*, an upstream steam electric power

plant exercising CBI claims) or represented in the model by STORET monitoring data (see Section 8.1.3), EPA eliminated the receiving water from consideration. If EPA deemed the pollutant loadings from the other point source discharges to be insignificant compared to the steam electric power plant pollutant loadings being evaluated, EPA included the receiving water in the analysis.[59]

Next, EPA assessed the representativeness of the steam electric power plants and receiving waters that were not eliminated based on the criteria above. EPA selected the receiving water flow rate, magnitude of pollutant loadings from the evaluated wastestreams, and water column concentrations output calculated based on these values as the primary factors in determining whether it considered a particular receiving water representative. EPA reviewed the average annual flow rates (as defined in NHDPlus Version 1), baseline loadings of the modeled pollutants, and water column concentrations output from the IRW model of each of the steam electric power plants and receiving waters that were not eliminated after application of the acceptance criteria. EPA assessed how each plant and receiving water compared to the general population in the EA and eliminated plant and receiving water combinations that did not reasonably represent typical conditions. From the population of lotic receiving waters that EPA determined would be suitable for WASP modeling and representative of typical pollutant loadings from discharges of the evaluated wastestreams, the Agency selected a collection that, when evaluated as a group, demonstrated pollutant removals across all modeled regulatory options and all four evaluated wastestreams. As a result, EPA identified five case study locations as the best candidates for modeling as part of a representative set of steam electric power plants that discharge to lotic systems. The selected case study locations are further described in Section 8.2.[60] Additional information about EPA's methodology for selecting plants and receiving waters that are representative and suitable for WASP modeling is further described in the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

Selection of Lentic and Estuarine Case Study Locations

Water quality modeling of lentic systems (lakes, ponds, and reservoirs) or estuarine systems involves more complex hydrodynamics that would not be adequately represented by stream gage flow data. Modeling steam electric power plants that discharge to lentic or estuarine systems requires using existing EPA-developed WASP models (or more specifically, the underlying hydrodynamic data) for the specific waterbodies of interest. Accordingly, EPA considered the availability of existing models a primary factor in selecting lentic and estuarine systems for case study water quality modeling.

---

[59] EPA considered receiving water flow rate, distance between outfalls, and relative magnitude of pollutant loadings when assessing whether the discharges from upstream or downstream plants or point sources could significantly affect the water quality modeling results for the selected case study location. EPA applied best professional judgment using these criteria, but did not apply numeric thresholds.

[60] Because of the level of effort required to design, execute, and evaluate the outputs for case study modeling, EPA did not complete case study modeling for all candidates that met all acceptance criteria and were determined to be representative. EPA used best professional judgment in determination of which five case study locations were the best candidates for modeling and represent a reasonable cross-section of the range of receiving waters evaluated in the EA.

EPA identified one preexisting WASP model for a lake (Lake Sinclair, GA) that receives steam electric power plant discharges from Georgia Power Company's Plant Harllee Branch. As of April 16, 2015, this plant has decertified and retired all four of its coal-fired generating units. Based on a review of the water concentration outputs generated by the IRW model in support of the proposed ELGs (which were developed prior to the announcement of plans to retire Plant Harllee Branch), EPA determined that Lake Sinclair remains a representative illustration of lentic waterbodies that receive discharges of the evaluated wastestreams. As discussed in Section 3, pollutant loadings to lentic systems often more strongly affect water quality and ecosystem health (compared to lotic systems) due to the longer residence times and associated long-term accumulation of pollutants in these systems. Accordingly, and despite the retirement of Plant Harllee Branch, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric power plant discharges on lentic waterbodies (including the 26 lake, pond, and reservoir receiving waters evaluated in this EA) and the potential environmental improvements under the final rule in other lentic waterbodies that receive discharges of the evaluated wastestreams.

EPA also identified one preexisting water WASP model for an estuary (Hillsborough Bay, FL) that receives steam electric power plant discharges. However, due to the hydrologic complexity of the model, and because estuarine systems represent less than 2 percent of the receiving waters evaluated in the EA, EPA elected to develop only freshwater river and lake WASP models for this case study analysis. Additionally, the ecological risk modeling approach described in Section 5.2 is based on selenium bioaccumulation within freshwater environments and would not be appropriate to apply to estuarine or marine aquatic systems, which would limit EPA's ability to analyze the ecological effects for the estuarine case study.

8.1.2 Scope and Technical Approach for Case Study Modeling

This section describes the scope and technical approach used for EPA's detailed case study modeling, including the selection of pollutants and wastestreams evaluated, the inclusion of other point and nonpoint sources, the development of a historical baseline for the case study location, and the prediction of decreased water and sediment pollutant concentrations under the regulatory options evaluated for the final rule.

Selection of Pollutants for Modeling

EPA approached the case study modeling with the goal of modeling the same 10 pollutants included in the IRW model, which are listed in Section 5.1. As described later in this section, however, EPA was unable to perform case study modeling for chromium VI and mercury. EPA performed case study water quality modeling for the following eight pollutants (or "toxicants" as defined in the WASP model), which were also included in the IRW model:

- Arsenic (As).
- Cadmium (Cd).
- Copper (Cu).
- Lead (Pb).
- Nickel (Ni).
- Selenium (Se).

- Thallium (Tl).
- Zinc (Zn).

These pollutants can be modeled using the Simple Toxicant module within WASP. Similar to the water quality module of the IRW model, the Simple Toxicant module applies pollutant-specific partition coefficients to estimate the degree to which pollutants in the water column will adsorb to benthic sediments and suspended solids. Unlike the IRW model, the Simple Toxicant module does not incorporate separate partition coefficients to define the benthic sediment/pore water equilibrium and the suspended sediment/water column equilibrium. Therefore, EPA selected only the suspended sediment-water (Kd_{sw}) partition coefficient for each pollutant (see Table C-4 in Appendix C).

EPA also considered using WASP to perform water quality modeling for chromium VI and mercury. These pollutants, however, require using more data-intensive modules within WASP. Accurately modeling chromium VI requires using the META4 module within WASP to accurately predict pollutant speciation and depends on the availability of extensive site-specific monitoring data. Modeling mercury (and methylmercury, a bioaccumulative organic form of mercury) requires using the MERC7 module within WASP to account for transformation processes such as methylation. Using the more data-intensive modules requires site-specific data that were not available for all locations.

Evaluated Wastestreams

The case study models quantified the water quality impacts resulting from discharges of the same four evaluated wastestreams included in the IRW model:

- Fly ash transport water.
- Bottom ash transport water.
- FGD wastewater.
- Combustion residual leachate.

As with the IRW model, EPA performed the WASP water quality modeling using average daily pollutant loadings derived from average annual pollutant loadings and normalized effluent flow rates. This assumption of a static loadings rate does not account for temporal variability in the loadings to receiving waters due to factors such as variable plant operating schedules, storm flows, low-flow events, and catastrophic events.

Inclusion of Other Point and Nonpoint Sources

Accounting for pollutant contributions from non-steam-electric point sources and nonpoint sources, to the extent practical using available data, can improve the accuracy of the case study water quality models. EPA identified the following data sources that provide pollutant loadings and/or concentration data for these other sources potentially affecting water quality in the case study location:

- Discharge Monitoring Reports (DMR). Point source dischargers are required to report certain wastewater monitoring data through the submittal of DMRs. However, they are required to report only for the pollutants that are listed in the facility's National

Pollutant Discharge Elimination System (NPDES) permit.[61] EPA evaluated 2011 pollutant loadings data for direct dischargers including publicly owned treatment works (POTWs) and industrial facilities.

- Toxics Release Inventory (TRI). TRI collects facility-reported estimates of wastewater loadings data for both direct and indirect dischargers. The TRI database does not include loadings from facilities with total annual chemical releases of less than 500 pounds and incorporates assumptions regarding plants with annual releases of less than 1,000 pounds. The point source loadings from smaller facilities, therefore, may not be well represented in the TRI database.[62] EPA evaluated 2011 pollutant loadings data for industrial facilities with indirect discharges of a modeled pollutant. EPA also evaluated TRI direct pollutant loadings data for these facilities and pollutants if the facilities are not also required to report this pollutant in their DMRs (to avoid double-counting direct discharges).
- STORET Monitoring Data. EPA's STORET database is a repository for water quality, biological, and physical data compiled from many data sources and locations throughout the country. The STORET database contains water quality and sediment quality monitoring data for all eight modeled pollutants and other input parameters for WASP including total organic carbon (TOC) and total suspended solids (TSS).

EPA reviewed these publicly available data sources to identify pollutant contributions from non-steam-electric point sources and nonpoint sources that may impact the case study water quality model. EPA also used available STORET monitoring data to help calibrate the modeled outputs. For additional documentation regarding EPA's collection and use of these data, refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

Modeling of Pollutant Loadings Prior to the Final Rule

EPA developed and executed WASP models (as described in Section 8.1.3) for the selected case study locations to predict the baseline accumulation of pollutants in the receiving water and sediment leading up to implementation of the final rule.

The modeling periods start at 1982 (the year of the last revision to the steam electric ELGs) or the date of installation of the most recent generating unit impacted by this rulemaking (if after 1982), and extend to the assumed compliance date.[63] If the available stream gage flow

---

[61] In addition, states (or other permitting authorities) have some discretion as to which data they make available (or enter) to the national database (*i.e.*, Permit Compliance System (PCS) and Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES)). For example, permitting authorities enter DMR and permit information for facilities that are considered major dischargers. However, they do not necessarily enter DMR or permit information into PCS for minor dischargers or facilities covered by a general permit.

[62] Other limitations of the data collected in TRI include the following: small establishments are not required to report, nor are facilities that do not meet reporting thresholds; releases reported are based on estimates, not measurements; certain chemicals are reported as a class, not as individual compounds; facilities are identified by North American Industrial Classification System (NAICS) code, not point source category; and TRI requires facilities to only report certain chemicals and therefore all pollutants discharged from a facility may not be captured.

[63] For each steam electric power plant in the case study modeling, EPA assumed a plant-specific date, derived from the plant's permitting cycle, that the plant would achieve the limitation under the final rule.

data did not cover the desired modeling period, EPA extrapolated the available data, incorporating another partial cycle of the flow data to reach the total desired modeling period.

Historical pollutant loadings data for the evaluated wastestreams and non-steam-electric point sources are very limited and difficult to obtain, so EPA used Steam Electric Survey data (representing plant operations in 2009), STORET monitoring data, and 2011 TRI and DMR loadings data as a representative set of discharge conditions. EPA acknowledges that these data may not reflect the actual pollutant loadings over the entire modeling period; however, they represent an appropriate estimation of annual pollutant loadings and how discharges may affect individual aquatic systems over time.

For each case study location, EPA assumed that the annual, historical pollutant loadings associated with fly ash transport water, bottom ash transport water, and combustion residual leachate discharges were equal to the baseline pollutant loadings calculated for these wastestreams (*i.e.*, the same annual pollutant loadings used to represent baseline conditions in the national-scale IRW model). The impoundment and discharge of these wastestreams has been a standard technique practiced since before 1982. EPA did not attempt to determine whether a modeled plant had historical discharges of an evaluated wastestream that are not represented in the baseline pollutant loadings. For example, for a plant that does not have fly ash transport water pollutant loadings under baseline conditions, EPA did not attempt to determine whether the plant had historical discharges of fly ash transport water.

In estimating the annual, historical pollutant loadings associated with FGD wastewater, EPA accounted for the fact that steam electric power plants may have installed FGD systems after the start of the modeling period. EPA used the FGD system installation dates, based on industry responses to the Steam Electric Survey, to determine how to incorporate FGD wastewater pollutant loadings into the case study model. If a plant installed multiple FGD systems during the modeling period, EPA assumed that the annual, historical FGD wastewater pollutant loadings associated with each individual system were proportional to that system's flow rate contribution compared to the total FGD wastewater flow rate under baseline conditions. The procedure for calculating and incorporating the proportional loadings for each FGD system is further described in the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

EPA accounted for pollutant loadings from non-steam-electric point sources within the modeling boundary by using 2011 TRI and DMR data. EPA assumed that the annual, historical pollutant loadings for these point sources throughout the modeling period were equal to the pollutant loadings reported in the 2011 TRI and DMR data sets. To account for contributions from nonpoint sources, EPA evaluated STORET water quality monitoring data collected upstream of the modeling boundary. The Agency used these monitoring data to represent the pollutant contributions from all point, nonpoint, and background sources upstream of the monitoring location, potentially avoiding the need to collect TRI and DMR pollutant loadings data and perform WASP modeling of those upstream or tributary reaches. The *Case Study Water Quality Modeling Memorandum* (DCN SE05570) further discusses how EPA incorporated DMR pollutant loadings data, TRI pollutant loadings data, and STORET monitoring data into the WASP water quality models.

The results of this baseline modeling provided initial receiving water and sediment concentrations for modeling discharges after the assumed compliance date, discussed in the following section.

Modeling of Pollutant Loadings Under the Final Rule

EPA developed and executed WASP water quality models (as described in Section 8.1.3) for the selected case study locations to predict the decreases of receiving water and sediment pollutant concentrations (relative to baseline conditions) following implementation of the final rule.

EPA executed separate models for continued baseline pollutant loadings and regulatory option pollutant loadings (Options A through D)[64]. These modeling periods started at the assumed compliance date, as determined by each steam electric power plant's permitting cycle, and continued for at least 10 years after the assumed compliance date. EPA used the pollutant loadings calculated under the regulatory options to represent the annual steam electric pollutant loadings for each year of the period following implementation of the final rule. EPA assumed that the pollutant contributions from non-steam-electric point sources (based on TRI and DMR data) and from nonpoint sources (based on STORET monitoring data) would remain constant and would be equal to those used to model the period leading up to implementation of the final rule.

8.1.3 Development and Execution of WASP Models

EPA built each case study model using the BASINS setup tool for WASP, known as the WASP Model Builder, which allows the user to open WASP directly from the BASINS interface. As described in Section 8.1.2, EPA's approach used the Simple Toxicant module within WASP for the eight modeled pollutants. The Simple Toxicant module puts stretches of the modeled receiving water into segments based on the hydrologic characteristics. The WASP model calculates the water column and benthic pollutant concentrations using user-defined parameters and default assumption values. The process described in this section is based on using WASP Version 7.52 and BASINS Version 4.1. Both represent the most current versions available for EPA's analysis.

EPA followed the general approach described below in developing the WASP models for each of the lotic case study locations:

- WASP calculates receiving water and sediment concentrations by dividing the waterbody into segments and performing calculations for each segment. EPA used NHDPlus Flowlines as the basis for defining waterbody segments. To maintain reasonable model runtimes and reduce system instability, EPA further refined these segments by combining short segments such that the flow time through each segment is at least a tenth of a day. In some cases, segment travel times were shorter than the

---

[64] Case study modeling omitted Option E because EPA determined that the additional pollutant removals for Option E are only marginally better than Option D. Under Option E, only R.D. Morrow Generating Station and W.H. Sammis plant would have additional removals.

desired minimum because the segment was located between an upstream and downstream tributary of some significance.

- EPA used USGS stream gage flow data to represent inflows at the upstream end of the case study location, as well as any significant tributary with a USGS stream gage station. In all cases, EPA scaled the stream gage flow data to account for the difference in drainage area between the actual gage location and the point where the contributing flow enters the model.
- For those tributaries without available USGS stream gage flow data for the simulation period, EPA set the flow rate equal to the average annual flow rate as per NHDPlus Version 1.
- To simplify the geographic extent of the modeling area, EPA did not model any tributaries with mean annual flow rates of less than 5 cubic feet per second (cfs) as per NHDPlus Version 1.
- EPA used stream gage flow data from the actual time period (*e.g.*, 1982 – 2014) to represent the baseline flow rate in the modeling area. EPA reused the historical flow data to the extent necessary to complete the modeling period through the assumed compliance date (*e.g.*, 2015 – 2020), preferentially selecting flow data from periods that excluded years of particularly high or low flow rates. Then EPA reused the historical flow data to represent the period through the end of the model run (*e.g.*, 2020 – 2036). This approach ensured that the modeling periods before and after the assumed compliance date were based on similar flow data.
- To represent non-steam-electric point sources within the modeling area, EPA assigned the TRI and DMR pollutant loadings to the stream reach (as represented in NHDPlus Version 1) that was closest to the location of the point source.
- EPA used STORET monitoring data, where available, to represent pollutant contributions flowing into the modeling area from upstream point sources, nonpoint sources, and background sources. Prior to incorporation into the WASP model, EPA converted the pollutant concentrations to mass loadings (for all pollutants except TOC and TSS) using the annual average flow rate for the stream segment where the sample was collected (as represented in NHDPlus Version 1). This approach ensured that the modeled pollutant concentrations flowing into the modeling area would vary with changes in the stream flow rate.
- To define initial concentrations for the organic solids, sands, and silts/fines parameters, EPA used TOC and TSS concentrations derived from STORET monitoring data collected within the modeling area.
- EPA calibrated the WASP water quality models by modifying the solids transport input parameters until the modeled pollutant concentrations in the benthic segments closely matched the sediment concentrations derived from STORET monitoring data.

The existing WASP model used for Lake Sinclair already divides the waterbody into segments and an existing Environmental Fluid Dynamics Code (EFDC) model provides hydrodynamics for the lentic system. Using an existing model of a lentic system was a reasonable approach to investigate the regulatory options without developing a detailed model from scratch. However, this approach does limit the modeling period to the period simulated in the existing EFDC model. Other than these differences, the approach for developing the WASP model for the lentic system was similar to the approach described above for lotic systems.

EPA developed the WASP water quality models (for both lotic and lentic systems) to provide output data for pollutant concentration (total, dissolved, and sorbed) in the water column and benthic segments on a daily output time step. The WASP models generate these outputs for both the immediate receiving water and every downstream segment. As described in Section 8.1.2, EPA then executed the models to represent conditions before and after implementation of the final rule.

Appendix G provides additional information regarding the specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data) and model settings (*e.g.*, solids transport parameters) for each of the WASP water quality models. For additional documentation regarding the use or bypassing of specific WASP model features, incorporating stream gage flow and pollutant loadings data, and default settings and assumptions, refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

8.1.4 Use of WASP Water Quality Model Outputs

For each modeled segment, EPA used the water column and benthic sediment pollutant concentration outputs (for baseline and Option D, both from the WASP model run representing the time period after the assumed compliance date) to perform the following environmental and human health analyses:

- EPA compared the modeled pollutant concentrations in the water column (daily outputs) to the water quality benchmarks listed in Table C-7 of Appendix C and calculated the frequency of exceedances over the entire modeling period (*i.e.*, the percentage of days that have a modeled exceedance).
- EPA compared the modeled pollutant concentrations in the benthic sediment (daily outputs) to the sediment biota chemical stressor concentration limit (CSCL) benchmarks listed in Table D-2 of Appendix D and calculated the frequency of exceedances over the entire modeling period (*i.e.*, the percentage of days with a modeled exceedance).
- EPA compared the modeled pollutant concentrations in the water column (averaged over the entire modeling period) to the water pollutant concentrations that would result in exceedances if used as inputs to the wildlife and human health modules in the IRW model (as described in Section 7.6).

For the Black Creek case study, which had relatively high concentrations of selenium compared to the other selected case studies, EPA also performed ecological risk modeling following the methodology described in Section 5.2.

Using the WASP water quality outputs in these analyses allowed EPA to evaluate, with greater focus and accuracy, the potential for additional environmental and human health impacts that were not reflected in the IRW model outputs. These included impacts associated with peak pollutant concentrations during low-flow periods; long-term accumulation of pollutants in benthic sediment; impacts in downstream receiving waters; and pollutant contributions from non-steam-electric sources.

8.1.5 Limitations of Case Study Modeling

The results of the case study models are intended to illustrate the types and magnitudes of environmental impacts that are likely to have occurred, and which may continue to occur, in surface waters that receive discharges of the evaluated wastestreams from steam electric power plants. Similarly, the case study modeling results provide valuable information regarding the relative magnitude of water quality improvements predicted for each of the regulatory options.

In developing the case study models, EPA found it necessary to incorporate several assumptions that simplified the modeling approach while introducing uncertainty into the model results. For example, due to a lack of data regarding temporal variability in point source loadings, EPA assumed that the pollutant loadings from steam electric power plants and other point sources are static loadings (*i.e.*, a constant daily average loading rate). This approach does not account for temporal variability in the loadings to receiving waters due to factors such as variable plant operating schedules, storm flows, low-flow events, and catastrophic events. In actuality, steam electric power plants and other point sources could adjust wastewater discharge rates based on stream flow conditions or other considerations. For instance, a plant could reduce discharges during periods of low flow in the receiving water and increase discharges during periods of high flow, resulting in surface water concentrations that differ from what is predicted by the case study model. These assumptions influence the relationship between modeled and actual surface water concentrations at specific locations and times.

Appendix G further discusses the limitations and assumptions made in developing the case study models and describes in more detail the development of each case study model, including input parameters (*e.g.*, pollutant loadings) and model settings. Refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570) for discussion of EPA's technical approach and data acceptance criteria to incorporate DMR, TRI, and STORET monitoring data.

8.2 QUANTIFIED ENVIRONMENTAL IMPACTS AND IMPROVEMENTS FROM CASE STUDY MODELING

As described in Section 8.1.1, EPA identified six representative case study locations that would capture the types of impacts to surface waters associated with steam electric power plant discharges, capture the improvements expected across the regulatory options, represent the four wastestreams evaluated in the EA, and represent both lentic and lotic systems. Figure 8-1 and Table 8-1 present the six receiving waters that EPA selected for case study modeling.

Section 8.2 introduces each of the six selected case study locations and presents the scope, inputs, and modeling results. For each case study, EPA presents:

- Potential impacts to aquatic life, wildlife, and human health under baseline conditions;
- Improvements to aquatic life, wildlife, and human health following compliance with the final rule; and

- Comparison of the case study and IRW model results for the case study location.

Although EPA modeled the expected environmental improvements under Options A through D, this section primarily presents the water quality, wildlife, and human health improvements under the final rule (Option D). Appendix G of this report includes figures illustrating the water column concentrations output for the immediate receiving water both for baseline conditions and following compliance with the final rule, for those modeled pollutants that exceed one or more water quality benchmarks based on modeling results. These figures present the National Recommended Water Quality Criteria (NRWQC) and Maximum contaminant level (MCL) benchmarks for the modeled pollutant and the steady-state water column concentration results from the IRW model. Appendix G also includes the average total water column concentration for each of the modeled pollutants in WASP model segments downstream of the modeled case study plants.

8.2.1 Black Creek Case Study

Black Creek flows south-southeast through southern Mississippi from Hattiesburg through the De Soto National Forest until it converges with the Pascagoula River. Black Creek is Mississippi's only designated National Wild and Scenic River (for 21 miles) under the National Wild and Scenic Rivers System Act. South Mississippi Electric Power Association's R.D. Morrow, Sr. (Morrow) Generating Site (Plant ID 1185) is a 400-megawatt (MW) coal-fired power plant operating alongside Black Creek near Purvis, Mississippi. Morrow's two stand-alone steam turbine generating units reported producing more than 2,000,000 megawatt-hours (MWh) of electricity in 2009. Based on data obtained from the Steam Electric Survey, Morrow Generating Site discharges FGD wastewater, bottom ash transport water, and combustion residual leachate directly into Black Creek. Table 8-2 contains some general information on the two steam electric generating units at Morrow Generating Site.

Table 8-2. Summary of Morrow Generating Site Operations

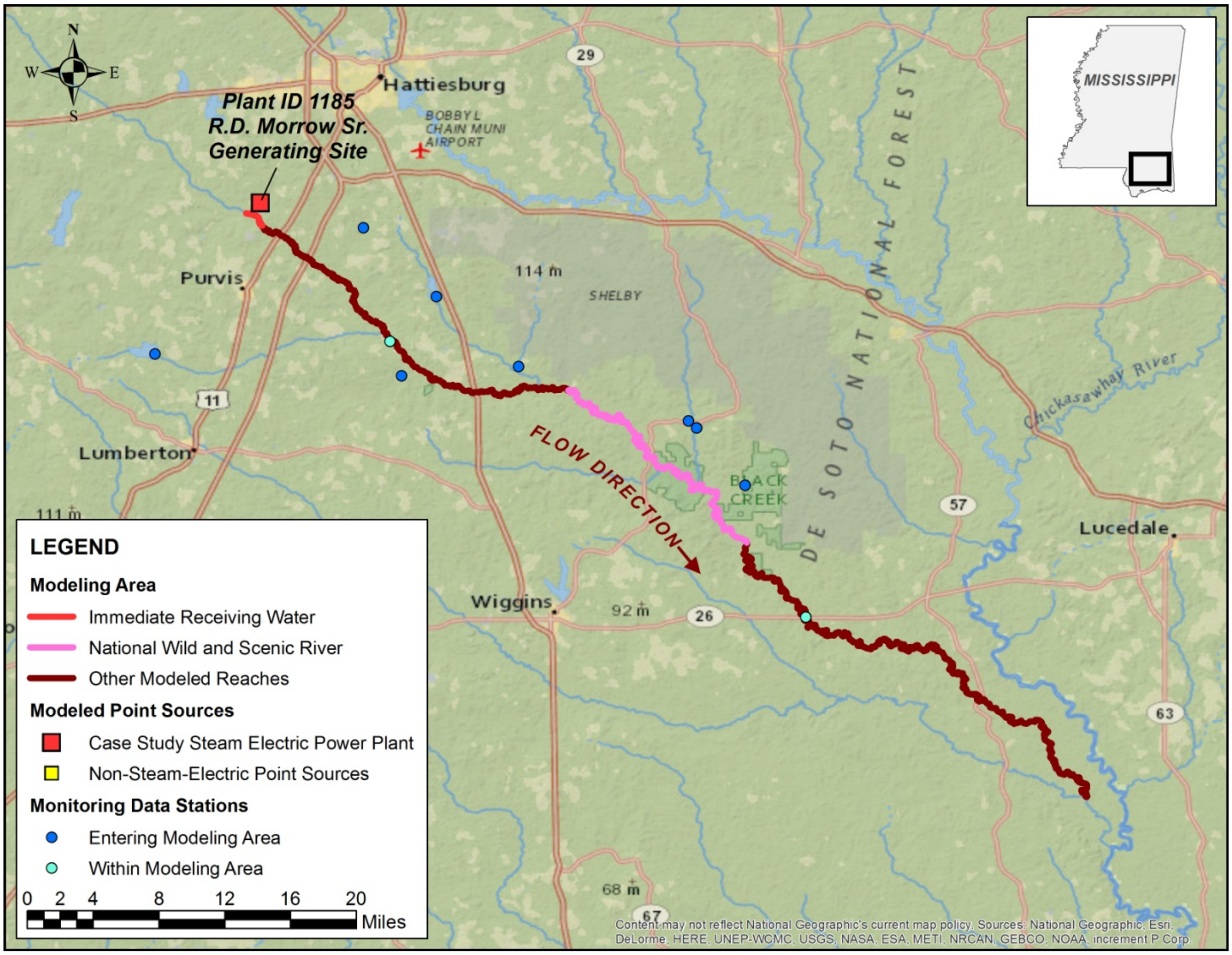
SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	200	Dry conveyed	Wet handled to impoundment	Wet system (1978)
2	Bituminous coal and No. 2 fuel oil	200	Dry conveyed	Wet handled to impoundment	Wet system (1978)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Black Creek WASP model encompasses a 95-mile reach of Black Creek, extending from the Morrow Generating Site discharge outfall on Black Creek to the confluence of Black Creek and Red Creek. The immediate receiving water that Morrow Generating Site discharges to is approximately 1.6 miles long, as defined in the WASP model. This modeling area includes the 21-mile span of the waterway, from Moody's Landing to Fairley Bridge Landing, that is protected under the National Wild and Scenic River Systems Act. Figure 8-2 illustrates the location and extent of the Black Creek WASP model.



Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 8-2. Black Creek WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Black Creek WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA did not identify sufficient STORET monitoring data to represent pollutant contributions from upstream of the Morrow Generating Site immediate receiving water. EPA did not identify any upstream non-steam-electric point sources with loadings for the eight modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area.
- **Downstream pollutant contributions**. EPA incorporated STORET data from eight monitoring stations to represent the pollutant contributions flowing into the modeling

area downstream of the Morrow Generating Site immediate receiving water (*i.e.*, tributaries flowing into Black Creek). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.

- **Monitoring data within the modeling area.** EPA compiled STORET data from two monitoring stations located within the modeling area and used these data to calibrate the WASP model.

Modeling Period

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on Morrow Generating Site's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Modeling Results - Water Quality

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the NRWQC water quality benchmarks for four modeled pollutants, indicating that pollutant loadings from the Morrow Generating Site may quantifiably reduce water quality in the modeled portions of Black Creek. The reduced water quality is primarily attributed to arsenic, cadmium, selenium, and thallium. Intervals of higher pollutant concentrations occur during periods of low flow in Black Creek for all eight modeled pollutants.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic, thallium, and selenium, as discussed below:

- Arsenic concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.018 micrograms per liter (µg/L)) for 99 percent of the modeling period. These exceedances continue downstream, generally at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Arsenic concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for 16 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.24 µg/L) for 17 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for 1 percent of the modeling period. These exceedances continue downstream throughout the entire 95-mile-long modeling area downstream of the plant. The frequency of

exceedances downstream ranges from less than 1 percent to 3 percent of the modeling period.

- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in reaches downstream of the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (170 µg/L). These exceedances occur in 5.3 miles of the modeling area downstream of the plant and up to 88 miles downstream of the plant.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of Black Creek could be at an elevated risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium and selenium under baseline conditions, as discussed below:

- Cadmium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 39 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout 28 miles of the modeling area downstream of the plant.
- Selenium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (5.0 µg/L) for 43 percent of the modeling period. These exceedances continue downstream throughout the entire 95-mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from 2 percent to 51 percent of the modeling period.

These case study modeling results indicate that, under baseline conditions, aquatic organisms inhabiting these modeled portions of Black Creek could be at an elevated risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches occasionally exceed the MCL drinking water benchmarks for three modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for cadmium, selenium, and thallium, as discussed below:

- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in the immediate receiving water exceed the MCL benchmark (5 µg/L). These exceedances continue downstream throughout the entire 95- mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from less than 1 percent to 5 percent of the modeling period.
- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in the immediate receiving water exceed the MCL benchmark (50 µg/L). These exceedances continue downstream, generally at a reduced frequency, in 93 miles of the modeling area downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), thallium concentrations in downstream reaches of the modeling area exceed the MCL (2

µg/L). These exceedances occur in 8.9 miles of the modeling area downstream of the plant and up to 92 miles downstream of the plant.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, nickel, lead, and zinc). Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of all modeled pollutants in the immediate receiving water, which will greatly improve water quality. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for Black Creek reveal the following water quality improvements under the final rule:

- For arsenic:
    - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 99 percent to 94 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated water and organisms.
    - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 16 percent to 6 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated organisms.
- For cadmium:
    - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
    - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.
- For selenium:
    - Exceedances of the human health water quality benchmark for consumption of water and organisms are eliminated throughout the entire modeling area.
    - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.

  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated in 13 miles of the modeling area, including the immediate receiving water. The exceedances of this benchmark reduce in frequency to less than 4 percent in all remaining sections of the downstream modeling area following compliance with the final rule. Most of these exceedances occur within the first year following compliance with the final rule (due to the gradual recovery of the system following the pollutant loading removals). Despite the continued exceedances of these human health criteria, reducing the pollutant concentrations in the water column may decrease risk to humans consuming contaminated water and/or organisms.
- For thallium:
  - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 17 percent to less than 1 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated water and organisms.
  - Exceedances of the human health water quality benchmark for consumption of organisms are eliminated in 6.2 miles of the modeling area, including the immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease risk to humans consuming contaminated organisms.

Modeling Results – Wildlife

EPA assessed the potential threat to piscivorous wildlife from the evaluated wastestreams by modeling the average pollutant concentrations in the water column and comparing these to the concentrations that would trigger exceedances of no effect hazard concentrations (NEHC) for minks and eagles developed by the USGS. Under baseline conditions, Black Creek may pose a risk to minks and eagles that consume fish contaminated with selenium. The average modeled selenium concentrations in 90 miles of the Black Creek modeling area are greater than the concentration that would translate to NEHC exceedances for minks and eagles, demonstrating that the fish inhabiting these portions of Black Creek may pose a potential reproductive threat to terrestrial food webs.

EPA also assessed the potential impact to wildlife exposed to sediments in surface waters by comparing estimated pollutant concentrations in the sediment to sediment biota CSCL benchmarks. Modeling results demonstrate that cadmium concentrations in the upper benthic sediment of the immediate receiving water exceed the CSCL criteria (0.596 mg/kg) during 36 percent of the modeling period. These exceedances continue downstream for 36 miles of the total modeling area.

Ecological risk modeling results indicate that baseline selenium loadings also present an elevated risk of widespread negative reproductive impacts (larval mortality and deformities) among fish that inhabit the immediate receiving water of Black Creek. The results illustrate the significant increase in risk that can result from minor variations in selenium bioaccumulation patterns and toxicity responses within the organisms that inhabit a particular waterbody. Specifically:

- The median (50th percentile) of the model outputs indicates that selenium concentrations in the fish eggs and ovaries would cause reproductive impacts in less than 1 percent of the exposed fish population.
- However, there is a 35 percent probability that these concentrations are high enough to cause reproductive impacts in more than 30 percent of the exposed fish population.
- There is a 25 percent probability that these concentrations are high enough to cause reproductive impacts in *more than 80 percent* of the exposed fish population.

Ecological risk modeling results also indicate an elevated risk of widespread negative reproductive impacts (hatching failure) among mallards that forage or breed in the immediate receiving water of Black Creek. Specifically:

- There is a 50 percent probability that selenium concentrations in the mallard eggs are high enough to cause reproductive impacts in at least 9 percent of the exposed mallard population.
- There is a 35 percent probability that these concentrations are high enough to cause reproductive impacts in more than 20 percent of the exposed mallard population.
- There is a 10 percent probability that these concentrations are high enough to cause reproductive impacts in *more than 70 percent* of the exposed mallard population.

Elevated risks of reproductive impacts to fish and mallards continue downstream from the immediate receiving water. Ecological risk modeling results indicate that the entire 95-mile modeled length of Black Creek has selenium concentrations that lead to a 10 percent or greater probability of negative reproductive impacts among at least 17 percent of the exposed fish or mallard populations. Additionally, several downstream segments of Black Creek (totaling 29 miles) have selenium concentrations that lead to a 25 percent or greater probability of negative reproductive impacts among at least 10 percent of the exposed mallard population.

The case study modeling results demonstrate that the final rule will significantly reduce pollutant concentrations and the associated impacts to wildlife that inhabit Black Creek. The final rule will eliminate selenium exceedances of the NEHC benchmarks for minks and eagles in all modeled reaches of Black Creek. The final rule will also eliminate CSCL benchmark exceedances for cadmium in 27 miles of the modeling area, including the immediate receiving water. The exceedances of this benchmark reduce in frequency to 3 percent or less in all remaining sections of the downstream modeling area following compliance with the final rule. Most of these remaining exceedances occur within the first year following compliance with the final rule. Ecological risk modeling results also indicate that the final rule will eliminate the risk of selenium-related adverse reproductive impacts among exposed fish and mallards in all modeled reaches of Black Creek (*i.e.*, the risk to fish and mallards is less than 0.1 percent at the 95th percentile egg/ovary concentration).

Modeling Results – Human Health

EPA evaluated the potential threat to human receptors due to consumption of contaminated fish from Black Creek. EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR). Under baseline conditions, the average water column concentration of arsenic throughout the modeling area downstream of the plant does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts. See Appendix E for details on the human health module of the IRW model and national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, cadmium, selenium, and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average thallium concentrations in the water column throughout the entire 95-mile-long modeling area are greater than the concentration that would translate to exceedance of the reference doses for at least one child subsistence fisher cohort (with all child subsistence cohorts impacted by 59 or more miles of the modeling area downstream of the plant), while the concentrations in 90 miles of the modeling area are high enough to trigger exceedance of the reference dose for adult subsistence fishers. Additionally, the average thallium concentrations in 59 miles of the modeling area are high enough to trigger exceedance of the reference dose for at least one child recreational fisher cohort.
- Average selenium concentrations in the water column throughout the entire 95-mile-long modeling area are greater than the concentration that would translate to exceedance of the reference dose for the adult subsistence fisher cohorts and at least one child subsistence fisher cohort (with all child subsistence cohorts impacted by 90 or more miles). Additionally, the average selenium concentrations are high enough to trigger exceedances of the reference doses for adult recreational fishers and at least one child recreational fisher cohort in 13 miles and 90 miles of the modeling area, respectively.
- Average cadmium concentrations in the water column in 38 miles of the modeling area are greater than the concentration that would translate to exceedance of the reference dose for at least one child subsistence fisher cohort.

Therefore, humans who consume cadmium-, selenium-, or thallium-contaminated fish inhabiting these waters may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The modeling results demonstrate significant reductions in average water column concentrations of cadmium, selenium, and thallium under the final rule, which would reduce average cadmium and selenium concentrations enough to eliminate the risk for non-cancer health effects for all cohorts throughout the entire modeling area. These loadings reductions would also reduce the thallium concentrations enough to eliminate the risk for non-cancer health effects for adult subsistence and child recreational fishers. While the case study model continues to show average thallium concentrations that may pose non-cancer health effects for at least one child subsistence cohort, the total area of impact is reduced by up to 37 miles (with some child subsistence cohort non-cancer risks being eliminated throughout the entire modeling period downstream of the plant).

Interpretation of Black Creek Results

Case study modeling results for Black Creek indicate greater water quality, wildlife, and human health impacts to the immediate receiving water under baseline conditions than predicted by the IRW model. Case study modeling results for Black Creek also demonstrate water quality benchmark exceedances and risks to wildlife and humans sustaining beyond Morrow Generating Site's immediate receiving water. In some instances, the average water column concentrations can increase in some portions of the downstream modeling area, posing a greater threat to humans, aquatic organisms, and terrestrial ecosystems. This phenomenon is most pronounced for modeled pollutants with the largest partition coefficients (*i.e.*, lead, zinc, cadmium, and copper) suggesting that sediment transport has significant influence in this small receiving water. Under baseline conditions, significant water quality, wildlife, and human health impacts are identified in the modeled area corresponding with 21-mile span of the waterway that is protected under the National Wild and Scenic River Systems Act.

Ecological risk modeling results for the Black Creek case study indicate that the risk of negative reproductive effects among fish and mallards exposed to selenium may be significantly greater than predicted using water quality outputs from the IRW model. Use of the case study water quality outputs, which include extended periods of elevated selenium concentrations that are not reflected in the IRW model outputs, reveals the potential for widespread ecological impacts among wildlife that inhabit, forage, or breed in the immediate receiving water of Black Creek and its downstream waters.

The USGS stream gage flow data used in the case study model indicate that flow rates in Black Creek are typically lower than the annual average flow rate used in the IRW model, while greatly exceeding the annual average flow rate during occasional high-flow events. During the frequent periods of below-average flow, the pollutant concentrations in the modeling area quickly climb to levels associated with negative impacts to fish, wildlife, and humans.

The exceedances identified in the Black Creek WASP model are based solely on discharges of the evaluated wastestreams from the steam electric power plant because EPA did not identify any STORET monitoring data or point sources suggesting any other sources were contributing pollutant discharges to the modeling area. The Black Creek WASP model may be underestimating the pollutant concentrations actually present if there are other discharges that were not captured in the DMR and TRI data sets. Under the final rule, case study modeling of Black Creek indicates that the waterbody will exhibit fewer exceedances of water quality benchmarks; will no longer pose reproductive risks to higher trophic-level wildlife; will pose less risk to benthic organisms; and will pose less risk to humans consuming fish. The extent of improvements identified by the case study model is greater than what was projected by the IRW model. The decrease of the average pollutant concentrations within the immediate receiving water occurs very quickly after compliance with the final rule; however, some downstream reaches of the modeling area take up to a year to reach equilibrium.

8.2.2 Etowah River Case Study

The Etowah River is a 164-mile-long waterway north of Atlanta, Georgia. The river flows west-southwest from Amicalola Creek, the primary tributary, to Rome, Georgia, where it meets the Oostanaula River and forms the Coosa River at their confluence. Once estimated to have 91 native fish species, the Etowah watershed is biologically one of the richest river systems in North America. Eight imperiled fish species, three of which are federally listed as endangered or threatened, are known to inhabit the Etowah watershed, and five mollusk species are believed to have been decimated [Etowah Aquatic Habitat Conservation Plan, 2015].


Georgia Power Company's Plant Bowen

The Etowah River serves as a source of cooling water for, and receives steam electric wastewater discharges from, Southern Company's Plant Bowen (Plant ID 2244), located in Cartersville, Georgia. In commercial operation since 1975, Plant Bowen is bordered on two sides by the Etowah River and Euharlee Creek. Plant Bowen's four stand-alone steam turbine generating units have a total nameplate capacity of 3,499 MW. As the nation's ninth-largest power plant in net generation of electricity, Plant Bowen reported producing almost 23,000,000 MWh of electricity in 2009 [Georgia Power, 2014]. Based on data EPA obtained in responses to the Steam Electric Survey, Plant Bowen discharges two of the evaluated wastestreams, FGD wastewater and bottom ash transport water, directly to the Etowah River. Table 8-3 contains general information on the four steam electric generating units at Plant Bowen.

In estimating the historical pollutant loadings associated with Plant Bowen's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 2008 and 2011. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Bowen's first FGD system.

Table 8-3. Summary of Plant Bowen Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	806	Dry conveyed	Wet handled to impoundment	Wet system (2010)
2	Bituminous coal and No. 2 fuel oil	789	Dry conveyed	Wet handled to impoundment	Wet system (2009)
3	Bituminous coal and No. 2 fuel oil	952	Dry conveyed	Wet handled to impoundment	Wet system (2008)
4	Bituminous coal and No. 2 fuel oil	952	Dry conveyed	Wet handled to impoundment	Wet system (2008)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Etowah River WASP model encompasses a 35-mile segment of the Etowah River, extending from the immediate receiving water to the confluence of the Etowah River and Silver Creek. The immediate receiving water to which Plant Bowen discharges is approximately 3.6 miles long, as defined in the WASP model. Figure 8-3 illustrates the location and extent of the Etowah River WASP model.

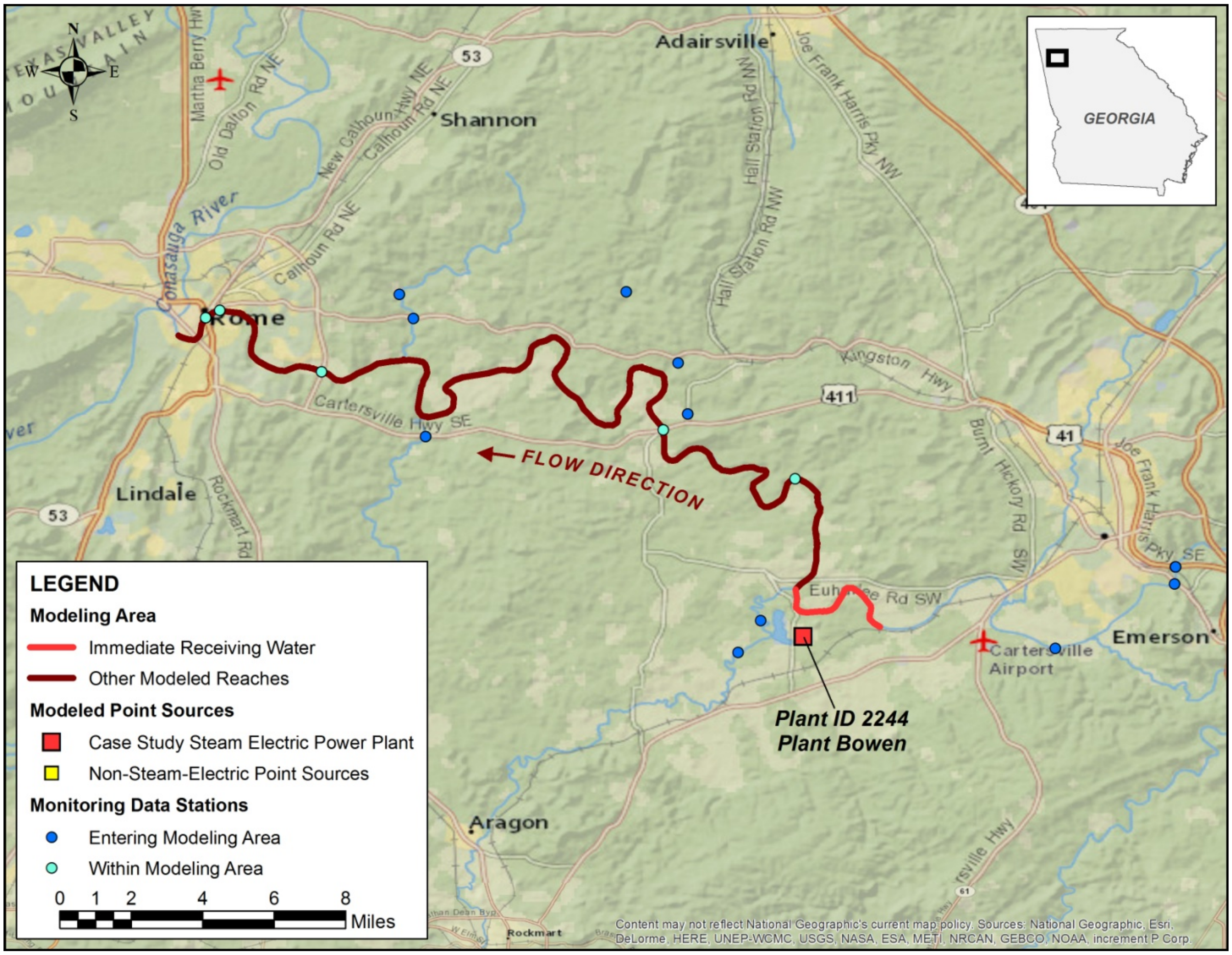


Figure 8-3. Etowah River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Etowah River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA incorporated STORET data from four monitoring stations to represent the pollutant contributions from upstream of the Plant Bowen immediate receiving water. EPA also identified two upstream non-steam-electric point sources whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET data from the four monitoring stations (which encompass all of the modeled pollutants except for selenium) adequately reflect the pollutant contributions from upstream point sources. Therefore, EPA did not incorporate pollutant loadings from the two identified upstream non-steam-electric point sources.

- **Downstream pollutant contributions**. EPA incorporated STORET data from 10 monitoring stations to represent the pollutant concentrations flowing into the modeling area downstream of the Plant Bowen immediate receiving water (*i.e.*, tributaries flowing into the Etowah River). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.
- **Monitoring data within the modeling area**. EPA compiled STORET data from six monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of arsenic, cadmium, copper, lead, and thallium from upstream sources have a much greater influence on the modeled pollutant concentrations in the Etowah River than the pollutant loadings from Plant Bowen. The contributions of nickel and zinc from upstream sources also strongly influence the modeled pollutant concentrations in the Etowah River.

The Etowah River case study model did not account for the documented surface water impacts from Plant Bowen that are discussed in Section 3.3.3. In 2002, a sinkhole developed in the surface impoundment at Plant Bowen that released 2.25 million gallons of ash/water mixture, estimated to contain 80 tons of ash, to Euharlee Creek, which immediately flows into the Etowah River [U.S. EPA, 2014b]. Additionally, an extreme rainfall event in 2008 caused a dry ash stockpile to collapse, depositing approximately two tons of ash in Euharlee Creek. The surface water quality impacts resulting from these events are not reflected in this model; therefore, the case study modeling could under-represent the actual baseline impacts of Plant Bowen on the Etowah River.

Modeling Period

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2032, covering a period of 51 years. Based on Plant Bowen's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2021.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the NRWQC water quality benchmarks for five modeled pollutants, indicating that pollutant loadings from Plant Bowen may contribute to a quantifiable reduction in water quality in the modeled portions of the Etowah River. The reduced water quality is primarily attributed to arsenic, cadmium, selenium, thallium, and lead.

The baseline modeled water concentrations exceed human health criteria primarily for arsenic and thallium, as discussed below:

- Arsenic concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

- Arsenic concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 35-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water exceed the water quality benchmarks for consumption of water and organisms (0.24 µg/L) for more than 99 percent of the modeling period. These exceedances continue downstream, at an increased frequency, throughout the entire 35-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for 90 percent of the modeling period. These exceedances continue downstream, at an increased frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of the Etowah River may be more at risk of the negative effects associated with oral exposure to arsenic and thallium (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium and selenium under baseline conditions, specifically:

- Cadmium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 52 percent of the modeling period. These exceedances continue downstream throughout the 35-mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from 33 percent to 55 percent of the modeling period.
- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in downstream reaches of the modeling area exceed the freshwater aquatic life criteria for chronic exposure (5 µg/L). These exceedances occur in 4.7 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.

These modeling results indicate that, under baseline conditions, aquatic organisms residing in the portions of the Etowah River with modeled exceedances may be more at risk to negative impacts from chronic exposure to cadmium and selenium.

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the MCL drinking water benchmarks for four modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for thallium, arsenic, cadmium and lead as discussed below:

- Thallium concentrations in the immediate receiving water exceed the MCL benchmark (2 µg/L) for 29 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

- On rare occasions (less than 1 percent of the modeling period), arsenic concentrations in the immediate receiving water exceed the MCL benchmark (10 µg/L). These exceedances do not occur beyond the 3.6-mile-long immediate receiving water.
- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in downstream reaches of the modeling area exceed the MCL benchmark (5 µg/L). These exceedances occur in 5.1 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), lead concentrations in downstream reaches of the modeling area exceed the MCL benchmark (15 µg/L). These exceedances occur in 5.1 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, nickel, and zinc). Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show a significant reduction in selenium concentrations and moderately decreased concentrations of cadmium, nickel, and zinc within the Etowah River, which will improve water quality. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for the Etowah River reveal the following water quality improvements under the final rule:

- Exceedances of the cadmium aquatic life water quality criteria for chronic impacts reduce in frequency (by 13 percent) in the immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite continued exceedances of these aquatic life criteria, reducing the pollutant concentrations in the water column may decrease the risk to aquatic life in the Etowah River.
- Exceedances of the selenium aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.

While case study modeling results continue to show exceedances for NRWQC benchmark exceedances of arsenic and thallium and MCL benchmark exceedances of arsenic, cadmium, lead, and thallium, the final rule will reduce loading contributions of these pollutants from Plant Bowen.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Etowah River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks of for any of the eight modeled pollutants; therefore, the Etowah River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR). Under baseline conditions, the average water column concentration of arsenic in the immediate receiving water over the modeling period results in an estimated cancer risk greater than 1-in-a-million for adult subsistence fishers. These exceedances do not occur beyond the 3.6-mile-long immediate receiving water. Therefore, adults who frequently consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer. Modeling results demonstrate no reduction in the cancer risk from inorganic arsenic under the final rule.

Based on the average pollutant concentrations in the water column under baseline conditions, selenium and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average selenium concentrations in the immediate receiving water are greater than the concentrations that would translate to exceedance of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. The average selenium concentrations throughout the entire 35-mile-long modeling area downstream of the plant are greater than the concentration that would translate to an exceedance of the reference dose for least one child subsistence cohort.
- Average thallium concentrations in the water column throughout the entire 35-mile-long modeling area downstream of the plant are greater than the concentrations that would translate to exceedance of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated).

Therefore, humans who consume selenium- or thallium-contaminated fish inhabiting the modeled area of the Etowah River may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in selenium concentrations in the Etowah River, which will eliminate selenium exceedances of the non-cancer health effects reference dose for all cohorts. While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference dose, the final rule will reduce thallium loading contributions from Plant Bowen.

Interpretation of Etowah River Results

Case study modeling results for the Etowah River indicate greater water quality and human health impacts than predicted by the IRW model (IRW modeling results did not indicate any quantifiable impacts in the immediate receiving water of Plant Bowen). By accounting for background pollutant contributions from upstream sources and other boundaries (for all modeled pollutants except selenium), case study modeling predicts higher pollutant concentrations under baseline conditions. For arsenic and thallium, and to a lesser extent cadmium, the projected exceedances are driven by the background concentrations flowing into the Etowah River modeling area. Plant Bowen's discharges of the evaluated wastestreams may be further impairing the degraded waterway.

Case study modeling results for the Etowah River also demonstrate water quality benchmark exceedances and risks to humans occur beyond Plant Bowen's immediate receiving water. In some instances, the average water column concentrations can increase in some portions of the downstream modeling area, posing a greater threat to humans and aquatic life. This phenomenon is most pronounced for modeled pollutants with the largest partition coefficients (*i.e.*, lead, zinc, cadmium, and copper), suggesting that sediment transport has moderate influence in the Etowah River.

Case study modeling of the Etowah River indicates that, under the final rule, the Etowah River will exhibit fewer exceedances of water quality benchmarks and pose less risk to humans consuming fish that inhabit these waters. The improvements identified by the case study model are more extensive than what was projected by the IRW model. This is due in part to the greater water quality and human health impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the Etowah River that were not evaluated as part of the IRW model. The average pollutant concentrations throughout the entire modeling area reduce promptly after compliance with the final rule.

8.2.3 Lick Creek & White River Case Study

The White River is a two-forked river that primarily flows southwest through central and southern Indiana. The two forks, the West Fork and the East Fork, are nearly equal in size when they converge in Daviess Country, just north of Petersburg, Indiana. From this confluence, the White River flows west-southwest for 50 river-miles until it joins the Wabash River at the Illinois-Indiana state border. Located on the banks of the lower White River, Indianapolis Power & Light's (IPL) Petersburg Generating Station (Plant ID 3997) has four stand-alone steam turbine units with a nameplate capacity of 1,864 MW. The plant reported that these four coal-fired generating units produced more than 12,000,000 MWh of electricity in 2009 in the Steam

Electricity Survey. Petersburg Generating Station also operates three minor oil-burning internal combustion units, which are exempt from the requirements of the final rule. Based on data obtained in responses to the Steam Electric Survey, this power plant discharges FGD wastewater and bottom ash transport water. Table 8-4 contains general information on the four coal-fired generating units at Petersburg Generating Station.

In estimating the historical pollutant loadings associated with Petersburg Generating Station's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 1977 and 1996. EPA included the pollutant loadings from the FGD systems on units 3 and 4 at the start of the historical modeling period (1986).

IPL's Petersburg Generating Station

Table 8-4. Summary of Petersburg Generating Station Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash [a]	Bottom Ash	FGD (Year Installed)
1	Subbituminous coal and No. 2 fuel oil	255	Dry conveyed	Wet handled to impoundment	Wet system (05/1996)
2	Subbituminous coal and No. 2 fuel oil	445	Dry conveyed	Wet handled to impoundment	Wet system (05/1996)
3	Subbituminous coal and No. 2 fuel oil	580	Dry conveyed	Wet handled to impoundment	Wet system (11/1977)
4	Subbituminous coal and No. 2 fuel oil	584	Dry conveyed	Wet handled to impoundment	Wet system (04/1986)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – Based on EPA projections, Petersburg Generating Station will convert to dry ash handling to comply with the CCR rulemaking.

Modeling Area

Based on data obtained in responses to the Steam Electric Survey, Petersburg Generating Station discharges FGD wastewater and bottom ash transport water to Lick Creek, a 1.8-mile-long tributary emptying into the White River. The White River WASP model encompasses Lick Creek and a 52-mile reach of the White River, 49 miles of which is downstream of Lick Creek. The immediate receiving water, Lick Creek, is the first of three upstream modeling boundaries for this WASP model. The other upstream model boundaries are on the West Fork White River and East Fork White River approximately one mile upstream of their confluence. EPA extended the modeling area upstream of Lick Creek to capture and incorporate available STORET monitoring data as further described below. The Lick Creek and White River WASP model ends at the confluence of the White River with the Wabash River. Figure 8-4 illustrates the location and extent of the White River WASP model.

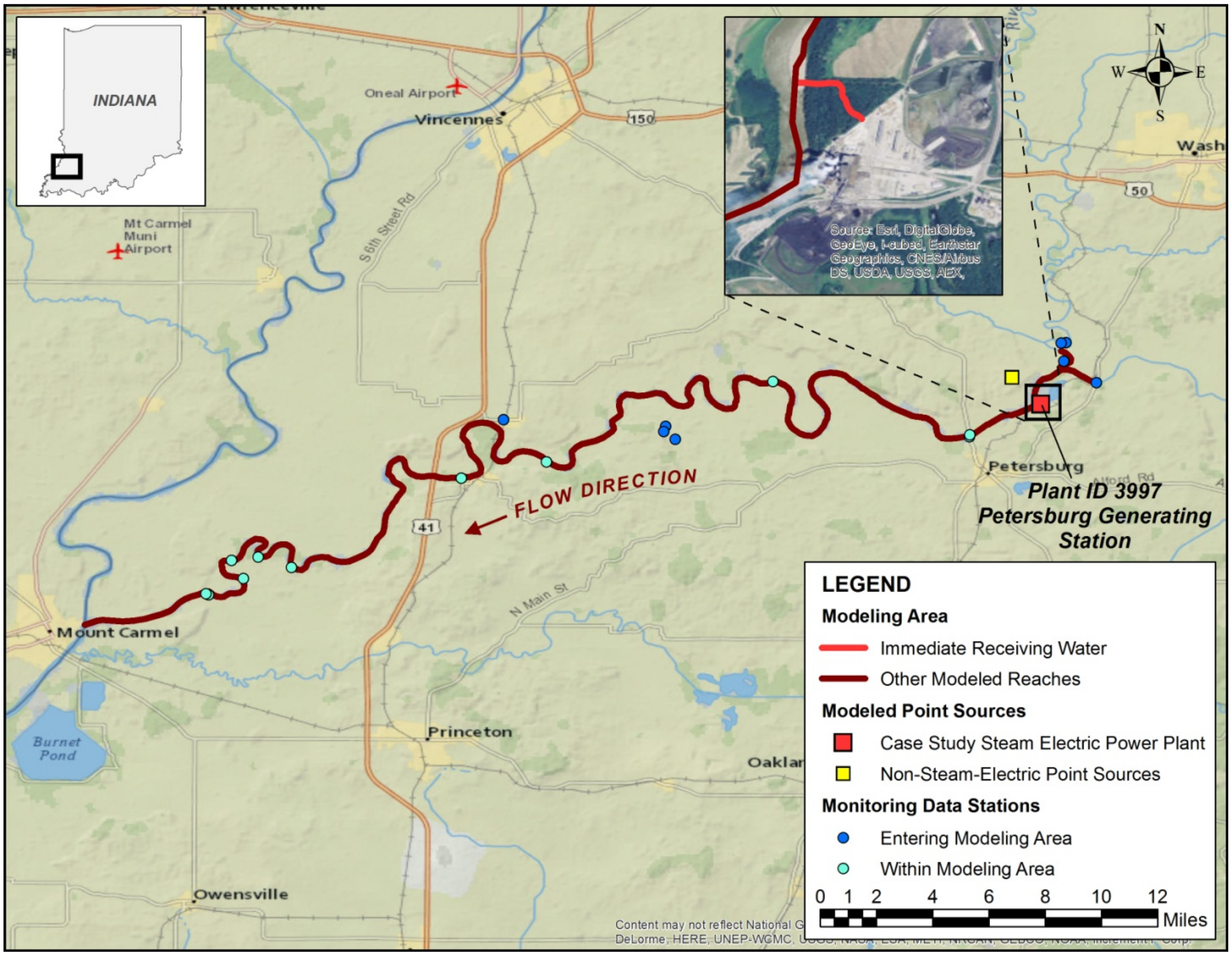


Figure 8-4. Lick Creek and White River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Lick Creek and White River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions (Lick Creek)**. EPA did not identify sufficient STORET monitoring data to represent pollutant contributions from upstream of the Petersburg Generating Station immediate receiving water (Lick Creek). EPA did not identify any upstream non-steam-electric point sources with loadings for the eight modeled pollutants on Lick Creek. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area.
- **Upstream pollutant contributions (West Fork White River)**. EPA incorporated STORET data from three monitoring stations to represent the pollutant contributions

from upstream on the west fork of the White River. EPA also identified three upstream non-steam-electric point sources whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET monitoring data (which include all of the modeled pollutants except for thallium) adequately reflect the pollutant contributions from upstream point sources. Similarly, EPA identified that a steam electric power plant, Edwardsport Generating Station (Plant ID 8544), has historically discharged to the west fork of the White River 30 miles upstream of the start boundary. Edwardsport Generating Station discontinued operation of all steam electric generating units in 2011 to construct a new integrated gasification combined cycle power plant. EPA assumed that the STORET monitoring data adequately reflect the pollutant contributions from this point source. Therefore, EPA did not incorporate pollutant loadings from the three identified upstream non-steam-electric point sources or Edwardsport Generating Station into the WASP model.

- **Upstream pollutant contributions (East Fork White River)**. EPA incorporated STORET data from one monitoring station to represent the pollutant contributions from upstream on the east fork of the White River. EPA also identified one upstream non-steam-electric point source whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET monitoring data (which include all of the modeled pollutants) adequately reflect the pollutant contributions from upstream point sources. Therefore, EPA did not incorporate pollutant loadings from this identified upstream non-steam-electric point source in the WASP model.
- **Downstream pollutant contributions**. EPA incorporated STORET data from four monitoring stations to represent the pollutant concentrations flowing into the modeling area downstream of the Petersburg Generating Station immediate receiving water, Lick Creek (*i.e.*, tributaries flowing into the White River). EPA did identify one non-steam-electric point source that discharges one or more of the modeled pollutants within the modeling area. EPA incorporated the pollutant loadings from the identified non-steam-electric point source into the model.
- **Monitoring data within the modeling area.** EPA compiled STORET data from 12 monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of arsenic, cadmium, copper, nickel, lead, and zinc from upstream sources have a much greater influence on the modeled pollutant concentrations in White River than the pollutant loadings from Petersburg Generating Station.

Due to the lack of pollutant loadings data, the White River case study model did not account for the ground water impacts from Petersburg Generating Station associated with the damage case listed in Appendix A. In 1997, the catastrophic release of coal combustion residuals degraded the quality of ground water and surface water around the plant.

The White River case study model does not account for pollutant loadings from Hoosier Energy’s Frank E. Ratts (Ratts) Generating Station (Plant ID 2314), a 232-MW steam electric power plant located less than a mile downstream of Petersburg Generating Station. Based on information obtained in responses to the Steam Electric Survey, Ratts Generating Station discharged one or more of the evaluated wastestreams directly to the White River. This plant, however, has publicly announced plans to retire all of its steam generating units prior to implementation of the final rule. EPA therefore excluded pollutant loadings from the Ratts Generating Station so that the changes in pollutant loadings during the modeling period, and the associated environmental improvements, reflect only those attributable to the final rule.

Modeling Period

The modeling period starts in 1986 (the year the last generating unit at Petersburg Generating Station began operating) and extends through 2034, covering a period of 49 years. Based on Petersburg Generating Station's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in Lick Creek, the immediate receiving water exceed NRWQC water quality benchmarks for five modeled pollutants, indicating that pollutant loadings from the Petersburg Generating Station may quantifiably reduce water quality in the modeled portions of Lick Creek. Additionally, the modeled pollutant concentrations in portions of the White River downstream of Lick Creek exceed NRWQC water quality benchmarks for four of the modeled pollutants, indicating that the water quality downstream of Lick Creek may also be reduced by the pollutant loadings form Petersburg Generating Station.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic, thallium, and selenium, as discussed below:

- Arsenic concentrations in Lick Creek exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, at the same frequency, throughout the entire 50-mile-long modeling area downstream of the plant.
- Arsenic concentrations in Lick Creek also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, generally at the same frequency, throughout the entire 50-mile-long modeling area downstream of the plant.
- Thallium concentrations in Lick Creek exceed the water quality benchmarks for consumption of water and organisms (0.24 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, at a much lower frequency (less than 2 percent of the modeling period), throughout the entire 50-mile-long modeling area downstream of the plant.
- Thallium concentrations in Lick Creek also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for the entire modeling period. On rare occasions (less than 1 percent of the modeling period), thallium concentrations in reaches downstream in the White River also exceed this benchmark.

These downstream exceedances occur in 26 miles of the modeling area downstream of the plant and up to 31 miles downstream of the plant.

- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in Lick Creek exceed the water quality benchmark for consumption of water and organisms (170 µg/L). These exceedances do not occur downstream after the confluence of the Lick Creek and White River.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of Lick Creek and the White River may be more at risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to copper, selenium, and cadmium under baseline conditions, as discussed below:

- Copper concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (9.0 µg/L) for 45 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Copper concentrations in Lick Creek also exceed the higher freshwater aquatic life criteria for acute exposure (13 µg/L) for 25 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Selenium concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (5.0 µg/L) for 99 percent of the modeling period. On rare occasions (less than 1 percent of the modeling period), selenium concentrations in reaches downstream in the White River also exceed this benchmark. These downstream exceedances occur in 21 miles of the modeling area downstream of the plant and up to 32 miles downstream of the plant.
- Cadmium concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 86 percent of the modeling period. On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in reaches downstream in the White River also exceed this benchmark. These downstream exceedances occur in 18 miles of the modeling area downstream of the plant.

These modeling results indicate that, under baseline conditions, aquatic organisms residing in the portions of Lick Creek and the White River with modeled exceedances may be more at risk to negative impacts from chronic exposure to cadmium and selenium. Additionally, the copper loadings from Petersburg Generating Station may pose a threat from chronic or acute exposure.

Under baseline conditions, the modeled pollutant concentrations in Lick Creek and downstream reaches in the White River exceed the MCL drinking water benchmarks for five modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for thallium, selenium, arsenic, lead, and cadmium as discussed below:

- Thallium concentrations in Lick Creek exceed the MCL benchmark (2 µg/L) for 96 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Selenium concentrations in Lick Creek exceed the MCL benchmark (50 µg/L) for 38 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Arsenic concentrations in Lick Creek exceed the MCL benchmark (10 µg/L) for 34 percent of the modeling period. These exceedances occur in 8.0 miles of the modeling area downstream of the plant and up to 35 miles downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), lead concentrations in Lick Creek exceed the MCL benchmark (15 µg/L). These exceedances continue to occur downstream in 24 miles of the White River as far as the end of the model (50 miles downstream of the plant discharge).
- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in Lick Creek exceed the MCL benchmark (0.25 µg/L). These exceedances do not occur downstream after the confluence of the Lick Creek and White River.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for nickel or zinc. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, copper, lead, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of all modeled pollutants in the immediate receiving water (Lick Creek), which will greatly improve water quality. The final modeling results also demonstrate that the reduction of pollutant loadings from Petersburg Generating Station will significantly reduce the concentrations of selenium and thallium in the White River, downstream of Lick Creek. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for Lick Creek and the White River reveal the following water quality improvements under the final rule:

- For arsenic:
    - Exceedances of the MCL benchmark are eliminated in Lick Creek. Despite the continued exceedances of this benchmark, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the human health risk.
    - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 100 percent to 87 percent of the modeling

period in Lick Creek. Despite the continued exceedances of this human health criteria, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated organisms.

- For cadmium:
  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For copper:
  - Exceedances of the aquatic life water quality criteria for chronic and acute impacts (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For lead:
  - Exceedances of the MCL benchmark are eliminated in Lick Creek. Despite the continued exceedances of this benchmark, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the human health risk.
- For selenium:
  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For thallium:
  - Exceedances of the MCL benchmark reduce in frequency from 96 percent to less than 1 percent of the modeling period in Lick Creek.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 100 percent to 84 percent of the modeling period in Lick Creek. Exceedances of this benchmark are eliminated through the modeling area downstream of the immediate receiving water (after the confluence of the Lick Creek and White River).
  - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 100 percent to 61 percent of the modeling period in Lick Creek. Exceedances of this benchmark are eliminated through the modeling area downstream of the immediate receiving water (after the confluence of the Lick Creek and White River).

The final rule modeling results demonstrate that, due to background concentrations of arsenic from upstream sources, there will still be exceedances of the human health water quality benchmark for consumption of water and organisms throughout the entire modeling area downstream of the plant; however, the final rule will reduce the arsenic loadings that the Petersburg Generating Station contributes to the White River.

Modeling Results – Wildlife

Under baseline conditions, Lick Creek may pose a risk to minks and eagles that consume fish contaminated with selenium. The average modeled selenium concentration in Lick Creek is more than 18 times greater than the concentration that would translate to NEHC exceedances for minks and eagles, demonstrating that this portion of the immediate receiving water may pose a potential reproductive threat to terrestrial food webs. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to these indicator species.

Modeling results indicate that on rare occasions (less than 1 percent of the modeling period), nickel concentrations in benthic sediment downstream reaches exceed the CSCL benchmark (18 mg/kg). These exceedances occur in 3.0 miles of the modeling area downstream of the plant and up to 35 miles downstream of the plant.

The case study modeling results demonstrate that the final rule will significantly reduce pollutant concentrations and the associated impacts to wildlife that inhabit Lick Creek. The final rule will eliminate selenium exceedances of the NEHC benchmarks for minks and eagles in all modeled reaches of Lick Creek. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million LECR. Under baseline conditions, the average water column concentration of arsenic in the immediate receiving water over the modeling period results in an estimated cancer risk of approximately 3-in-a-million for adult subsistence fishers. Therefore, adults who frequently consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer.

Based on the average pollutant concentrations in the water column under baseline conditions, cadmium, selenium, and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average thallium concentrations in Lick Creek are significantly greater than the concentrations that would translate to exceedances of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated), with some cohorts potentially being exposed to concentrations more than 200 times the reference dose. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.

- Average selenium concentrations in Lick Creek are greater than the concentration that would translate to exceedances of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated). The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.
- Average cadmium concentrations in Lick Creek are greater than the concentration that would translate to exceedances of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.

Therefore, humans who consume thallium-, selenium-, or cadmium-contaminated fish inhabiting Lick Creek may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in selenium and cadmium concentrations in Lick Creek, which will eliminate exceedances of the non-cancer health effects reference dose for all cohorts for these pollutants. While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference doses for all cohorts, the final rule will reduce the magnitude of the human health impacts and reduce thallium loading contributions from Petersburg Generating Station.

Interpretation of Lick Creek and White River Results

Case study modeling results for Lick Creek indicate that there are severe water quality, wildlife, and human health impacts in Lick Creek. Case study modeling of Lick Creek reveals more exceedances of water quality and human health benchmarks than the IRW model; however, the IRW model predicts more impacts to benthic organisms than the case study modeling results. The exceedances identified in Lick Creek are based solely on discharges of the evaluated wastestreams from Petersburg Generating Station because EPA did not identify any STORET monitoring data or point sources suggesting any other sources were contributing pollutant discharges on this small tributary.

The pollutant loadings discharged by Petersburg Generating Station contribute to the overall concentrations in the White River, along with other upstream sources. Case study modeling indicates that some of the water quality impacts identified in Lick Creek for arsenic, cadmium, selenium, thallium, and lead can occur in the White River, far downstream of where Lick Creek flows into it. For thallium, these downstream impacts are solely caused by the discharges of the evaluated wastestreams from the plant because EPA did not identify any other sources of thallium within the modeling period. For arsenic and lead, the projected exceedances are driven by the background concentrations flowing into the White River modeling area. Pollutant loadings from Petersburg Generating Station may be further impairing the degraded waterway for arsenic and lead. For lead and zinc, the average water column concentrations are highest downstream in the White River, indicating that pollutants with high partition coefficients may pose a greater threat to humans and aquatic life in the White River than in Lick Creek. The case study modeling results suggest that while high concentrations of toxic pollutants may dilute once Lick Creek empties into the White River, there are still impacts downstream that are not captured by the IRW model.

Under the final rule, case study modeling of Lick Creek and the White River indicate that both these waterbodies will exhibit fewer exceedances of water quality benchmarks. Additionally, Lick Creek will no longer pose reproductive risks to higher trophic-level wildlife and will pose less risk to humans consuming fish for cancer and non-cancer impacts. Case study modeling predicts more water quality improvements in the modeling area than the IRW model. This is due in part to the greater water quality impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the White River that were not evaluated as part of the IRW model. Case study modeling predict fewer human health improvements than the IRW model. The average pollutant concentrations throughout the entire modeling area reduce promptly after compliance with the final rule.

8.2.4 Ohio River Case Study

The 948-mile Ohio River flows westward from Pittsburgh, Pennsylvania, to Cairo, Illinois, where it meets the Mississippi River. According to 2013 TRI reporting, 23 million pounds of chemicals were discharged into the Ohio River, more than any other surface water in the TRI database [U.S. EPA, 2013a]. EPA identified that 24 steam electric power plants evaluated in the EA discharge one or more of the evaluated wastestreams to the Ohio River or to tributaries that flow into the Ohio River in under five miles. FirstEnergy Corp. (FirstEnergy) owns and operates several of the coal-fired power plants that discharge to the Ohio River.

The Bruce Mansfield plant (Plant ID 2269) is FirstEnergy's largest coal-fired power plant by nameplate capacity. The plant is located in Shippingport, Pennsylvania, along the Ohio River, approximately 25 miles northwest of Pittsburgh. This plant operates three stand-alone steam turbines, each with a nameplate capacity of 914 MW. These three generating units have a total capacity of 2,741 MW and reported producing approximately 19,000,000 MWh of electricity in 2009 [ERG, 2015j]. The Bruce Mansfield plant discharges FGD wastewater and bottom ash transport water directly to the Ohio River from the Little Blue Run surface impoundment, which straddles the border of Pennsylvania and West Virginia. Table 8-5 contains general information about the three coal-fired generating units at the Bruce Mansfield plant.

Located along the Ohio River in Stratton, Ohio, FirstEnergy's W.H. Sammis plant (Plant ID 103) is the largest coal-fired power plant in Ohio. W.H. Sammis Plant's seven stand-alone steam turbine generating units have a total nameplate capacity of 2,460 MW. Based on data EPA obtained in responses to the Steam Electric Survey, the W.H. Sammis plant reported generating more than 9,500,000 MWh of energy with these seven coal-fired generating units in 2009. The W.H. Sammis plant discharges three of the evaluated wastestreams (FGD wastewater, bottom ash transport water, and combustion residual leachate) directly to the Ohio River. Table 8-6 contains general information about each of the seven steam electric generating units at the W.H. Sammis plant.

Table 8-5. Summary of Bruce Mansfield Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	914	Wet scrubber [a]	Wet handled to impoundment	Wet system (1975)
2	Bituminous coal and No. 2 fuel oil	914	Wet scrubber [a]	Wet handled to impoundment	Wet system (1977)
3	Bituminous coal and No. 2 fuel oil	914	Dry conveyed	Wet handled to impoundment	Wet system (1980)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – EPA does not consider the ash collected by venturi-type wet scrubbers as fly ash, and therefore, the water generated by these systems is not considered fly ash transport water.

Table 8-6. Summary of W.H. Sammis Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
2	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
3	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
4	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
5	Bituminous coal, subbituminous coal, and No. 2 fuel oil	334	Dry conveyed	Wet handled to impoundment	Wet system (2010)
6	Bituminous coal, subbituminous coal, and No. 2 fuel oil	680	Dry conveyed	Wet handled to impoundment	Wet system (2010)
7	Bituminous coal, subbituminous coal, and No. 2 fuel oil	680	Dry conveyed	Wet handled to impoundment	Wet system (2010)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

In estimating the historical pollutant loadings associated with W.H. Sammis' three FGD systems, EPA incorporated the pollutant loadings for FGD wastewater as the systems were installed, between March and May 2010. EPA did not model any FGD wastewater pollutant loadings in the model prior to the installation of W.H. Sammis plant's first FGD system.

Modeling Area

The Ohio River WASP model encompasses a 49-mile-long reach of the Ohio River, 37 miles of which is downstream of one or both of the two modeled steam electric power plant immediate receiving waters. Located furthest upstream, the Bruce Mansfield plant discharges approximately 12 miles downstream of the start of the modeling area. The immediate receiving water that the Bruce Mansfield plant discharges to is approximately 3.3 miles long, as defined in the WASP model. W.H. Sammis plant discharges 13 miles downstream of the Bruce Mansfield plant's immediate receiving water. The immediate receiving water that W.H. Sammis plant discharges to is approximately 3.4 miles long, as defined in the WASP model. The modeling area ends just upstream of the discharges from another steam electric power plant, the Cardinal plant (Plant ID 3265). EPA did not model the pollutant loadings from the Cardinal plant because of CBI claims on one or more of the evaluated wastestream flow rates. Figure 8-5 illustrates the location and extent of the Ohio River WASP model.

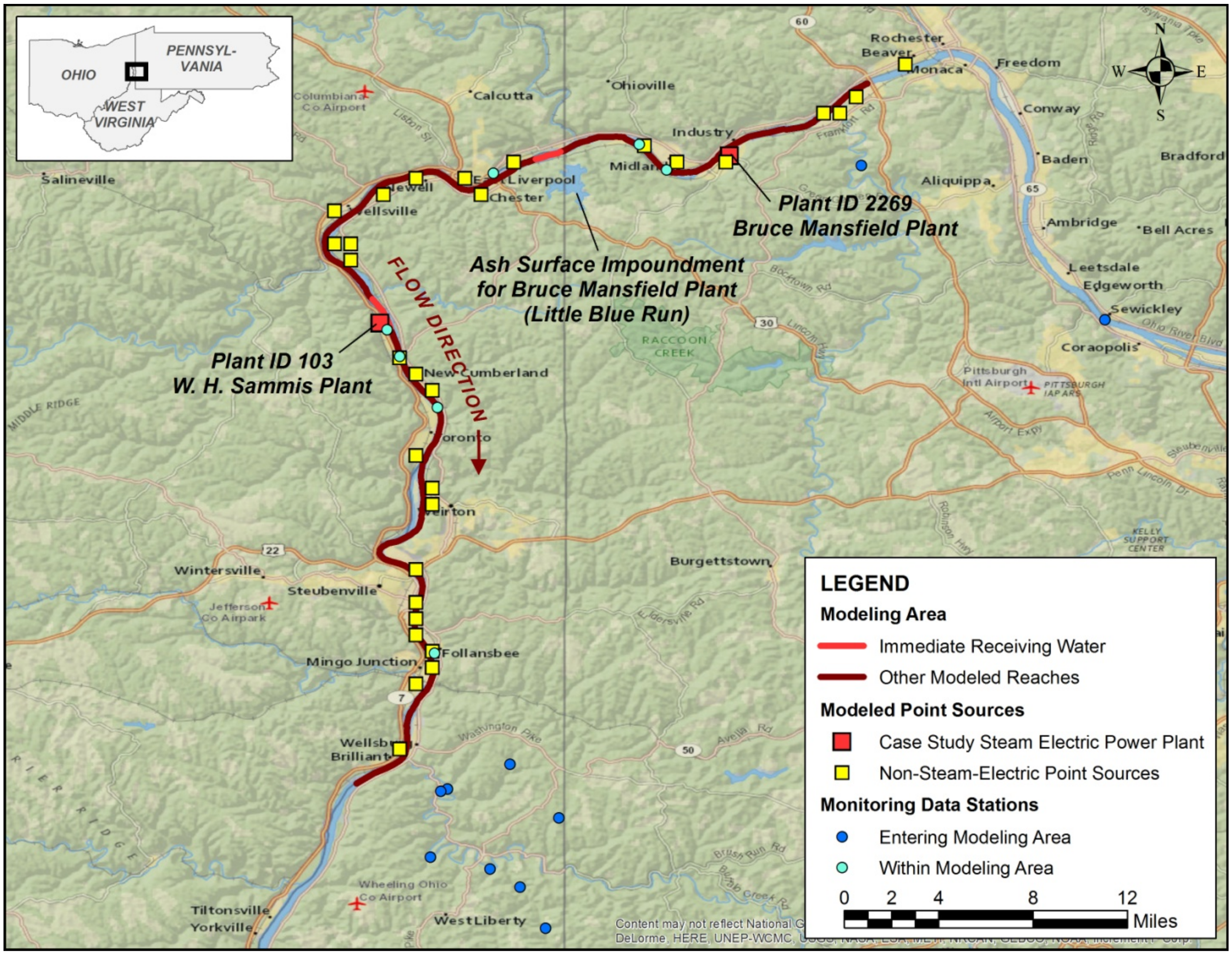


Figure 8-5. Ohio River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Ohio River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA identified many upstream non-steam-electric point sources whose pollutant loadings could influence the model results. EPA identified STORET data from one monitoring station on the Ohio River (approximately 28 river-miles upstream of Bruce Mansfield plant's immediate receiving water). EPA incorporated the monitoring data (which encompass five of the modeled pollutants) to represent the pollutant contributions flowing into the modeling area. EPA identified additional STORET monitoring data from one station on a tributary to the Ohio River; EPA incorporated these data to represent pollutant contributions flowing in from that tributary. EPA also incorporated the pollutant loadings, based on DMR and TRI data, from seven non-steam-electric point sources upstream of the Bruce Mansfield plant's immediate receiving water to account for the pollutant contributions not captured by the STORET monitoring data.
- **Downstream pollutant contributions**. EPA incorporated STORET data from eight monitoring stations to represent TSS concentrations flowing into the modeling area downstream of both steam electric power plant immediate receiving waters (*i.e.*, tributaries flowing into the Ohio River). These monitoring stations all represent one tributary that flows into the Ohio River near the downstream end of the modeling area. EPA identified 29 non-steam-electric point sources whose pollutant loadings could influence the model results downstream of the Bruce Mansfield plant immediate receiving water and incorporated these pollutant loadings into the Ohio River WASP model.
- **Monitoring data within the modeling area.** EPA compiled STORET data from seven monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of copper, lead, nickel, and zinc from upstream sources are significantly greater than the pollutant loadings from the Bruce Mansfield and W.H. Sammis plants.

The Ohio River case study model did not account for the documented surface water and ground water impacts from Bruce Mansfield or Little Blue Run that are listed in Appendix A. In 1993, a catastrophic release of steam electric power plant wastewater compromised the quality of ground water and surface water around the Bruce Mansfield plant and Little Blue Run impoundment. Due to the lack of pollutant loadings data, surface water quality impacts resulting from this event are not reflected in this model; therefore, the case study modeling could underrepresent the actual baseline impacts of the Bruce Mansfield plant on the Ohio River.

Modeling Period

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Bruce Mansfield and W.H. Sammis plants will achieve the limitations under the final rule by 2020 and 2021, respectively. EPA focused the assessment of the improvements under the final rule on the period after the 2021 assumed compliance date.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the modeled portion of the Ohio River exceed a human health NRWQC water quality benchmark for one modeled pollutant (arsenic), indicating that arsenic loadings from the two steam electric power plants may contribute to a quantifiable reduction in water quality in the modeled portions of the Ohio River. Arsenic concentrations in 33 miles of the modeling area downstream of the Bruce Mansfield plant exceed the human health water quality benchmark for consumption of water and organisms (0.018 µg/L). These exceedances begin several miles downstream of the Bruce Mansfield plant due to the pollutant loadings from a non-steam-electric point source. This area of exceedances continues downstream of the W.H. Sammis plant for 24 miles (including the W.H. Sammis plant's immediate receiving water) and exceeds the arsenic benchmark during 30 percent of the modeling period. In some portions of the modeling area, the frequency of these exceedances increases due to arsenic contributions from other non-steam-electric point sources. These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of the Ohio River may be more at risk of the negative effects associated with oral exposure to arsenic (see Section 3.1.1). On rare occasions (less than 1 percent of the modeling period), the modeled pollutant concentrations exceed the MCL drinking water benchmark for one pollutant (lead), indicating that lead loadings from the two steam electric power plants may contribute to a quantifiable reduction in water quality in the modeled portions of the Ohio River. These rare lead exceedances occur in 15 miles of the modeling area downstream of the Bruce Mansfield plant, of which 13 miles are also downstream of the W.H. Sammis plant (including the immediate receiving water).

Modeling results do not indicate any exceedances of human health NRWQC criteria for the other modeled pollutants (cadmium, copper, nickel, selenium, thallium, and zinc) and do not indicate any exceedances of aquatic life NRWQC or MCL criteria for any of the eight modeled pollutants. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic and lead. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of four of the modeled pollutants (arsenic, cadmium, selenium, and thallium) in the modeled portion of the Ohio River, which will improve water quality. These pollutant removals result in less frequent exceedances of human health NRWQC benchmarks compared to those estimated in the baseline modeling. Arsenic exceedances of human health water quality benchmarks for consumption of water and organisms reduce in frequency from 30 percent to 6 percent of the modeling period in the W.H. Sammis plant's immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of the arsenic human health criteria and the lead MCL benchmark, reducing the pollutant concentrations in the water column may decrease the risk to humans.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Ohio River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks for any of the eight modeled pollutants; therefore, the modeled portion of the Ohio River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

Under baseline conditions, the average concentration of arsenic in fish over the modeling period does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, thallium poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Average thallium concentrations in the W.H. Sammis plant's immediate receiving water are greater than the concentration that would translate to exceedances of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. Average thallium concentrations in 24 miles of the modeling area downstream of the W.H. Sammis plant are high enough to trigger exceedances of the reference dose for at least one subsistence cohort. Therefore, humans who consume fish inhabiting these waters may be at greater risk for developing the negative health effects associated with thallium, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in thallium, eliminating thallium exceedances of the non-cancer health effects reference dose throughout the entire modeling area.

Interpretation of Ohio River Results

Case study modeling results for the Ohio River indicate greater water quality and human health impacts under baseline conditions than predicted by the IRW model. The impacts identified in the Ohio River by case study modeling are more extensive than the IRW model because EPA has accounted for pollutant contributions from upstream on the Ohio River, other waterways flowing into the Ohio River, and non-steam electric point sources. Modeled alone, the Bruce Mansfield plant and W.H. Sammis plant would not cause any quantifiable impacts over the modeling period; however the modeled potion of the Ohio River is heavily industrialized. EPA identified 34 non-steam electric point sources that discharge one or more of the modeled pollutants and report to DMR or TRI. The pollutant contributions from the Bruce Mansfield plant, W.H. Sammis plant, and these other non-steam electric point sources modeled accumulate in the waterbody, increasing the overall water column concentrations to a degree that adversely affects water quality and human health. EPA identified exceedances of human health benchmarks that indicate that consuming water and/or organisms from the modeled portion of the Ohio River, including the W.H. Sammis plant's immediate receiving water and areas downstream, can cause health problems related to arsenic, lead, or thallium. The Ohio River case study model results exemplify that, by not accounting for non-steam-electric point sources discharging to the same waterbodies as steam electric power plants, the IRW model may be under-representing the total number of receiving waters with impacts that are caused, in part, by pollutant contributions from the steam electric power generating industry. The case modeling results also suggest that the discharges of the evaluated wastestreams from Bruce Mansfield plant and W.H. Sammis plant may be further impairing the degraded waterway.

Case study modeling of the Ohio River indicates that, under the final rule, the Ohio River will exhibit less frequent exceedances of water quality benchmarks and will eliminate risk to humans consuming fish that inhabit these waters. The human health non-cancer impacts and improvements under the final rule are solely caused by the reduction in steam electric plant pollutant loadings (there are no other input sources of thallium in the Ohio River WASP model).The improvements identified by the case study model are more extensive than what was projected by the IRW model for either of Bruce Mansfield plant or W.H. Sammis plant. This is due in part to the greater water quality and human health impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the Ohio River that were not evaluated as part of the IRW model. The average pollutant concentrations throughout the entire modeling area reduce within a year after compliance with the final rule.

8.2.5 <u>Mississippi River Case Study</u>

The Mississippi River watershed is the largest in North America, covering about 40 percent of the lower 48 states. The 190-mile stretch of the Mississippi River between the confluence with the Missouri River at St. Louis, Missouri, and the confluence with the Ohio River at Cairo, Illinois, is known as the Middle Mississippi River. South of St. Louis along this stretch of the river, Ameren Corporation operates the Rush Island steam electric power plant (Plant ID 5038) on the west bank of the Mississippi River. The Rush Island plant operates two stand-alone steam turbine units with a nameplate capacity of 670 MW each. Together, these two coal-fired generating units have a capacity of 1,340 MW and reported producing over 8,500,000 MWh of electricity in 2009 in the Steam Electric Survey. The Rush Island plant discharges fly ash and bottom ash transport water directly to the Mississippi River. Table 8-7 contains general information on the two coal-fired units at the Rush Island plant.

Table 8-7. Summary of Rush Island Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Subbituminous coal and No. 2 fuel oil	670	Dry conveyance & wet handled to impoundment	Wet handled to impoundment	No FGD system
2	Subbituminous coal and No. 2 fuel oil	670	Dry conveyance & wet handled to impoundment	Wet handled to impoundment	No FGD system

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Mississippi River WASP model encompasses a 46-mile-long reach of the Mississippi River, 23 miles of which is downstream of the Rush Island plant immediate receiving water. The model has two start boundaries that are on the Meramec River and Mississippi River shortly upstream of their confluence. The immediate receiving water that the Rush Island plant discharges to is approximately 1.5 miles long, as defined in the WASP model. This model ends at the confluence of the Mississippi River and Kaskaskia River. Figure 8-6 illustrates the location and extent of the Mississippi River WASP model.

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Mississippi River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions from non-steam-electric point sources**. EPA identified several upstream non-steam-electric point sources whose loadings could influence the model results. EPA therefore extended the modeling area upstream to model these point sources and incorporate upstream monitoring data. EPA identified STORET data from four monitoring stations on the Mississippi River prior to the confluence with the Meramec River (approximately 24 river-miles upstream of Rush Island's immediate receiving water). EPA incorporated the monitoring data (which encompass all of the modeled pollutants except for thallium) to represent the pollutant contributions in the Mississippi River prior to where it converges with the Meramec River. EPA assumed that the monitoring data adequately reflect the pollutant contributions from upstream of this confluence. EPA incorporated the pollutant loadings from three non-steam-electric point sources downstream of the convergence to account for the pollutant contributions not captured by the STORET monitoring data.
- **Upstream pollutant contributions from steam electric sources**. EPA identified one steam electric power plant, Ameren's Meramec plant (Plant ID 1435), whose loadings could influence the model results at the Rush Island immediate receiving water and other downstream locations. EPA incorporated the loadings from the Meramec plant into the extended Mississippi River model, as discussed further below.

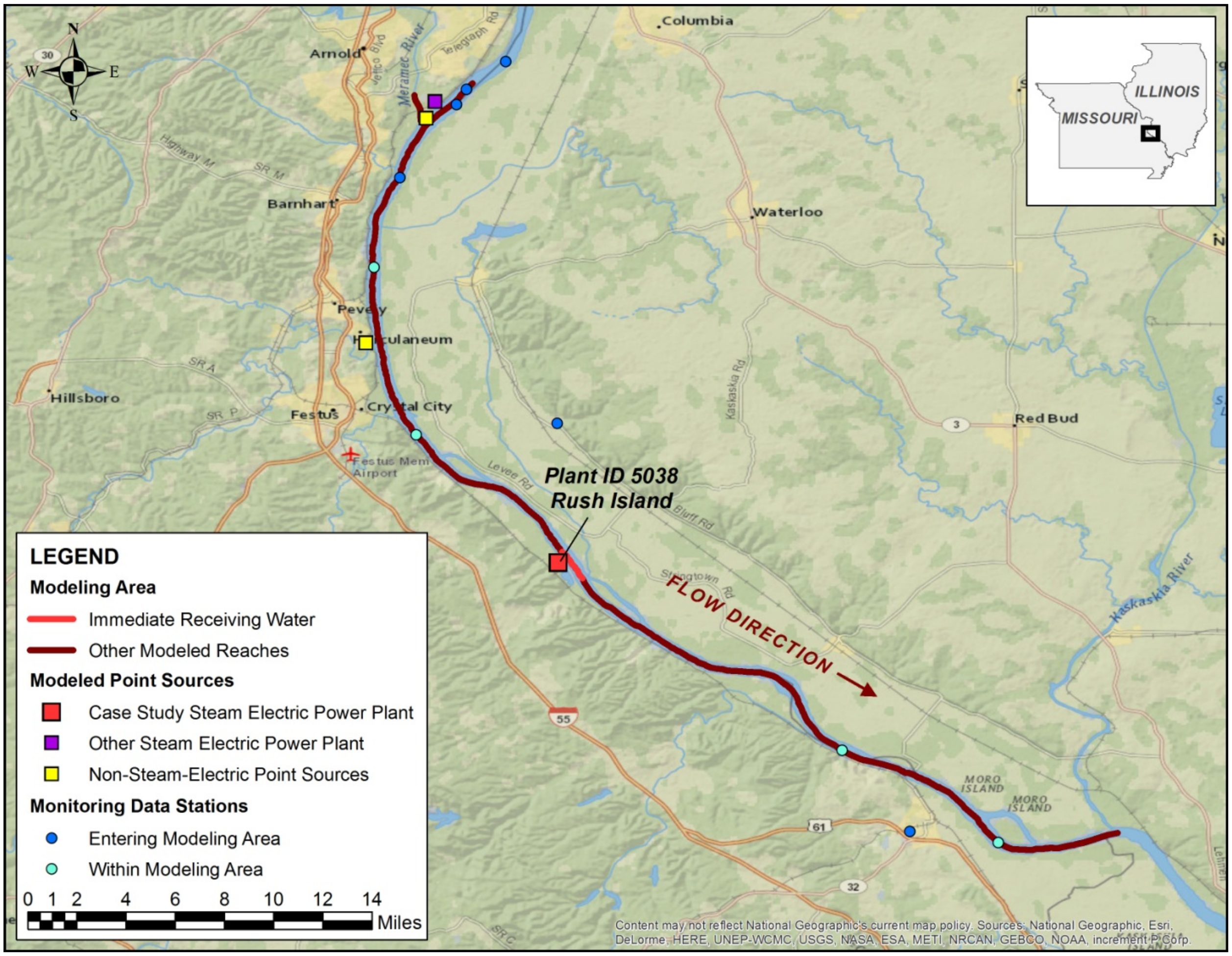


Figure 8-6. Mississippi River WASP Modeling Area

- **Downstream pollutant contributions**. EPA incorporated STORET data from two monitoring stations to represent pollutant concentrations flowing into the modeling area downstream of the Rush Island immediate receiving water (*i.e.*, tributaries flowing into the Mississippi River). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.
- **Monitoring data within the modeling area**. EPA compiled STORET data from four monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The Meramec plant discharges approximately 24 river miles upstream of the Rush Island plant's immediate receiving water. EPA did not identify STORET monitoring data between the two plants to represent the pollutant concentrations from the Meramec plant; therefore, EPA incorporated the pollutant loadings from the Meramec plant (as calculated for this rulemaking) into the Mississippi River model. The Meramec plant operates four coal-fired generating units with a total nameplate capacity of 923 MW. All pollutant loadings from the evaluated wastestreams are from bottom ash transport water. EPA assumed that the Meramec plant will comply with the standards of the final rule by 2019. EPA did not evaluate the water quality, wildlife, or human health impacts associated with discharges from the Meramec plant because this plant did not meet the case study location selection criteria described in Section 8.1.1. EPA incorporated the loadings from Meramec plant solely to account for the upstream pollutant contributions flowing into the Rush Island plant's immediate receiving water from upstream, under baseline conditions and the final rule.

The contributions of arsenic, cadmium, copper, lead, nickel, and zinc from upstream sources are significantly greater than the pollutant loadings from the Rush Island plant.

Modeling Period

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Meramec and Rush Island plants will achieve the limitations under the final rule by 2019 and 2023, respectively. For the Rush Island plant's immediate receiving water and downstream reaches, EPA focused the assessment of the baseline impacts and improvements under the final rule on the period after the 2023 assumed compliance date.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the Rush Island plant's immediate receiving water and downstream reaches exceed human health NRWQC water quality benchmarks for one modeled pollutant (arsenic), indicating that loadings from Rush Island may contribute to a quantifiable reduction in water quality in the modeled portions of the Mississippi River. Arsenic concentrations in the Rush Island plant's immediate receiving water exceed the human health water quality benchmark for consumption of water and organisms (0.018 µg/L) and the human health water quality benchmark for consumption organisms (0.14 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 23-mile-long modeling area downstream of the plant. The case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms that inhabit these modeled portions of the Mississippi River may be more at risk of the negative effects associated with oral exposure to arsenic (see Section 3.1.1).

Modeling results do not indicate any exceedances of human health NRWQC benchmarks for the other modeled pollutants (cadmium, copper, nickel, lead, selenium, thallium, and zinc). In addition, modeling results do not indicate any exceedances of aquatic life NRWQC or MCL criteria for any of the eight modeled pollutants. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic. This figure also presents the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling continues to show human health NRWQC benchmark exceedances for arsenic within the Mississippi River due to additional arsenic contributions from other sources (*i.e.*, Mississippi River background concentrations and non-steam electric point sources). However, under the final rule, both the Meramec and Rush Island plants will no longer discharge any of the evaluated wastestreams and will therefore no longer contribute to the arsenic or lead impairment of the Mississippi River.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Mississippi River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks of for any of the eight modeled pollutants; therefore, the modeled portion of the Mississippi River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million LECR. Under baseline conditions, the average water column concentration of arsenic throughout the modeling area downstream of the plant results in an estimated cancer risk greater than 1-in-a-million for adult subsistence fishers. Therefore, humans who consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer. Modeling results demonstrate no reduction in the cancer risk from inorganic arsenic under the final rule.

Under baseline conditions, the average pollutant concentrations over the modeling period does not pose the threat to cause non-cancer health effects for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated).

Interpretation of Mississippi River Results

Case study modeling results for the Mississippi River indicate greater water quality and human health impacts under baseline conditions than predicted by the IRW model. By accounting for pollutant contributions from background and upstream sources, the case study model predicts higher pollutant concentrations under baseline conditions. For arsenic, the projected exceedances are driven by the pollutant contributions entering the Mississippi River upstream of the Rush Island plant. Alone, the steam electric discharges of the evaluated wastestreams would not cause any quantifiable impacts, which is consistent with the IRW model results; however, the pollutant loadings from the Rush Island plant may be further exacerbating the impairment of the degraded waterway.

The case study modeling of the Mississippi River indicates that, under the final rule, it will continue to exceed all of the water quality and human health benchmarks observed at baseline, with little to no reduction in frequency. Under the final rule, the Rush Island plant will no longer discharge any fly ash or bottom ash transport water. After compliance with the final rule, the modeled steam electric power plants will no longer contribute to the impairment of the Mississippi River and the overall magnitude of the pollutant concentrations in the aquatic system will decrease.

8.2.6 Lake Sinclair Case Study

Lake Sinclair is a reservoir located in central Georgia. The lake was created in 1953 when the waters of the Oconee River were dammed by Georgia Power, a subsidiary of Southern Company, to create a hydroelectric generating station. Georgia Power also owns and operates Plant Harllee Branch (Plant ID 5762), a steam electric power plant situated on the northern shore of Lake Sinclair. Based on 2009 data obtained in responses to the Steam Electric Survey, Plant Harllee Branch operated four coal-fired generating units with a total nameplate capacity of 1,750 MW and produced more than 6,800,000 MWh of electricity in 2009. As of April 16, 2015 (the date by which the plant would be required to comply with the U.S. EPA's Clean Power Plan [Clean Air Act Section 111(d)]), this plant has decertified and retired all four of its coal-fired generating units. Georgia Power cited several factors, including the cost to comply with existing and future environmental regulations, recent and future economic conditions, and lower natural gas prices, in the decision to close the plant. Plant Harllee Branch discharged FGD wastewater, fly ash transport water, and bottom ash transport water directly to Lake Sinclair. Table 8-8 contains general information on the four coal-fired units at Rush Island Plant.

Despite the retirement of all coal-fired generating units at this plant, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric discharges on lentic waterbodies (including the 26 lake, pond, and reservoir receiving waters evaluated in this EA) and the potential environmental improvements that could reasonably be expected under the final rule in other lentic waterbodies that receive discharges of the evaluated wastestreams. EPA did not include Plant Harllee Branch or Lake Sinclair in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

In estimating the historical pollutant loadings associated with Plant Harllee Branch, EPA incorporated the loadings only from generating unit IDs 3 and 4 because generating unit IDs 1 and 2 were flagged for retirement at the time of the proposed revised ELGs. EPA incorporated the loadings with the FGD wastewater as the systems were installed (starting in 2013). EPA did not model any FGD wastestream loadings in the historical model prior to the installation of Plant Harllee Branch's first FGD system.

Table 8-8. Summary of Plant Harllee Branch Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1 [a]	Bituminous coal and No. 2 fuel oil	299	Wet handled to impoundment	Wet handled to impoundment	Wet system (2014)
2 [a]	Bituminous coal and No. 2 fuel oil	359	Wet handled to impoundment	Wet handled to impoundment	Wet system (2014)
3	Bituminous coal and No. 2 fuel oil	544	Wet handled to impoundment	Wet handled to impoundment	Wet system (2013)
4	Bituminous coal and No. 2 fuel oil	544	Wet handled to impoundment	Wet handled to impoundment	Wet system (2013)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – EPA did not model any pollutant loadings associated with these generating units.

Modeling Area

As discussed in Section 8.1.1, EPA relied upon the availability of existing models to perform case study modeling of lentic systems: an existing WASP model that divided the waterbody into segments and EFDC model that provided hydrodynamics and simulated the aquatic system in three dimensions. The EFDC model uses stretch or sigma vertical coordinates and Cartesian coordinates to represent the physical characteristics of Lake Sinclair.

The three-dimensional EFDC model, which provides the hydrodynamic foundation for the WASP model, divides the waterbody into 1,235 segments; each segment represents a unique location and stratum within Lake Sinclair. The model accounts for a total volume of approximately 340 million cubic meters. In contrast to the WASP models that EPA developed to model lotic systems, the Lake Sinclair model is not set up to quantify the pollutant concentrations in the benthic sediment; therefore, EPA was unable to assess whether pollutant accumulation in the sediment was occurring over prolonged discharge periods. Figure 8-7 illustrates the location and extent of the Lake Sinclair modeling area.

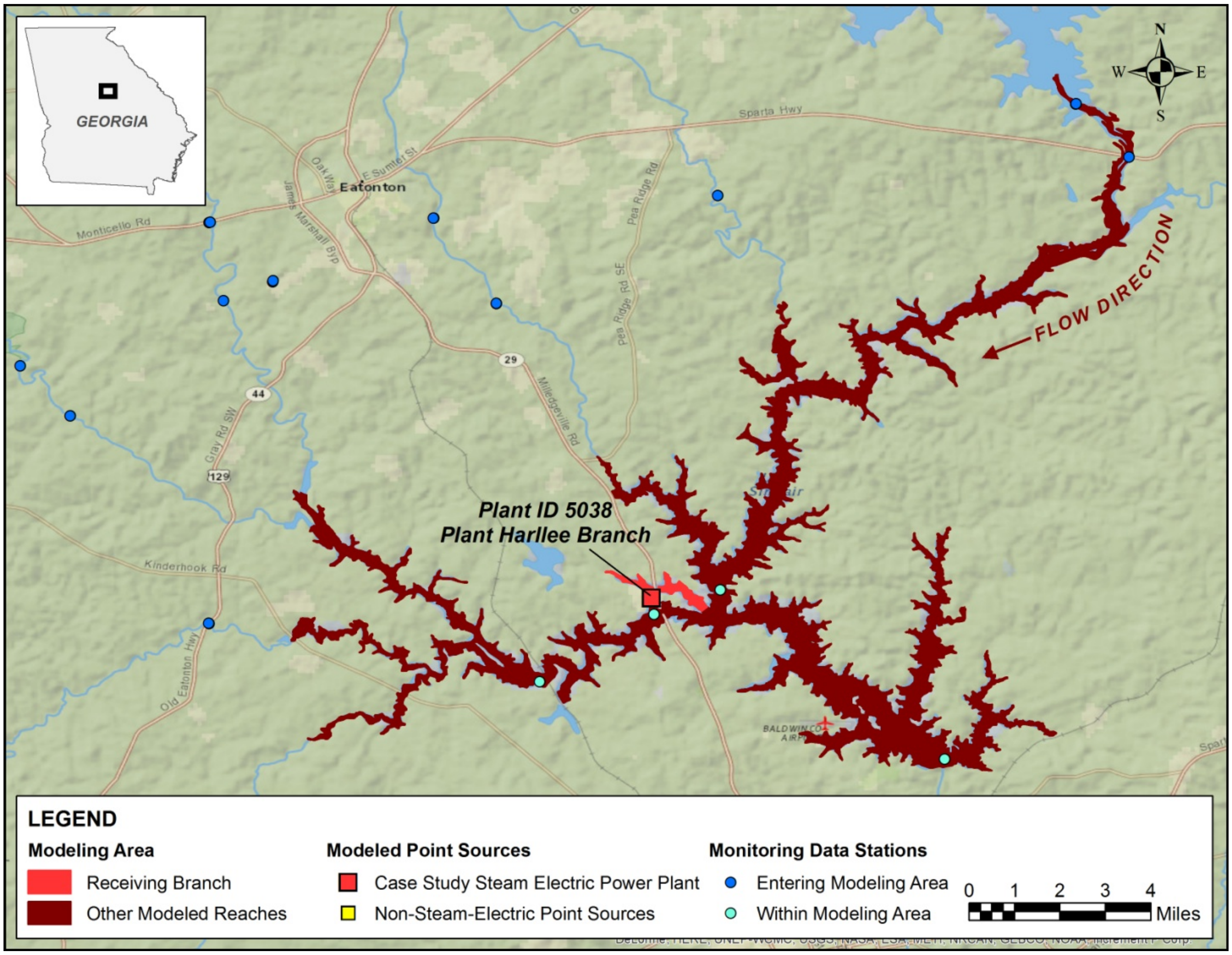


Figure 8-7. Lake Sinclair WASP and EDFC Modeling Area

<u>Identified Point Sources and Background Concentrations</u>

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Lake Sinclair water quality model to represent pollutant contributions from background and non-steam-electric point sources, and for use in validating and calibrating the model results.

- **Upstream pollutant contributions.** EPA incorporated STORET data from three monitoring stations to represent TOC and TSS contributions from upstream of Lake Sinclair on the Oconee River. EPA did not identify sufficient STORET monitoring data to represent the pollutant contributions of the eight modeled pollutants or any upstream non-steam-electric point sources with loadings for the eight modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column flowing into Lake Sinclair from the Oconee River.
- **Other pollutant contributions**. EPA incorporated STORET data from 15 monitoring stations to represent the modeled pollutants, TOC, and TSS concentrations flowing into Lake Sinclair from other streams. EPA did not identify any non-steam-electric

point sources whose pollutant loadings would significantly influence the model results.

- **Monitoring data within the modeling area.** EPA compiled STORET data from six monitoring stations located within the modeling area and used these data to calibrate the Lake Sinclair water quality model.

The pollutant concentrations entering the modeling area for arsenic, copper, lead, and thallium which EPA calculated using monitoring data, are much greater than the pollutant loadings from Lake Sinclair plant. The concentrations entering the modeling area for cadmium, nickel, and zinc also strongly influence the model outputs.

Modeling Period

As discussed earlier in this section, EPA adopted the preexisting Lake Sinclair EFDC model. The preexisting model was designed with seven years of hydrodynamic and flow input, limiting the length of the period EPA could model. Based on Plant Harllee Branch's NPDES permitting cycle, EPA assumed that the plant would have achieved the limitations under the final rule by 2019 if it continued to operate. The modeling period begins in February 2012 (approximately seven years before the assumed compliance date) and extends through November 2025 (approximately seven years after the assumed compliance date).

Modeling Results – Water Quality

EPA selected three portions of Lake Sinclair to evaluate the modeled pollutant concentrations: 1) the immediate receiving water (a 720,000-cubic-meter cell of the lake); 2) the average of all segments in the reach of the lake where Plant Harllee Branch discharges, including subsurface water segments (hereafter referred to as the "receiving branch"), and 3) the average of all segments included in the Lake Sinclair model, including subsurface water segments (hereafter referred to as the "entire modeling area").

Under baseline conditions, the modeled pollutant concentrations in Lake Sinclair, including the immediate receiving water and the receiving reach, exceed NRWQC water quality benchmarks for three modeled pollutants, indicating that pollutant loadings from Plant Harllee Branch may quantifiably reduce water quality in the modeled portions of Lake Sinclair. The reduced water quality is primarily attributed to arsenic, cadmium, and thallium.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic and thallium, as discussed below:

- Arsenic concentrations exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L):
    - In the immediate receiving water for the entire modeling period.
    - In all modeled segments of the receiving branch for more than 99 percent of the modeling period.
    - In 97 percent of the entire modeling area for 10 percent or more of the modeling period.

- Arsenic concentrations also exceed the higher water quality benchmark for consumption of organisms (0.14 µg/L):
    - In five of the six modeled segments of the receiving branch for up to 19 percent of the modeling period.
    - In 54 percent of the entire modeling area for 10 percent or more of the modeling period.
- Thallium concentrations exceed the water quality benchmark for consumption of water and organisms (0.24 µg/L):
    - In three of the six modeled segments of the receiving branch for up to 6 percent of the modeling period.
    - In 14 percent of the entire modeling area for 10 percent or more of the modeling period.
- Thallium concentrations also exceed the higher water quality benchmark for consumption of organisms (0.47 µg/L):
    - In two of the six modeled segments of the receiving branch for less than 1 percent of the modeling period.
    - In 11 percent of the entire modeling area for 10 percent or more of the modeling period.

The case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms that inhabit these modeled portions of Lake Sinclair may be more at risk of the negative effects associated with oral exposure to arsenic and thallium (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium under baseline conditions. Specifically, cadmium concentrations exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) in 4 percent of the entire modeling area for 10 percent or more of the modeling period. These case study modeling results indicate that, under baseline conditions, aquatic organisms inhabiting these modeled portions of Lake Sinclair could be at an elevated risk of the negative effects associated with oral exposure to cadmium (see Section 3.1.1).

Under baseline conditions, the modeled pollutant concentrations in Lake Sinclair occasionally exceed the MCL drinking water benchmarks for two of the modeled pollutants (arsenic and thallium), as discussed below:

- Arsenic concentrations exceed the MCL drinking water criteria (10 µg/L) in less than 1 percent of the segments for 10 percent or more of the modeling period.
- Thallium concentrations exceed the MCL drinking water criteria (2 µg/L) in 5 percent of the segments for 10 percent or more of the modeling period.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, lead, nickel, selenium, and zinc). Appendix G of this report includes figures that illustrate the average water column pollutant concentration output for the entire lake for arsenic, cadmium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased average concentrations of two of the modeled pollutants (nickel and selenium) in the modeled portion of Lake Sinclair. Case study modeling results for Lake Sinclair reveal the water quality improvements for arsenic under the final rule. Specifically, arsenic exceedances of the human health NRWQC benchmark for consumption of water and organisms reduce in frequency from the entire modeling period to 23 percent of the modeling period in the immediate receiving water and reduce from above 99 percent of the modeling period to as low as 23 percent of the modeling period in the receiving branch. Additionally, slightly less (2 percent of the modeling area) of Lake Sinclair will exceed this benchmark under the final rule. Arsenic exceedances of the higher human health NRWQC benchmark for consumption of organisms also reduce throughout the entire lake as 12 percent less of the modeling area exceed this benchmark for more than 10 percent of the modeling period.

While the modeling results demonstrate continuing arsenic, cadmium, and thallium exceedances of NRWQC and MCL benchmarks in the receiving reach and the entire modeling area, the pollutant loading contributions to the lake would be reduced under the final rule (if Plant Harllee Branch did not retire all generating units).

Modeling Results – Wildlife

For the analysis of wildlife impacts and improvements, EPA assumed that aquatic life travel freely throughout Lake Sinclair and do not confine themselves within particular segments of the lake. EPA calculated the average fish tissue concentrations of all segments within the Lake Sinclair model (*i.e.*, entire modeling area) for purposes of the wildlife assessment.

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of Lake Sinclair does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains (if Plant Harllee Branch did not retire all generating units).

The Lake Sinclair EFDC model is not set up to quantify the pollutant concentrations in the benthic sediment; therefore, EPA was unable to assess whether pollutant concentrations in the sediment exceeded CSCL benchmarks and pose a threat to benthic organisms.

Modeling Results – Human Health

For the analysis of human health impacts and improvements, EPA also assumed that fish travel freely throughout Lake Sinclair and do not confine themselves within particular segments of the lake. EPA calculated the average fish tissue concentrations of all segments within the Lake Sinclair model (*i.e.*, entire modeling area) for purposes of the human health assessment.

Under baseline conditions, the average water column concentration of arsenic in Lake Sinclair over the modeling period does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, thallium poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Average thallium concentrations in the water column of the entire Lake Sinclair modeling area are greater than the concentrations that would translate to exceedance of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated). Therefore, humans who consume thallium-contaminated fish inhabiting the modeled area of Lake Sinclair may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference dose, the final rule will reduce thallium loading contributions from Plant Harllee Branch (if Plant Harllee Branch did not retire all generating units).

Interpretation of Lake Sinclair Results

The case study modeling results indicate that the water quality impacts are greater in the receiving branch (closest portion of the lake to the Plant Harllee Branch discharge) of Lake Sinclair compared to the rest of the lake. EPA identified that the receiving branch of Lake Sinclair also exhibited more quantifiable improvements (*i.e.*, reduced NRWQC and MCL benchmark exceedances) under the final rule than the average of all Lake Sinclair model segments. Despite the model not indicating any wildlife or human health impacts in Lake Sinclair, the reduction of pollutant loadings under the final rule would lessen the contribution of steam electric power plant discharges on the entire aquatic and terrestrial ecosystems.

8.3 COMPARISON OF CASE STUDY AND IRW MODELING RESULTS

In general, the case study modeling results from the six case study models support the overall conclusions of the IRW model.

Case study modeling of smaller receiving waters, such as Black Creek and Lick Creek, indicate that more severe water quality, wildlife, and human health impacts are occurring at baseline conditions than the IRW model predicted. Since flow rates in small receiving waters fluctuate significantly, the case study modeling demonstrates impacts that can occur during periods when the flow is lower than the annual average used in the IRW model. During the frequent periods of low flow in smaller rivers and streams, the case study modeling shows that pollutant concentrations quickly climb to levels that will negatively affect fish, wildlife, and humans. The Black Creek and Lick Creek case study model also suggests the potential for additional improvements under the final rule than the IRW model predicts. Case study modeling therefore indicates that small receiving waters with highly variable flow rates may benefit from the final rule more than the IRW model results suggest.

The case study modeling also demonstrates that the impacts from steam electric power plant discharges can propagate much further downstream than the immediate receiving water used in the IRW modeling. In four of the six case study models, results illustrate that the pollutant loadings from steam electric power plant discharges of the evaluated wastestreams may contribute to water quality impacts up to 95 miles downstream of the plant discharge. These additional impacts, as well as additional improvements under the final rule, are not represented in the IRW modeling results.

Additionally, case study modeling of smaller water bodies revealed that downstream reaches may be heavily influenced by the sediment transport and exhibit much higher water column concentrations than the immediate receiving water. In the Black Creek, Etowah River, and White River results, “hot spots” with higher pollutant concentrations were observed and posed a greater risk to humans, aquatic life, and terrestrial food chains than reaches closer to the steam electric power plants.

EPA performed one case study model of a representative lentic receiving water to assess the potential impact on similar lakes or reservoirs that receive steam electric power plant discharges of the evaluated wastestreams. Case study modeling of Lake Sinclair showed that impacts are occurring in the lake, and these are more severe in the immediate area of the steam electric discharge as compared to the lake average. The water quality improvements demonstrated by the reduced exceedances of water quality benchmarks indicate that other lentic receiving waters may also exhibit similar improvements. Although the case study modeling of Lake Sinclair was unable to quantify the accumulation of pollutant concentrations in benthic sediment, lower concentrations of pollutants under the final rule should reduce pollutant long-term accumulation and consequential resuspension.

Each of the case study models demonstrated at least one exceedance of a water quality, wildlife, or human health benchmark for a modeled pollutant discharged from stream electric power plants. Under the final rule, the steam electric power plant(s) will contribute a reduced loading of the pollutant(s), thereby improving water quality in these receiving waters. As demonstrated by the Black Creek, Etowah River, Lick Creek and White River, Ohio River, and Lake Sinclair case study modeling results, pollutant removals will result in quantifiable improvements through reduced exceedances of environmental benchmarks.

SECTION 9
CONCLUSIONS

Based on evidence in the literature, damage cases, other documented impacts, and modeled receiving water pollutant concentrations, it is clear that current wastewater discharge practices at steam electric power plants are impacting the surrounding aquatic and terrestrial environments and pose a human health threat to nearby communities. EPA estimates that discharges from steam electric power plants contribute over one-third of the toxic-weighted pollutant loadings of the combined discharges of all industrial categories currently required to report discharges to U.S. waters. These discharges add large quantities of toxic bioaccumulative pollutants (*e.g.*, selenium, arsenic, and mercury) to the aquatic environment. Substantial evidence exists that pollutants from steam electric power plant wastewater discharges are transferring from the aquatic environment to terrestrial food webs; this indicates the potential for broader impacts to ecological systems by altering population diversity and community dynamics in the areas surrounding steam electric power plants. Ecosystem recovery from exposure to steam electric power plant wastewater discharges can be extremely slow and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years. The strong bioaccumulative properties and long residence times of pollutants in immediate receiving waters reinforce the threat of these wastes to the local environment, and many of the impacts may not be fully realized for years to come.

In addition, EPA's modeling demonstrates that pollutant loadings from discharges of the evaluated wastestreams are impacting areas beyond the immediate receiving waters and pose a threat to wildlife and human populations in thousands of river-miles downstream from steam electric power plants under current discharge practices. Furthermore, EPA predicts that the recently promulgated Clean Air Act requirements (*i.e.*, Clean Power Plan) and other state and local regulations may lead to additional air pollution controls (and resulting wastestreams) that will increase the pollutant loadings to surface waters in the future. These additional pollutant loadings above current baseline conditions will increase the number of immediate receiving waters exceeding water quality, wildlife, and human health benchmarks in the future.[65]

Steam electric power plants discharge wastewater into waterbodies used for recreation, and these discharges can present a potential threat to human health. Documented fish kills have resulted in states issuing fish advisories to protect the public from exposure to fish with elevated pollutant concentrations in recreational waters that receive these discharges. Combustion residual leachate from surface impoundments and landfills is known to impact off-site ground water and drinking water wells at concentrations above Maximum contaminant level (MCL) drinking water standards and pose a potential threat to human health.

---

[65] The analyses presented in this report incorporate some adjustments to current conditions in the industry. For example, these analyses account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants. These analyses also account for changes to the industry that are expected to occur as a result of the recent Coal Combustion Residuals (CCR) rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER). These analyses, however, do not reflect changes in the industry that may occur as a result of the proposed Clean Power Plan [Clean Air Act section 111(d)].

The final steam electric effluent limitations guidelines and standards (ELGs) will result in quantifiable improvements in ecological and human health by reducing immediate receiving water pollutant concentrations, on average, by 57 percent.[66] The final rule will result in the following environmental improvements as estimated by the national-scale immediate receiving water (IRW) model:

- A 51 to 67 percent reduction in the number of immediate receiving waters exceeding National Recommended Water Quality Criteria (NRWQC) for the protection of aquatic life.
- A 45 to 50 percent reduction in the number of immediate receiving waters exceeding an NRWQC for the protection of human health.
- A 63 to 64 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations exceed benchmarks for the protection of piscivorous wildlife (represented by minks and eagles).
- A 61 to 67 percent reduction in the number of immediate receiving waters where selenium contamination in the food web presents reproductive risks[67] to aquatic wildlife (represented by fish and mallards).
- A 56 to 75 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a cancer risk to exposed populations.
- A 52 to 56 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a risk of non-cancer health effects in exposed populations.

The results of the case study modeling for selected plants and receiving waters indicate that the environmental and human health impacts associated with steam electric power plant discharges, and the corresponding improvements under the final rule, could be even more extensive than those predicted by the IRW model. Case study modeling results demonstrate that the impacts from steam electric power plant discharges of the evaluated wastestreams can propagate much further downstream of the immediate receiving water. While the steam electric power plant discharges may not cause these impacts in isolation, case study modeling reveals that the discharges contribute to the further impairment of such waterways. Case study modeling results identified a larger increase in baseline impacts and improvements under the final rule in small receiving waters with variable flow than larger receiving waters. The analyses presented in the environmental assessment (EA) focus on quantifying the environmental improvements within rivers and lakes from post-compliance pollutant removals for metals, bioaccumulative pollutants, and nutrients.

---

[66] Reductions apply to the subset of pollutants evaluated in the environmental assessment (*i.e.*, arsenic, cadmium, chromium VI, copper, lead, mercury, nickel, selenium, thallium, and zinc).

[67] For this statistic, reproductive risk is indicated by a 50-percent (or higher) probability that adverse reproductive effects will occur in at least 10 percent of the exposed population of fish and mallards.

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

- Reducing the loadings of bioaccumulative pollutants to the broader ecosystem, decreasing long-term exposures and sublethal ecological effects.
- Reducing sublethal chronic effects of toxic pollutants on aquatic life not captured by the NRWQC.
- Reducing loadings of pollutants for which EPA did not perform water quality modeling in support of the EA (*e.g.*, boron, manganese, aluminum, vanadium, and iron).
- Mitigating impacts to aquatic and aquatic-dependent wildlife population diversity and community structures.[68]
- Reducing wildlife exposure to pollutants through direct contact with combustion residual impoundments and constructed wetlands built as treatment systems at steam electric power plants.
- Reducing water withdrawals from surface waters and aquifers, leading to greater availability of groundwater supplies for alternative uses and reducing fish impingement and entrainment mortality due to surface water intake structures.
- Reducing the potential of harmful algal blooms to form.

Data limitations prevented EPA from appropriately modeling the scale and complexity of the ecosystem processes potentially impacted by steam electric power plant wastewater and therefore did not fully quantify the improvements listed above. However, damage cases and other documented impacts in the literature reinforce that these impacts are common in the environments surrounding steam electric power plants and fully support the conclusion that pollutant removals will improve overall environmental and wildlife health.

As surface impoundments accumulate fly ash, bottom ash and flue gas desulfurization sludges, they can begin to fill up and lose their treatment capability.

Although the EA quantifies some impacts to wildlife that consume fish contaminated with pollutants from steam electric power plant wastewater, it does not capture the full range of exposure pathways through which bioaccumulative pollutants can enter the surrounding food web. Wildlife can encounter bioaccumulative pollutants from steam electric power plant wastewater discharges through direct exposure, drinking water, consuming

---

[68] EPA did evaluate impacts to aquatic and aquatic-dependent wildlife from selenium contamination as part of the ecological risk modeling. EPA did not quantify impacts that might occur due to other pollutant contamination.

contaminated vegetation, and consuming contaminated prey other than fish. Therefore, the quantified improvements underestimate the complete loadings of bioaccumulative pollutants that can impact wildlife in the ecosystem. EPA did quantify improvements to aquatic and aquatic-dependent wildlife due to reduced selenium exposure via the food web. The reduced selenium loadings under the final rule will significantly reduce the risk of negative reproductive effects to wildlife in waterbodies that receive discharges from steam electric power plants. In addition to the improvements resulting from reduced selenium loadings, EPA estimates that the post-compliance pollutant removals under the final rule will lower the total amount of bioaccumulative pollutants entering the food web in immediate receiving waters and downstream waters.

EPA estimates that pollutant removals will also decrease sublethal effects associated with many of the pollutants in steam electric power plant wastewater that may not be captured by comparisons with NRWQC for aquatic life. Well-documented studies suggest that organisms in aquatic environments near steam electric power plants exhibit chronic effects such as changes in metabolic rates, decreased growth rates, changes in morphology (*e.g.*, fin erosion, oral deformities), and changes in behavior (*e.g.*, decreased ability to swim, catch prey, or escape from predators) that can negatively affect long-term survival [Raimondo *et al*., 1998; Rowe *et al*., 1996, 2002]. However, these effects are not fully quantified in the EA due to data limitations, and therefore improvements to wildlife health and survival from the final rule may be underestimated. Reduced organism survival rates from chronic effects such as abnormalities can alter interspecies relationships (*e.g.*, declines in the abundance or quality of prey) and prolong ecosystem recovery. EPA was unable to quantify changes to aquatic and wildlife population diversity and community dynamics; however, population effects (*i.e.*, decline in number and type of organisms present) attributed to exposure to steam electric power plant wastewater are well documented in the literature [Lemly, 1985a; Garrett and Inman, 1984; Sorensen *et al*., 1982]. Changes in aquatic populations can alter the structure of aquatic communities and cause cascading effects within the food web that have long-term impacts to ecosystem dynamics. EPA estimates that post-compliance pollutant removals associated with the final rule will lower the stressors that can alter population and community dynamics and will improve the overall function of ecosystems surrounding steam electric power plants.

SECTION 10
REFERENCES

Abt. 2008. Abt Associates, Inc. “Revised Draft – Updating the Boron TWF.” (December). DCN SE04467.

Andersen L.J. and B. Madsen. 1983. Use of “The Capillary Barrier” as a Shield against Groundwater Pollution from Fly-Ash Deposits. Water Science Technology, 15:207-212 (As cited in Prasad *et al*., 1996).

ATSDR. 1998a. Agency for Toxic Substances and Disease Registry. *Health Consultations: Martin Creek Lake. Department of Health and Human Services*. Atlanta, GA. (September). DCN SE01877.

ATSDR. 1998b. *Health Consultations: Brandy Branch Reservoir. Department of Health and Human Services*. Atlanta, GA. (September). DCN SE01878.

ATSDR. 1998c. *Health Consultations: Welsh Reservoir. Department of Health and Human Services*. Atlanta, GA. (September). DCN SE01880.

ATSDR. 1999. Mercury Fact Sheet. Department of Health and Human Services. Atlanta, GA. Available online at: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=113&tid=24. DCN SE1990.

ATSDR. 2008a. Cadmium Fact Sheet. Department of Health and Human Services. Atlanta, GA (September). DCN SE01898.

ATSDR. 2008b. *Toxicological Profile for Manganese*. Department of Health and Human Services. Atlanta, GA. (September). DCN SE01899.

ATSDR. 2010a. Minimal Risk Levels (MRLs). Department of Health and Human Services. Atlanta, GA. (December). Available online at: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls_december_2010.pdf. DCN SE01901.

ATSDR. 2010b. *Toxicological Profile for Boron*. Department of Health and Human Services. Atlanta, GA. (November). DCN SE01902.

ATSDR. 2012. *Toxicological Profile for Cadmium*. Department of Health and Human Services Atlanta, GA. (September). DCN SE04468.

Baba, A. and A. Kaya. 2004. Leaching characteristics of solid wastes from thermal power plants of western Turkey and comparison of toxicity methodologies. Journal of Environmental Management, 73:199-207. DCN SE01866.

Ballard, A.M. 2012. “Water Pollution Groundwater Violations Found Near All 14 North Carolina Power Plants With Ash Ponds.” *BNA Today*. (January 26). DCN SE01896.

Barrows, M.E., S.R. Petrocelli, K.J. Macek, and J.J. Carroll. 1980. Chapter 24: Bioconcentration and Elimination of Selected Water Pollutants by Bluegill Sunfish (Lepomis macrochirus). *Dynamics, Exposure and Hazard Assessment of Toxic Chemicals*. Edited by R. Haque. Ann Arbor, MI: Ann Arbor Science. DCN SE01897.

Baumann, P.C. and R.B. Gillespie. 1986. Selenium bioaccumulation in gonads of largemouth bass and bluegill from three power plant cooling reservoirs. Environmental Toxicology and Chemistry, 5:695-701. DCN SE01846.

Bengtsson D., A. Avril, G. Gunnarsson, J. Elmberg, P. Söderquist, G. Norevik, C. Tolf, K. Safi, W. Fiedler, M. Wikelski, B. Olsen, and J. Waldenström. 2014. Movements, home range size and habitat selection of mallards during autumn migration. PLOS ONE, 9(6):e100764. doi:10.1371/journal.pone.0100764. DCN SE04616.

Benson, W.H., and W.J. Birge. 1985. Heavy metal tolerance in metallothionein induction in fathead minnows: Results from field and laboratory investigations. Environmental Toxicology and Chemistry, 4(2):209-217. DCN SE01849.

Besser, J.M., T.J. Canfield, and T.W. La Point. 1993. Bioaccumulation of organic and inorganic selenium in a laboratory food chain. Environmental Toxicology and Chemistry. 12(1):57-72. DCN SE06510.

Besser, J. M., J.P. Giesy, R.W. Brown, J.M. Buell, and G.A. Dawson, 1996. Selenium bioaccumulation and hazards in a fish community affected by coal fly ash effluent. Ecotoxicology and Environmental Safety, 35: 7-15. DCN SE02139.

Birge, W.J. 1978. Aquatic Toxicology of Trace Elements of Coal and Fly Ash. Energy and Environmental Stress in Aquatic Systems, Selected Papers from a Symposium, held at Augusta, Georgia November 2-4, 1977. DCN SE01854.

Bryan, A.L., Jr, W.A. Hopkins, J.A. Baionno, and B.P. Jackson. 2003. Maternal transfer of contaminants to eggs in common grackles (Quiscalus quiscala) nesting on coal fly ash basins. Archives of Environmental Contamination and Toxicology, 45(2):273-277. DCN SE01836.

Burger, J., K.F. Gaines, C.G. Lord, I.L. Brisbin, S. Shukla, and M. Gochfield. 2002. Metal levels in raccoon tissues: differences on and off the Department of Energy's Savannah River site in South Carolina. Environmental Monitoring and Assessment, 74:67-84. DCN SE01869.

Cantor, K.P., C.M. Villanueva, C.T. Silverman, J.D. Figueroa, F. X. Real, M. Garcia-Closas, N. Malats, S. Chanock, M. Yeager, A. Tardon, R. Garcia-Closas, C. Serra., A. Carrato, G. Castano-Vinyals, C. Samanic, N. Rothman, and M. Kogevinas. 2010. Polymorphisms in GSTT1, GSTZ1, and CYP2E1, disinfection by-products, and risk of bladder cancer in Spain. Environmental Health Perspectives, 118(11):1545-1550. DCN SE1981.

Carlson, C.L. and D.C. Adriano. 1993. Environmental impacts of coal combustion residues. Journal of Environmental Quality, 22:227-247. DCN SE02144.

Chapman, P., W. Adams, M. Brooks, C. Delos, S. Luoma, W. Maher, H. Ohlendorf, T. Presser, and D. Shaw, eds. 2009. Pellston Workshop on Ecological Assessment of Selenium in the Aquatic Environment. Pensacola FL (USA): Society of Environmental Toxicology and Chemistry (SETAC). DCN SE04519.

Charlotte Observer, 2010. “Coal Ash in Water Worries Officials.” (October). DCN SE01879.

Cherry, D.S., R.J. Currie, and D.J. Soucek. 2000. *Review of the Global Adverse Environmental Impacts to Ground Water and Aquatic Ecosystem from Coal Combustion Wastes*. Hoosier Environmental Council and Citizens Coal Council. Indianapolis, Indiana. (March). DCN SE01884.

Chesapeake Bay Program. 2015a. The Chesapeake Bay Watershed (website). http://www.chesapeakebay.net/discover/baywatershed. DCN SE06506.

Chesapeake Bay Program. 2015b. Facts & Figures (website). http://www.chesapeakebay.net/discover/bay101/facts. DCN SE06507.

Clark, D.R. 1987. Selenium accumulation in mammals exposed to contaminated California irrigation drainwater. The Science of the Total Environment, 66:147-168. DCN SE01874.

Coughlan, D.J. and J.S. Velte. 1989. Dietary toxicity of selenium-contaminated red shiners to striped bass. Transactions of the American Fisheries Society, 118:400-408. DCN SE01850.

Cowman, G. A. and P. C. Singer. 1996. Effect of bromide ion on haloacetic acid speciation resulting from chlorination and chloramination of aquatic humic substances. Environmental Science & Technology 30(1): 16-24. (As cited in VanBriesen, 2013).

Cross, F.L. 1981. Coal pile environmental impact problems. Pollution Engineering, 13(7):35-37. DCN SE01881.

Crutchfield, J. and S. Ferguson. 2000a. Predicting recovery of a fish population after heavy metal impacts. Environmental Science & Policy, 3:183-189. DCN SE01838.

Crutchfield, J.U., Jr. 2000b. Recovery of a power plant cooling reservoir from selenium bioaccumulation. Environmental Science & Policy, 3:145-163. DCN SE02138.

Cumbie, P.M. and S.L. Van Horn. 1978. *Selenium Accumulation Associated with Fish Mortality and Reproductive Failure.* Proceedings of Annual Conference of the Southeastern Association of Fish and Wildlife, 32:612-624. DCN SE01851.

CUWA. 2011. California Urban Water Agencies. *Drinking Water Treatment Evaluation Project Report*. Malcolm Pirnie, Inc. (April). DCN SE06509.

Duke Energy. 2007. “Gibson Lake Will Not Reopen for Fishing April 1.” Press Release. EPA-HQ-OW-2008-0517-0427.

EPRI. 1997. Electric Power Research Institute. *Coal Combustion By-products and Low-Volume Wastes Comanagement Survey*, EPRI TR-108369. Palo Alto, CA (as cited in Rowe *et al.*, 2002).

EIP (Environmental Integrity Project), Earthjustice, and Sierra Club. 2010a. Out of Control: Mounting Damages from Coal Ash Waste Sites. (February). DCN SE00351.

EIP, Earthjustice, and Sierra Club. 2010b. In Harm's Way: Lack of Federal Coal Ash Regulations Endangers Americans and their Environment. (August). DCN SE01365.

ERG. 2010. Eastern Research Group, Inc. “Drinking Water Treatment Technologies that Can Reduce Metal and Selenium Concentrations Associated with Discharges from Steam Electric Power Plants.” DCN SE02154.

ERG. 2013a. “Literature Review – Impacts of Coal Pile Runoff and Leachate.” DCN SE02153.

ERG. 2013b. Literature Search Database. DCN SE01962.

ERG. 2015a. “Loadings Analysis for the Steam Electric ELGs Environmental Assessment.” (September). DCN SE04446.

ERG. 2015b. “Review of Toxic Weighting Factors in Support of the Final Steam Electric Effluent Limitations Guidelines and Standards.” (September). DCN SE04479.

ERG. 2015c. “Proximity Analysis Methodology.” (September). DCN SE04448.

ERG. 2015d. “Supporting Documentation for Summarization of Environmental Assessment Analyses.” (September). DCN SE04449.

ERG. 2015e. "Water Quality Module: Plant and Receiving Water Characteristics." (September). DCN SE04513.

ERG. 2015f. "Pollutant Loadings Supporting Documentation." (September). DCN SE04515.

ERG. 2015g. "Fish Consumption Rates used in the Environmental Assessment Human Health Module." (September). DCN SE04482.

ERG. 2015h. "Water Quality Module Supporting Documentation." (September). DCN SE04451.

ERG. 2015i. "Wildlife and Human Health Modules Supporting Documentation." (September). DCN SE04452.

ERG. 2015j. Steam Electric Technical Questionnaire Database ("Steam Electric Survey"). (September). DCN SE05903.

ERG. 2015k. "EA Model Validation and Calibration." (September). DCN SE04454.

ERG. 2015l. "Downstream Modeling Methodology and Supporting Documentation." (September). DCN SE04455.

ERG. 2015m. Damage Cases and Other Site Impacts. (September). DCN SE04518.

ERG. 2015n. "Technical Approach for Case Study Water Quality Modeling of Aquatic Systems in Support of the Final Steam Electric Power Generating Industry Environmental Assessment." (September). DCN SE05570.

ERG. 2015o. EA Loadings versus TDD Loadings Sensitivity Analysis Spreadsheet. (September). DCN SE04539A1.

Etowah Aquatic Habitat Conservation Plan. 2015. Available online at: http://www.etowahhcp.org. DCN SE05608.

Evers, D.C., J.G. Wiener, C.T. Driscoll, D.A., Gay, N. Basu, B.A. Monson, K.F. Lambert, H.A. Morrison, J.T. Morgan, K.A. Williams, and A.G. Soehl. 2011. *Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region*. Biodiversity Research Institute. Gorham, Maine. Report BRI 2011-18. DCN SE01904.

Fan *et al*. 2002. T.W. Fan, S.J. The, D.E. Hinton, R.M. Higashi. Selenium biotransformations into proteinaceous forms by foodweb organisms of selenium-laden drainage waters in California. Aquat.Toxicol, 57(1-2):65-84. (April). DCN SE04618.

Fiske *et al.* 2011. P. S. Fiske, J. Oppenheimer, *et al.* In tank aeration predicts and reduces THMs. Opflow: 22-24. (As cited in VanBriesen, 2013).

Fleming, L.N., H.N. Abineth, and H.I. Inyang, 1996. Leachate pH effects on the leachability of metals from coal fly ash. Journal of Soil Contamination, 5(1):53-59 (as cited in Baba and Kaya, 2004).

Garrett, G.P. and C.R. Inman. 1984. Selenium-induced changes in fish populations in a heated reservoir. Proc. Ann. Conf. Southeast Assoc. Fish. Wildl. Agencies, 38:291-301. DCN SE01885.

Georgia Power. 2014. Data sheet: Plant Bowen. Southern Company. Cartersville, GA. Available online at: http://www.georgiapower.com/docs/about-us/1400756-.pdf. DCN SE05609.

Gillespie, R.B. and P.C. Baumann. 1986. Effects of high tissue concentrations of selenium on reproduction by bluegills. Transactions of the American Fisheries Society, 115:208-213. DCN SE01852.

Great Lakes Restoration Initiative. 2010. Great Lakes Restoration Initiative Action Plan. (February 21). DCN SE06427.

Green, A.J. and J. Elmberg. 2014. Ecosystem services provided by waterbirds. Biological Reviews, 89(1):105-122. (February) DCN SE04619.

Guthrie, R.K. and Cherry, D.S. 1976. Pollutant removal from coal ash basin effluent. Journal of the American Water Resources Association, 12(5):889-902. DCN SE01853.

Handke, P. 2009. Trihalomethane speciation and the relationship to elevated total dissolved solid concentrations affecting drinking water quality at systems utilizing the Monongahela River as a primary source during the 3rd and 4th quarters of 2008. Pennsylvania Department of Environmental Protection Bureau of Water Standards and Facility Regulation. (As cited in VanBriesen, 2013).

Heinz, G.H., D.J. Hoffman, A.J. Krynitsky, and D.M.G. Weller. 1987. Reproduction in mallards fed selenium. Environmental Toxicology and Chemistry, 6:423-433. DCN SE04620.

Heinz, G.H., D.J. Hoffman, and L.G. Gold. 1989. Impaired reproduction of mallards fed an organic form of selenium. Journal of Wildlife Management, 53:418-428. DCN SE04621.

Heinz, G.H. and D.J Hoffman. 1996. Comparison of the effects of seleno-L-methionine, seleno-DLmethionine, and selenized yeast on reproduction of mallards. Environmental Pollution, 91:169-175. (As cited in Ohlendorf, 2003).

Heinz, G.H. and D.J. Hoffman. 1998. Methylmercury chloride and selenomethionine interactions on health and reproduction in mallards. Environmental Toxicology and Chemistry, 17:139-145. DCN SE04623.

Heller-Grossman. 1993. L. Heller-Grossman, L., J. Manka, *et al.* Formation and distribution of haloacetic acids, THM, and TOX in chlorination of bromide-rich lake water. Water Research 27(8): 1323-1331. (As cited in VanBriesen, 2013).

Hofer, C., F.J. Gallagher, and C. Holzapfel. 2010. Metal accumulation and performance of nestlings of passerine bird species at an urban brownfield site. Environmental Pollution, 158:1207-1213. DCN SE01867.

Hopkins, W.A., M.T. Mendonça, and J.D. Congdon. 1997. Increased circulating levels of testosterone and corticosterone in southern toads, Bufo terrestris, exposed to coal combustion waste. General and Comparative Endocrinology, 108:237-246. DCN SE02146.

Hopkins, W.A., M.T. Mendonça, C.L. Rowe, and J.D. Congdon. 1998. Elevated trace element concentrations in southern toads, Bufo terrestris, exposed to coal combustion waste. Archives of Environmental Contamination and Toxicology, 35:325-329. DCN SE02140.

Hopkins, W.A., J.W. Snodgrass, J.H. Roe, B.P. Jackson, J.C. Gariboldi, and J.D. Congdon. 2000. Detrimental effects associated with trace element uptake in lake chubsuckers Erimyzon sucetta exposed to polluted sediments. Archives of Environmental Contamination and Toxicology, 39:193-199. DCN SE01841.

Hopkins, W.A., J.W. Snodgrass, J.H. Roe, B.P. Staub, B.P. Jackson, and J.D. Congdon. 2001. Effects of food ration on survival and sublethal responses of lake chubsuckers (Erimyzon sucetta) exposed to coal combustion wastes. Aquatic Toxicology, 21(5):906-913. DCN SE02141.

Hopkins, W.A., J.H. Roe, J.W. Snodgrass, B.P. Staub, B.P. Jackson, and J.D. Congdon. 2002. Effects of chronic dietary exposure to trace elements on banded water snakes (Nerodia fasciata). Environmental Toxicology and Chemistry, 21(5):906-13. DCN SE01855.

Hopkins, W.A., J.W. Snodgrass, B.P. Staub, B.P. Jackson, and J.D. Congdon. 2003. Altered swimming performance of benthic fish (Erimyzon sucetta) exposed to contaminated sediments. Archives of Environmental Contamination and Toxicology., 44:383-389. DCN SE01856.

Hopkins, W.A., S.E. Durant, B.P. Staub, C.L. Rowe, and B.P. Jackson. 2006. Reproduction, embryonic development, and maternal transfer of contaminants in the amphibian Gastrophryne carolinensis. Environmental Health Perspectives, 114(5):661-666. DCN SE01839.

Janz, D.M., D.K. DeForest, M.L. Brooks, P.M. Chapman, G. Gilron, D. Hoff, W.A. Hopkins, D.O. McIntyre, C.A. Mebane, V.P. Palace, J.P. Skorupa and M.Wayland. 2010. Selenium Toxicity to Aquatic Organisms (As cited in Chapman, *et.al*, 2009).

Jobson, H. E., 1996. *Prediction of Traveltime and Longitudinal Dispersion in Rivers and Streams*, U.S. Geological Survey Water Resources Investigations Report 96-4013. (As cited in the NHD Plus User's Guide).

King, K.A., T.W. Custer, and D.A. Weaver. 1994. Reproductive success of barn swallows nesting near a selenium-contaminated lake in East Texas. U.S. Environmental Pollution, 84:53-58. DCN SE01870.

Kopsick, D.A. and E.E. Angino. 1981. Effect of leachate solutions from fly and bottom ash on groundwater quality. Journal of Hydrology, 54:341-356. DCN SE01865.

Krasner *et al.*, 1989. S. W. Krasner, M. J. McGuire, *et al.* The occurrence of disinfection by-products in united-states drinking-water. Journal American Water Works Association 81(8): 41-53. (As cited in VanBriesen, 2013).

Kumada, H., S. Kimura, M. Yokote, and Y. Matida. 1972. Acute and chronic toxicity, uptake, and retention of cadmium in freshwater organisms. Bulletin of Freshwater Fisheries Research Laboratory, 22(2):157-165. DCN SE01894.

Lemly, A.D. 1985a. Toxicology of selenium in a freshwater reservoir: implications for environmental hazard evaluation and safety. Ecotoxicology and Environmental Safety, 10:314-338. DCN SE01842.

Lemly, A.D. 1985b. Ecological basis for regulating aquatic emissions from the power industry: the case with selenium. Regulatory Toxicology and Pharmacology, 5:465-486. DCN SE01887.

Lemly, A.D. 1993. Teratogenic effects of selenium in natural populations of freshwater fish. Ecotoxicol. Environ. Safety, 26(2):181-204. DCN SE04624.

Lemly, A.D., 1997a. Ecosystem recovery following selenium contamination in a freshwater reservoir. Ecotoxicology and Environmental Safety, 36:275-281. DCN SE02138.

Lemly, A.D. 1997b. A teratogenic deformity index for evaluating impacts of selenium on fish populations. Ecotoxicology and Environmental Safety, 37:259-266. DCN SE04625.

Lemly, A. D. 1999. Selenium transport and bioaccumulation in aquatic ecosystems: a proposal for water quality criteria based on hydrological units. Ecotoxicology and Environmental Safety. 42:150-156 (as cited in Rowe *et al*., 2002).

Lemly, A.D. 2002. *Selenium Assessment in Aquatic Ecosystems*. Springer-Verlag, New York. (As cited in U.S. EPA, 2015b).

Liang, L. and P. Singer. 2003. Factors influencing the formation and relative distribution of haloacetic acids and trihalomethanes in drinking water. Environmental & Science Technology, 37:2920-2928. DCN SE01982.

Luoma, *et.al.* 1992. S.N. Luoma, C. Johns, N.S. Fisher, N.A. Steinberg, R.S. Oremland, J.R. Reinfelder. Determination of Selenium Bioavailability to a Benthic Bivalve from Particulate and Solute Pathways. Environ. Sci. Technol, 26:485-491. DCN SE04627.

MacDonald, D.D.; C. G. Ingersoll; and T. A. Berger. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 2000, 39(1)20 (as cited in NOAA, 2008).

Magnuson, J. J., A.M. Forbes, D.M. Harrell, J.D. Schwarzmeier. 1980. *Responses of stream invertebrates to an ashpit effluent Wisconsin power plant impact study.* EPA/600/3-80/081.U.S. EPA Office of Research and Development. August. DCN SE04628.

Maier, K.J. and A.W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Reviews of Environmental Contamination and Toxicology, 134:31-48. (As cited in Chapman, *et. al.,* 2009)

McTigue, N., K. Graf, and R. Brown. 2014. *Occurrence and Consequences of Increased Bromide in Drinking Water Sources.* EE&T. DCN SE04503.

Metcalf and Eddy, Inc. 2003. *Wastewater Engineering: Treatment and Reuse*. McGraw-Hill, Inc. 4th edition. DCN SE01967.

MDE, 2008. Maryland Department of Environment. Constellation Reaches $54M Settlement on Fly Ash Lawsuit. DCN SE02149.

MDNR. 2007. Maryland Department of Natural Resources. *Assessment of Water Quality Impacts Associated with Use of Coal Combustion Products as Structural Fill at the BBSS Site.* Annapolis, Maryland. DNR 12-6182007-221. (June). DCN SE02147.

MDNRE. 2010. Michigan Department of Natural Resources and Environment. Hazardous Waste Management System, Identification and Listing of Special Wastes. Disposal of Coal Combustion Residuals from Electric Utilities Docket Comments. EPA-HQ-RCRA-2009-0640-6815. DCN SE01895.

Murphy, B.R., G.J. Atchison, and A.W. McIntosh. 1978. Cadmium and zinc in muscle of bluegill (*Lepomis macrochrius*) and largemouth bass (*Micropterus solmoides*) from an industrially contaminated lake. Environmental Pollution, 17(4):253-257 (as cited in U.S. EPA, 2010b).

Nagle, R.D., C.L. Rowe, and J.D. Congdon. 2001. Accumulation of selective maternal transfer of contaminants in the turtle Trachemys scripta associated with coal ash disposition. Archives of Environmental Contamination and Toxicology, 40:531-536. DCN SE01843.

NCDENR, 2011. North Carolina Department of Environment and Natural Resources. Duke Energy's Riverbend Steam Station - Groundwater Monitoring Results. (October) DCN SE01271.

NOAA 2008. National Oceanic and Atmospheric Association. Screening Quick Reference Tables (SQuiRTs). DCN SE01905.

NPS. 1997. National Parks Service. Environmental Contaminants Encyclopedia Selenium Entry. Fort Collins, Colorado. (July). DCN SE01906.

NRC. 2006. National Research Council of the National Academies. Managing Coal Combustion Residues in Mines. National Academies Press, Washington, DC. DCN SE02136.

Ohlendorf, H.M., D.J. Hoffman, M.K. Saiki, and T.W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. The Science of the Total Environment, 52:49-63. DCN SE01873.

Ohlendorf, H.M., A.W. Kilness, J.L. Simmons, R.K. Stroud, D.J. Hoffman, and J.F. Moore. 1988a. Selenium toxicosis in wild aquatic birds. Journal of Toxicology and Environmental Health, 24:67-92. DCN SE01882.

Ohlendorf, H.M., R.L. Hothem, and T.W. Aldrich. 1988b. Bioaccumulation of selenium by snakes and frogs in the San Joaquin Valley, California. Copeia, 3:704-710. DCN SE01883.

Ohlendorf, H.M., R.L. Hothem, and D. Welsh. 1989. Nest success, cause-specific nest failure, and hatchability of aquatic birds at selenium-contaminated Kesterson Reservoir and a reference site. The Condor, 91:787-796. DCN SE01872.

Ohlendorf, H.M., R.L. Hothem, C.M. Bunck, and K.C. Marois, 1990. Bioaccumulation of selenium in birds at Kesterson Reservoir, California. Archives of Environmental Contamination and Toxicology, 19:495-507. DCN SE01871.

Ohlendorf, H.M. 2003. Ecotoxicology of selenium. *In Handbook of Ecotoxicology*, 2nd., Eds. D.J. Hoffman, B.A. Rattner, G.A. Burton Jr., and J.C. Cairns, Jr., pp.465-500. Lewis Publishers, Boca Raton, FL. DCN SE04630.

Ohlendorf, H.M. and G.H. Heinz. 2011. Selenium in birds. *In Environmental Contaminants in Biota: Interpreting Tissue Concentrations.* Eds. W.N. Beyer and J.P. Meador, pp. 669-701. CRC Press. Boca Raton, FL: DCN SE04631.

Prasad B., N.N. Banjeree, and B.B. Dhar. 1996. Environmental assessment of coal ash disposal: a review. Journal of Scientific & Industrial Research, 55:772-780. DCN SE01891.

Presser, T.S. and S.N. Luoma. 2010. A methodology for ecosystem-scale modeling of selenium. Integrated Environmental Assessment and Management, 6(4):685-710. DCN SE04632.

Presser, T.S and H.M. Ohlendorf, 1987. Biogeochemical Cycling of Selenium in the San Joaquin Valley, California, USA. Environmental Management. 11(6):805-821. (November). DCN SE04633

Presser, *et. al.* 1994. T.S. Presser, M.A. Sylvester, and W.H. Low. Bioaccumulation of Selenium from Natural Geologic Sources in Western States and its Potential Consequences. Environmental Management. 18(3):423-436. DCN SE04634.

Pruitt, L., 2000. Indiana's First HCP Conserves Least Tern - Brief Article. Endangered Species Bulletin. Accessed online at: FindArticles.com. DCN SE02148.

Raimondo, S.M., C.L. Rowe, and J.D. Congdon. 1998. Exposure to coal ash impacts swimming performance and predator avoidance in larval bullfrogs. Journal of Herpetology, 32(2):289-292. DCN SE01857.

Rattner, B.A., M.A. McKernan, K.M. Esereich, W.A. Link, G.H. Olsen, D.J. Hoffman, K.A. Knowles, and P.C. McGowan. 2006. Toxicity and hazard of vanadium to mallard ducks (Anas platyrhynchos) and Canada geese (Branta canadensis). Journal of Toxicology and Environmental Health, Part A, 69:331-351. DCN SE01835.

Roe, J.H., W.A. Hopkins, and B.P. Jackson. 2005. Species- and stage-specific patterns of trace element accumulation (tissue concentration) in amphibians exposed to coal-combustion wastes. Environmental Pollution, 136:353-363. DCN SE01847.

Roe, J.H., W.A. Hopkins, S.E. Durant, and J.M. Unrine. 2006. Effects of competition and coal-combustion wastes on recruitment and life history characteristics of salamanders in temporary wetlands. Aquatic Toxicology, 79(2):176-84. DCN SE01863.

Rosetta, T.N. and A.W. Knight. 1995. Bioaccumulation of selenate, selenite, and seleno-DL-methionine by the brine fly larvae Ephydra cinerea Jones. Archives of Environmental Contamination and Toxicology, 29(3):351-357. DCN SE04635.

Rowe, C.L., O.M. Kinney, and J.D. Congdon. 1996. Oral deformities in tadpoles (Rana catesbeiana) associated with coal ash deposition: effects on grazing ability and growth. Freshwater Biology, 36(3):723-730. DCN SE02142.

Rowe, C.L., O.M. Kinney, R.D. Nagle, and J.D. Congdon. 1998a. Elevated maintenance costs in an anuran exposed to a mixture of trace elements during the embryonic and early larval periods. Physiological Zoology, 71(1):27-35. DCN SE01845.

Rowe, C.L., O.M. Kinney, and J.D. Congdon. 1998b. Oral deformities in tadpoles of the bullfrog (Rana catesbeiana) caused by conditions in a polluted habitat. Copeia, 1:244-246. DCN SE01858.

Rowe, C.L., W.A. Hopkins, and V.R. Coffman. 2001. Failed recruitment of southern toads (Bufo terrestris) in a trace element-contaminated breeding habitat. Archives of Environmental Contamination and Toxicology, 40(3):399-405. DCN SE01859.

Rowe, C.L., W.A. Hopkins, and J.D. Congdon. 2002. Ecotoxicological implications of aquatic disposal of coal combustion residues. Environmental Monitoring & Assessment, 80(3):207-276. DCN SE02143.

Ruhl, L., A. Vengosh, G.S. Dwyer, H. Hsu-Kim, G. Schwartz, A. Romanski, and S.D. Smith. 2012. The impact of coal combustion residue effluent on water resources: a North Carolina example. Environmental Science and Technology, 46:12226-12233. DCN SE01984.

Sager, D.R. and C.R. Colfield. 1984. Differential accumulation of selenium among axial muscle, reproductive and liver tissues of four warmwater fish species. Journal of the American Water Resources Association, 20(3):359-363. DCN SE01860.

Saiki and Lowe. 1987. M. K. Saiki and T. P. Lowe. Selenium in aquatic organisms from subsurface agricultural drainage water, San Joaquin Valley, California. Archives of Environmental Contamination and Toxicology. 16(6): 657 – 670. (November). DCN SE04636.

Schultz, S. 2008. “Constellation Reaches $54M Settlement on Fly Ash Lawsuit.” Baltimore Business Journal. (December). DCN SE02149.

Simsiman, G.V., G. Chesters, and A.W. Andren. 1987. Effect of ash disposal ponds on groundwater quality at a coal-fired power plant. Water Resources, 21(4):417-426. DCN SE01868.

Snodgrass, J.W., W.A. Hopkins, J. Broughton, D. Gwinna, J.A. Baionno, and J. Burge. 2004. Species-specific responses of developing anurans to coal combustion wastes. Aquatic Toxicology, 66:171-182. DCN SE01844.

Sorensen, E.M.B., C.W. Harlan, and J.S. Bell. 1982. Renal changes in selenium-exposed fish. Amer. J. Forensic Med. Pathol., 3:123-129. DCN SE01888.

Sorensen, E.M.B., J.S. Bell, and C.W. Harlan. 1983. Histopathological changes in selenium-exposed fish. Amer. J. Forensic Med. Pathol., 4(2):111-123. DCN SE01862.

Sorensen, E.M.B. and T.L. Bauer. 1984a. A correlation between selenium accumulation in sunfish and changes in condition factor and organ weight. Environmental Pollution Series A, 32:357-366. DCN SE01886.

Sorensen, E.M.B., P.M. Cumbie, T.L. Bauer, J.S. Bell, and C.W. Harlan. 1984b. Histopathological, hematological, condition-factor, and organ weight changes associated with selenium accumulation in fish from Belews Lake, North Carolina. Archives of Environmental Contamination and Toxicology, 13:153-162. DCN SE01840.

Sorensen, E.M.B. 1988. Selenium accumulation, reproductive status, and histopathological changes in environmentally exposed redear sunfish. Archives of Toxicology, 61:324-329. DCN SE01861.

Specht, W.L., D.L. Cherry, R.A. Lecleitner, and J. Cairns, Jr. 1984. Structural, functional, and recovery responses of stream invertebrates to fly ash effluent. Canadian Journal of Fisheries and Aquatic Sciences, 41(6):884-896. DCN SE01848.

Stanley, Jr., T.R., J.W. Spann, G.J. Smith, and R. Rosscoe. 1994. Main and interactive effects of arsenic and selenium on mallard reproduction and duckling growth and survival. Archives of Environmental Contamination and Toxicology, 26:444-451. DCN SE04637.

Stanley, Jr., T.R., G.J. Smith, D.J. Hoffman, G.H. Heinz, and R. Rosscoe. 1996. Effects of boron and selenium on mallard reproduction and duckling growth and survival. Environmental Toxicology and Chemistry, 15:1124-1132. DCN SE04638.

States, S. *et al.* 2013. Marcellus Shale drilling and brominated THMs in Pittsburgh, PA, drinking water. Journal - American Water Works Association. DCN SE06508.

Stephan, C.E. 1993. *Derivation of Proposed Human Health and Wildlife Bioaccumulation Factors for the Great Lakes Initiative (Draft).* PB93-154672. Environmental Research Laboratory, Office of Research and Development, Duluth, MN. (March). DCN SE01938.

Theis, T.L. and R.O. Richter. 1979. Chemical speciation of heavy metals in power plant ash pond leachate. Environmental Science Technology, 13:219-224 (as cited in Simsiman *et al*., 1987).

Theis, T.L. and K.H. Gardner. 1990. Environmental assessment of ash disposal. Critical Reviews in Environmental Control, 20(1):21-24. (As cited in Prasad *et al*., 1996).

Thorneloe, S.A., D.S. Kosson, F. Sanchez, A.C. Garrabrants, and G. Helms. 2010. Evaluations of the fate of metals in air pollution control residues from coal-fired power plants. Environmental Science Technology, 44:7351-7356. DCN SE01889.

Tsipoura, N., J. Burger, R. Feltes, J. Yacabucci, D. Mizrahi, C. Jeitner, and M. Gochfeld. 2008. Metal concentrations in three species of passerine birds breeding in the Hackensack meadowlands of New Jersey. Environmental Research, 107:218-228. DCN SE01875.

U.S. DOE. 1992. U.S. Department of Energy. *Ecological Effects of Contaminants in McCoy Branch, 1989-1990*. Washington, DC. (January). DCN SE01837.

U.S. EPA. 1980. *Ambient Water Quality Criteria for Copper* (EPA-440-5-80-036). Washington, DC. (October). DCN SE04487.

U.S. EPA. 1984. U.S. Environmental Protection Agency. *Ambient Aquatic Life Water Quality Criteria for Lead*. (January). Available online at: <http://water.epa.gov/scitech/swguidance/standards/criteria/upload/AWQC-for-Lead_1984.pdf. DCN SE01929.

U.S. EPA. 1986. *Quality Criteria for Water 1986*. EPA 440-5-86-001. Washington, DC. (May). DCN SE01930.

U.S. EPA. 1996. *Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod Hyalella Azteca and the Midge Chironomus Riparius*. Assessment and Remediation of Contaminated Sediments (ARCS) Program, Great Lakes National Program. EPA-905-R96-008. (September). DCN SE01931.

U.S. EPA. 1993. *Wildlife Exposure Factors Handbook*. EPA-600-R-93-187. Washington, DC. (December). DCN SE06428.

U.S. EPA. 1997a. *Mercury Study Report to Congress Volume III: Fate and Transport of Mercury in the Environment*. EPA-452/R-97-005. Washington, DC. (December). Page B-34. DCN SE01932.

U.S. EPA. 1997b. *Arsenic and Fish Consumption*. EPA-822-R-97-003. Washington, DC. (December). DCN SE01933.

U.S. EPA. 1998a. *Non-Groundwater Pathways, Human Heath and Ecological Risk Analysis for Fossil Fuel Combustion Phase 2 (FFC2)*. Draft Final Report. Washington, DC. (June). DCN SE01934.

U.S. EPA. 1998b. *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions*. EPA 600/R-98/137. Washington, DC. (December). DCN SE01935.

U.S. EPA. 2000a. *Guidance for Assessing Chemical Contaminant Data for Uses in Fish Advisories, Volume 1*. EPA 823-B-00-007. Washington, DC. (November). DCN SE01922.

U.S. EPA. 2000b. Selenium Compounds (website). (January). Available online at: http://www.epa.gov/ttn/atw/hlthef/selenium.html. DCN SE01923.

U.S. EPA. 2000c. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health*. EPA-822-B-00-004. Washington, DC. (October). DCN SE06429.

U.S. EPA. 2002. *National Recommended Water Quality Criteria: 2002.* EPA-822-R-02-047. Washington DC. (November). DCN SE04484.

U.S. EPA. 2004. Draft Aquatic Life Water Quality Criteria for Selenium. EPA-822-D-04-001. Washington, D.C. (November). DCN SE06511.

U.S. EPA. 2005a. *Partition Coefficients for Metals in Surface Water, Soil, and Waste* (Final). EPA/600/R-05/074. Washington, DC. (July). DCN SE01892.

U.S. EPA. 2005b. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (HHRAP).* EPA 520-R-05-006. Washington, DC. (September). DCN SE01926.

U.S. EPA. 2005c. *Drinking Water Criteria Document for Brominated Trihalomethanes.* EPA 822-R-05-011. Office of Water. Washington, DC. (November 15). DCN SE06443.

U.S. EPA. 2007a. *Framework for Metals Risk Assessment.* EPA 120/R-07/001. Washington, DC. (March). DCN SE01927.

U.S. EPA. 2008a. *Child-Specific Exposure Factors Handbook.* EPA/600/R-06/096F. Washington, DC. (September). DCN SE01876.

U.S. EPA. 2008b. *Lake Erie Lakewide Management Plan 2008.* DCN SE01940.

U.S. EPA. 2009a. *Toxicological Review of Thallium and Compounds. Integrated Risk Information System.* EPA/635/R-08/001F. Washington, DC. (September). DCN SE01907.

U.S. EPA. 2009b. *Steam Electric Power Generating Point Source Category: Final Detailed Study Report.* EPA-821-R-09-008. Washington, DC. (October). DCN SE00003.

U.S. EPA. 2009c. *Technical Support Document for the Preliminary 2010 Effluent Guidelines Program Plan.* EPA-821-R-09-006. Washington, DC. (October). DCN SE02134.

U.S. EPA. 2009d. National Recommended Water Quality Criteria. Washington, DC. DCN SE01908.

U.S. EPA. 2009e. *National Primary Drinking Water Regulations.* EPA 816-F-09-004. Washington, DC. (May). DCN SE01909.

U.S. EPA. 2010a. *Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds. National Center for Environmental Assessment*. Superfund Health Risk Technical Support Center, Cincinnati, OH. (September). DCN SE01941.

U.S. EPA. 2010b. *Human and Ecological Risk Assessment of Coal Combustion Wastes (CCW)* (Draft). Washington, DC. (April). DCN SE01834.

U.S. EPA. 2010c. Discharge Monitoring Report (DMR) Pollutant Loading Tool: 2010 Data. Available online at: http://cfpub.epa.gov/dmr/. DCN SE01959.

U.S. EPA. 2010d. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment*. Washington, DC. (December). DCN SE01910.

U.S. EPA. 2011a. Technical Factsheet on: THALLIUM. National Primary Drinking Water Regulations. Available online at: http://water.epa.gov/drink/contaminants/basicinformation/historical/upload/Archived-Technical-Fact-Sheet-on-Thallium.pdf. DCN SE01911.

U.S. EPA. 2011b. *Exposure Factors Handbook: 2011 Edition.* EPA/600/R-09/052F. Washington, DC. (September). DCN SE01912.

U.S. EPA, 2011c. Integrated Risk Information System (IRIS). National Center for Environmental Assessment. Washington, DC. Available online at: http://www.epa.gov/IRIS/. DCN SE01960.

U.S. EPA. 2011d. *Technical Support Document for the 2010 Effluent Guidelines Program Plan.* EPA-821-R-09-006. Washington, DC. (October). DCN SE02135.

U.S. EPA. 2011e. *Office of Science & Technology Annual Report, Calendar Year 2011*. EPA 820-R-12-006. Washington, DC. DCN SE01951.

U.S. EPA. 2011f. Ecological Toxicity Information (website). EPA Region 5. (December). Available online at: http://www.epa.gov/R5Super/ecology/toxprofiles.htm. DCN SE01913.

U.S. EPA. 2012a. "EPA Weighs Setting Possible First-Time Water Quality Criteria for Bromide." *Inside EPA.* (January 4). DCN SE01949.

U.S. EPA. 2012b. *Toxic Weighting Factors Methodology*. EPA-820-R-12-005. Washington, DC. (March). DCN SE04470.

U.S. EPA. 2012c. TWF Database (EPA-HQ-OW-2008-0517-0713). MS Excel^{TM}. Washington, DC. DCN SE04465.

U.S. EPA. 2012d. *Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems.* EPA-810-F-11-001. Washington, DC. (July). DCN SE04466.

U.S. EPA. 2012e. Final Determination of Identified Proven Damage and Recently Alleged Damage Cases. SE01966.

U.S. EPA. 2013a. DMR & TRI Loadings Database for Case Study Modeling. DCN SE05589.

U.S. EPA. 2013b. Impact Case Study Analysis Database. Washington, DC. DCN SE02156.

U.S. EPA. 2014a. CCR Damage Cases Database. Office of Solid Waste and Emergency Response (OSWER)/Office of Resource Conservation and Recovery (ORCR). Washington, DC. DCN SE04457.

U.S. EPA. 2014b. *Damage Case Compendium Technical Support Document, Volume I: Proven Damage Cases*. OSWER/ORCR. Washington, DC. DCN SE04458.

U.S. EPA. 2014c. *Damage Case Compendium Technical Support Document, Volume IIa: Potential Damage Cases*. OSWER/ORCR. Washington, DC. DCN SE04459.

U.S. EPA. 2014d. *Damage Case Compendium Technical Support Document, Volume IIb Part One: Potential Damage Cases.* OSWER/ORCR. Washington, DC. DCN SE04460.

U.S. EPA. 2014e. *Damage Case Compendium Technical Support Document, Volume IIb Part Two: Potential Damage Cases.* OSWER/ORCR. Washington, DC. DCN SE04461.

U.S. EPA. 2014f. *External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater*. EPA 822-P-14-001. Washington, DC. (May). DCN SE06438.

U.S. EPA. 2014g. *Human and Ecological Risk Assessment of Coal Combustion Residuals*. (December) DCN SE06442.

U.S. EPA. 2014h. National Fish Consumption Advisories NHD Indexed Dataset. Reach Address Database (RAD). Extracted on July 7. Available online at: http://epamap32.epa.gov/radims/. DCN SE04545.

U.S. EPA. 2014i. National 303(d) Listed Impaired Waters National Hydrography Data (NHD) Indexed Dataset. RAD. Extracted on August 4. Available online at: http://www.epa.gov/waters/data/downloads.html. DCN SE04544.

U.S. EPA. 2015a. *Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria*. EPA 820-S-15-001. Washington, DC. (February). DCN SE04505.

U.S. EPA. 2015b. *Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater.* EPA 822-P-15-001. Washington, DC. (July). DCN SE06439.

U.S. EPA and Environment Canada. 1997. *Great Lakes Binational Toxics Strategy*. DCN SE01942.

U.S. EPA and Environment Canada. 2009. *State of the Great Lakes 2009.* EPA 905-R-09-031. DCN SE01939.

USFWS. 2008. U.S. Fish and Wildlife Service. "Steps Taken to Address Selenium Concerns at Cane Ridge Wildlife Management Area." News Release. (June 13). DCN SE02150.

USFWS. 2012. "Selenium Threat Averted." News Release. (June 19). DCN SE01943.

USGS. 2008. U.S. Geological Survey. Environmental contaminants in freshwater fish and their risk to piscivorous wildlife based on a national monitoring program. Environmental Monitoring and Assessment, 152:469-494. DCN SE01893.

USGS. 2015. *The Quality of the Nation's Groundwater*. Barbara Mahler and Jon Campbell. (January 21). DCN SE04639.

VanBriesen, Jeane M. 2013. *Potential Drinking Water Effects of Bromide Discharges from Coal-Fired Electric Power Plants*. EPA-HQ-OW-2009-0819-4687-A10.

Vengosh, A. 2009. The Tennessee Valley Authority's Kingston Ash Slide: Potential Water Quality Impacts of Coal Combustion Waste Storage. A Testimony to the Subcommittee on Water Resources and Environment, U.S. House of Representatives. Available online at: http://transportation.house.gov/Media/file/water/20090331/Vengosh%20Testimony.pdf. DCN SE01864.

Villanueva, C.M., K.P. Cantor, S. Cordier, J.J.K. Jaakkola, W.D. King, D.F. Lynch, S. Porru, and M. Kogevinas. 2004. Disinfection byproducts and bladder cancer: a pooled analysis. Epidemiology, 15(3):357-367. DCN SE01983.

Vogel, *et. al.,* 1999. R.M. Vogel, I.W. Wilson, and C. Daly. Regional Regression Models of Annual Streamflow for the United States. Journal of Irrigation and Drainage Engineering. 125 (3): 148-157. (As cited in the NHD Plus User's Guide).

Weinberg. 2002. H.S. Weinberg, S. W. Krasner, *et al. The Occurrence of Disinfection By-Products (DBPs) of Health Concern in Drinking Water: Results of a Nationwide DBP Occurrence Study* (EPA/600/R-02/068) Athens, GA. (As cited in VanBriesen, 2013).

WHO. 1976. World Health Organization. Environmental Health Criteria 1: Mercury. International Programme on Chemical Safety. Geneva, Switzerland. DCN SE01914.

WHO. 1987. Environmental Health Criteria 58: Selenium. International Programme on Chemical Safety. Geneva, Switzerland. DCN SE01915.

WHO. 1992. Environmental Health Criteria 135: Cadmium. International Programme on Chemical Safety. Geneva, Switzerland. DCN SE01916.

WHO. 1996. Environmental Health Criteria 182: Thallium. International Programme on Chemical Safety. Geneva, Switzerland. DCN SE01917.

WHO. 1998. Environmental Health Criteria 204: Boron. International Programme on Chemical Safety. Geneva, Switzerland. DCN SE01918.

WHO. 2001. Arsenic in Drinking Water. Available online at: http://www.who.int/mediacentre/factsheets/fs210/en/. (20 January). DCN SE01919.

WHO. 2009. *Bromide in Drinking-Water. Background Document for Development of WHO Guidelines for Drinking-Water Quality*. WHO/HSE/WSH/09.01/6. Geneva, Switzerland. DCN SE01920.

WHO. 2011. *Manganese in Drinking-Water. Background Document for Development of WHO Guidelines for Drinking-Water Quality*. WHO/HSE/WSH/03.04/104/Rev/1. Geneva, Switzerland. DCN SE01921.

Wilson *et al*. 2013. J.M. Wilson, Y. Wang, *et al.* Sources of high total dissolved solids to drinking water supply in Southwestern Pennsylvania. ASCE Journal of Environmental Engineering. (As cited in VanBriesen, 2013).

APPENDIX A
LITERATURE REVIEW METHODOLOGY AND RESULTS

This appendix presents the methodology, resources, and summary results for the literature review. The U.S. Environmental Protection Agency (EPA) used the keyword list in Table A-1 to identify peer-reviewed journal articles that document environmental and human health impacts caused by steam electric power plant discharges of the evaluated wastestreams. The literature search focused on information regarding impacts caused by pollutants of concern for the steam electric power generating industry (*e.g.*, toxic bioaccumulative pollutants such as mercury and selenium, metals such as arsenic and lead, and nutrients) in the discharges. EPA also searched for environmental assessments, impact studies, and related documents from state and federal governments.

In addition, the literature search involved collecting information from newspapers, environmental groups, industry organizations, and other non-peer-reviewed information sources. These sources are considered to be “gray literature” and are not acceptable forms of formal documentation of environmental impact events. However, these literature sources can provide useful information for identifying potential areas of concern. Often, an environmental event is reported in gray literature sources before it is well documented in peer-reviewed journals or government reports. EPA used gray literature to help highlight areas of interest and facilitate additional searches of peer-reviewed journals for more detailed information on the impacted area.

EPA used several different search engines to broaden the range of reference materials represented in the results. The Agency searched the following search engines in the order presented, using the keyword list in Table A-1:

- Scirus – A comprehensive science-specific search engine that provides access to a large database of scientific, technical, and medical journals.
- Science Direct – An online library that features full text journals from Elsevier, Academic Press, and other scholarly publishers.
- Ingenta – A scholarly research database that provides access to a large collection of academic and professional research articles.
- Google Scholar – A search engine used to find other articles that cited previously identified references as well as perform a general search of scholarly literature, including peer-reviewed papers, theses, books, abstracts, and articles from academic publishers, professional societies, preprint repositories, and universities and other scholarly organizations.
- Google – A search engine used to perform a general search of information readily available on the Internet.

Table A-1. Keyword Search Terms for Environmental Impacts from Steam Electric Power Plants

Category	Keyword
General Terms	Ash pond
	Discharge
	Lake
	Landfill
	Leachate
	Leaks
	Lotic system
	Plume
	Pond
	Power plant
	Receiving water
	River
	Sediment
	Steam electric
	Stream
	Surface waters
	Water
	Wastewater
	Water pollution
	Water quality
	Waste management
	Wastewater discharges
Environmental Terms	Algal blooms
	Attractive nuisance
	Background levels/concentrations
	Bioaccumulation
	Biomagnification
	Biomagnify
	Contamination
	Environmental impact
	Environmental assessment
	Eutrophication
	Fish
	Fish consumption advisory
	Fish kill
	Fish mortality
	Fish recovery
	Hot Spot
	Toxicity
	Wildlife
Pollutants of Concern	Arsenic
	Arsenate
	Arsenite
	Boron
	Boric Acid

Table A-1. Keyword Search Terms for Environmental Impacts from Steam Electric Power Plants

Category	Keyword
	Chloride(s)
	Chromium
	Magnesium
	Mercury
	Metals
	Methylmercury
	Nitrate
	Nitrogen
	Selenium
	Selenate
	Selenite
	Sulfate
Fuel Source Terms	Coal
	Coal combustion by-products
	Coal combustion residues
	Oil
Human Health Terms	Cancer
	Carcinogen
	Carcinogenic
	Drinking water
	Health effects
	Human health
	Toxicity
Other Terms	Case study
	Damage case assessment
	Environmental impacts
	Environmental aspects

To perform the literature search, EPA paired each fuel source term (see Table A-1) with at least one keyword to focus the search results. Although EPA used multiple fuel source terms, the environmental impacts from the steam electric power generating industry are documented most commonly for coal-fired power plants. EPA used best professional judgment to create multiple keyword combinations to further focus the literature search.

In addition to the key word combinations and search engines described above, EPA used the following supplemental methods to identify more articles for the targeted topic areas:

- Reviewed references cited in previously identified published literature for additional documented cases of environmental impact.
- Searched the Agency for Toxic Substances and Disease Registry's (ATSDR) website for public health assessments and health consultations with information on the case study sites referenced in Dr. Christopher Rowe's literature review paper published in 2002 [Rowe *et al.*, 2002].

- Searched for case studies of attractive nuisances unrelated to the steam electric power generating industry using the search engines described above.
- Reviewed EPA's December 2014 Coal Combustion Residuals (CCR) Damage Cases Database and supporting compendiums [U.S. EPA, 2014a; U.S. EPA, 2014b; U.S. EPA, 2014c; U.S. EPA, 2014d; U.S. EPA, 2014e][1] and Michigan's Department of Natural Resources and Environment (MDNRE's) Docket Comments (see Table A-3 for a full list of references).
- Searched magazines related to the steam electric industry and newspapers for articles documenting additional environmental impacts.

EPA created a database for the literature review that documents the identified literature and summarizes key information. EPA finalized the primary literature review on November 24, 2010; however, the database also includes literature identified after the primary search efforts were completed [ERG, 2013b]. EPA created a second database to summarize the damage cases and other documented site impacts [ERG, 2015m].

The following tables in Appendix A summarize information EPA gathered from the literature review:

- Table A-2. Summary of Literature Review Results by Information Source.
- Table A-3. Summary of Damage Cases and Other Documented Site Impacts to Surface Water and Ground Water from Steam Electric Power Plant Discharges.
- Table A-4. Summary of Documented Ground Water Damage Cases from Surface Impoundments.
- Table A-5. Summary of Documented Ground Water Damage Cases from Landfills.
- Table A-6. Summary of Documented Surface Water Damage Cases from Surface Impoundments.
- Table A-7. Summary of Documented Surface Water Damage Cases from Landfills.
- Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants.
- Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants.
- Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects.

Table A-2 highlights the results of the literature search, including documents identified by keyword searches and relevant documents identified from supplemental methods. During the period following completion of the literature review and the associated database, EPA obtained additional documents (*e.g.*, through public comments and informal searches) that supported development of the final steam electric effluent limitations guidelines and standards (ELGs). EPA

---

[1] These 2014 references are updates to EPA's September 18, 2012 review of damage cases which were primarily identified in EPA's *Damage Case Assessment Report*; Environmental Integrity Project's (EIP's) *Out of Control: Mounting Damages From Coal Ash*; and EIP's *In Harm's Way: Lack of Federal Coal Ash Regulations Endangers Americans and Their Environment.*

incorporated relevant information from the additional literature in the EA report and in the other tables included in this Appendix.

Table A-3 summarizes the number of documented site impacts to surface water and ground water identified during the literature search and organized by steam electric power plant. Table A-4 and Table A-5 summarize the damage cases to ground water from combustion residuals surface impoundments and landfills, respectively. Table A-6 and Table A-7 summarize the damage cases to surface water from combustion residuals surface impoundments and landfills, respectively. Table A-8 and Table A-9 summarize attractive nuisances identified during the literature search, related and unrelated to steam electric power plants, respectively. Table A-10 presents selenium concentrations in the environment that are documented in the literature as causing sublethal and lethal effects to organisms.

Table A-2. Summary of Literature Review Results by Information Source

Source Type	Number of Documents Identified	Number of Documents Reviewed [f]	Number of Documents that Discussed Environmental and Human Health Impacts
Peer-Reviewed Literature [a]	151	128	117
Government Publication [b]	53	47	32
University Research [c]	13	12	9
Gray Literature [d]	18	16	14
Industry Publication [e]	4	3	3
Total	**239**	**206**	**175**

Source: ERG, 2013b.

a – Peer-reviewed literature consists of journal articles that undergo a formal review process prior to publishing.

b – Government publications are documents affiliated with state or federal government agencies.

c – University research includes finalized dissertations and theses, as well as papers published on behalf of a university or presented at a conference.

d – Gray literature includes documents that are subjected to a less stringent review process (*e.g.*, newspaper articles, environmental group publications).

e – Industry publications include documents prepared by or for industry-affiliated entities.

f – EPA did not review several documents as part of the formal literature review either because EPA was unable to acquire the full text of the document for review or because once the full text document was obtained a preliminary review determined the document was not appropriate for inclusion in the literature review.

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
A.B. Brown Generating Station, Southern Indiana Gas and Electric Company (SIGECO) (IN)	0	1
Allen Fossil Plant Tennessee Valley Authority (TVA) (TN)	0	1
Allen Steam Generating Plant, Duke Power (NC)	1	1
Alma Station, Dairyland Power (WI)	0	2
Asheville Plant, Progress Energy (NC)	2	1
B.C. Cobb Power Plant, Consumers Energy (MI)	0	2
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	0	2
Belews Creek Steam Station, Duke Energy (NC)	14	1
Belle River Power Plant, Detroit Edison Company (MI)	1	1
Big Bend Station, Tampa Electric Company (FL)	1	1
Big Cajun 2 Power Plant, NRG Energy/Louisiana Generating, LLC (LA)	0	1
Brandon Shores, Constellation Energy (MD)	0	1
Brayton Point Station, Dominion (MA)	0	1
Bruce Mansfield Power Plant, First Energy (PA)	1	1
Buck Steam Station, Duke Energy (NC)	1	0
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	1	1
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	0	1
C.R. Huntley Generating Station, NRG Energy (NY)	0	1
Canadys Plant, South Carolina Electric & Gas (SCE&E) (SC)	0	1
Cape Fear Steam Plant, Progress Energy (NC)	0	1
Cardinal Plant, American Electric Power (AEP) (OH)	1	1
Cargill Salt Power Plant, Cargill (MI)	1	1
Cayuga Generating Station, Duke Energy (NY)	1	1
Chalk Point Generating Station, Mirant (MD)	1	1
Chesapeake Energy Facility, Dominion Power (VA)	1	2

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Cholla Steam Electric Generating Station, Arizona Public Service Company (AZ)	0	1
Christ Power Plant, Gulf Power (Southern Company) (FL)	0	1
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	0	1
Clinch River Plant, American Electric Power (AEP)/Appalachian Power (VA)	1	0
Coal Creek Station, Cooperative Power Association/United Power (ND)	0	1
Coffeen Power Station, Ameren (IL)	0	1
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	0	1
Coleto Creek Power Station, International Power (TX)	0	1
Colstrip Power Plant, PPL Montana (MT)	0	1
Columbia Electric Generating Station (WI)	5	0
Columbia Energy Center, Alliant Energy (WI)	1	0
Conesville Power Plant, American Electric Power (AEP) (OH)	0	1
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	0	1
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	1	1
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	1	1
Dallman Station, City Water, Light and Power (IL)	0	1
Dan River Steam Station, Duke Energy (NC)	2	1
Danskammer Generating Station, Dynegy (NY)	0	1
D-Area Coal-Fired Power Plant, Savannah River Site (SRS) (SC)	24	0
Dave Johnston Power Plant (WY)	1	1
Dickerson Generating Station, Mirant (MD)	1	1
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	0	1
Duck Creek Station, Central Illinois Light Company (IL)	0	1
Dunkirk Generating Station, NRG Energy (NY)	0	1
E.J. Stoneman Generating Station, Dairyland Power Cooperative (WI)	0	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts[a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts[a]
East Bend Generating Station, Cinergy (KY)	0	1
Eckert Station, Lansing Board of Water & Light (MI)	0	1
Edgewater Generating Station, Alliant Energy (WI)	0	1
Elizabethtown Power Plant, North Carolina Power Holdings (NC)	0	1
Elrama Power Plant, Reliant Energy (PA)	1	1
Erickson Station, Lansing Board of Water & Light (MI)	0	1
Fair Station, Central Iowa Power Cooperative (IA)	0	2
Fayette Power Project, Lower Colorado River Authority (TX)	0	1
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	1	1
Gallatin Fossil Plant, Tennessee Valley Authority (TVA) (TN)	0	1
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	1	1
George Neal Station North, Berkshire Hathaway/MidAmerican Energy Company (IA)	0	1
George Neal Station South, Berkshire Hathaway/MidAmerican Energy Company (IA)	0	1
Gibson Generating Station, Duke Energy (IN)	5	1
Glen Lyn Plant, American Electric Power (AEP)/Appalachian Power (VA)	6	0
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	1	1
Greenidge Generation Plant, AES (NY)	0	1
Harbor Beach Power Plant, Detroit Edison Company (MI)	1	1
Hatfield's Ferry Power Station, Allegheny Energy (PA)	1	1
Havana Power Plant, Illinois Power Company (IL)	0	1
Hennepin Power Station, Illinois Power Company (IL)	0	1
Herbert A. Wagner, Constellation Energy (MD)	0	1
Hickling Generation Plant, AES (NY)	0	1
Hopewell Power Station, Dominion Power (VA)	0	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts[a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts[a]
Hunlock Power Station, UGI Development Company (PA)	0	1
Hutsonville Power Station, Central Illinois Public Service Company (IL)	0	1
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	0	1
Indian River Generating Station, NRG Energy (DE)	1	1
J.H. Campbell Power Plant, Consumers Energy (MI)	1	1
J.R. Whiting Generating Plant, CMS/Consumers Energy (MI)	1	0
Jennison Generation Plant, AES (NY)	0	1
John Amos Plant, American Electric Power (AEP)/Appalachian Power (WV)	1	0
John H. Warden Generating Station, Integrys (MI)	1	1
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	1	1
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	2	2
Joliet Generating Station 9, Midwest Generation (IL)	0	2
Joppa Steam Plant, Ameren (Electric Energy) (IL)	0	1
Karn/Weadock Generating Facility, Consumer Energy (MI)	0	1
Kenansville Plant, Green Power Energy Holdings (NC)	0	1
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	7	1
Lansing Smith Plant, Florida Power and Light (FL)	0	1
Lee Steam Plant, Progress Energy (NC)	0	1
Leland Olds Station, Basin Electric Power Cooperative (ND)	0	1
Lumberton Power Plant, North Carolina Power Holdings (NC)	0	1
Marion Plant, Southern Illinois Power Cooperative (IL)	1	1
Marshall Steam Station, Duke Energy (NC)	1	0
Martin Lake Steam Station, Texas Utilities Electric Service Company (TX)	9	0
Martin's Creek Power Plant, PPL (PA)	1	0
Marysville Power Plant, Detroit Edison Company (MI)	1	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Mayo Steam Station, Progress Energy (NC)	1	0
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	0	1
Mendosa Power Station, Ameren Energy Generating Company, (IL)	0	1
Merom Generating Station, Hoosier Energy (IN)	1	1
Miamiview Landfill, Cincinnati Gas & Electric Company (OH) [b]	0	1
Michigan City Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	0	1
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	0	1
Mitchell Power Station, Allegheny Energy (PA)	0	1
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	1	1
Morgantown Generating Station, Mirant (MD)	2	2
Muskingum River Plant, American Electric Power (AEP)/ Ohio Power Company (OH)	0	1
Nelson Dewey Generating Station, Alliant Energy (WI)	0	1
Northeastern Station, American Electric Power/Public Service Company Oklahoma (OK)	0	1
Oak Creek Power Plant, Wisconsin Energy (WE Energies (WE))/Wisconsin Electric Power Company (WI)	1	0
Oak Ridge Y-12 Plant, Department of Energy (TN)	4	1
Paradise Fossil Plant, Tennessee Valley Authority (TVA) (KY)	0	1
Parish Generating Station, NRG Energy/Texas Genco II (TX)	0	1
Pearl Station, Prairie Power Inc./Soyland Power Coop (IL)	0	1
Petersburg Generating Station, Indianapolis Power & Light (IN)	0	1
Phillips Power Plant, Duquesne Light Company (PA)	1	1
Pirkey Power Plant, Southwestern Electric Power Company (SWEPCO) (TX)	2	0
Plant Bowen, Georgia Power (GA)	1	0
Port Washington Facility, Wisconsin Electric Power Company (WEPCO) (WI)	0	2
Portland Generating Station, RRI Energy (PA)	1	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Powerton Plant, Commonwealth Edison (IL)	1	1
Prairie Creek Station, Interstate Power and Light (Alliant) (IA)	0	1
Presque Isle Power Plant, WE Energies (WE) (MI)	0	1
Pulliam Power Plant, Wisconsin Public Service Corp. (WI)	0	1
R.M. Heskett Station, Montana-Dakota Utilities (ND)	0	1
R.M. Schahfer Generating Station (IN)	0	1
Reid Gardner Generating Facility, Nevada Energy (NV)	1	1
Riverbend Steam Station, Duke Energy (NC)	4	0
Rock River Generating Station, Alliant Energy (WI)	0	1
Rocky Mount Power Plant (NC)	0	1
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	0	1
Roxboro Plant, Progress Energy (NC)	8	0
Salem Harbor Station, Dominion (MA)	0	1
SCANA Williams Station (SC)	1	0
Seminole Generating Station, Seminole Electric Cooperative (FL)	1	1
Seward Generating Station, RRI Energy (PA)	1	1
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	1	1
Sheldon Station, Nebraska Public Power District (NE)	0	1
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	0	1
Shiras, Marquette Board of Light & Power (MI)	0	1
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	0	1
Sutton Steam Plant, Progress Energy (NC)	1	1
Unnamed Plant 1[c]	1	0

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	**Number of Damage Cases and Other Literature that Document Surface Water Impacts** [a]	**Number of Damage Cases and Other Literature that Document Ground Water Impacts** [a]
Unnamed Plant 2 [c]	1	0
Unnamed Plant 3 [c]	1	0
Unnamed Plant 4 [c]	1	0
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	0	1
Valley Power Plant, Wisconsin Energy (WI)	0	1
Venice Power Station, Union Electric Company/Ameren Energy/AmerenUE (IL)	0	1
Vermillion Power Station, Illinois Power (IL)	0	1
W.C. Beckjord Station, Duke Energy (formerly Cinergy) (OH)	0	1
W.J. Neal Station, Basin Electric Power Cooperative (ND)	1	1
Wateree Station, SCE&G (SC)	1	1
Waukegan Generating Station, Midwest Generation (Edison International) (IL)	0	1
Welsh Power Plant, Southwestern Electric Power Company (SWEPCO) (TX)	3	0
Westover Generation Plant, AES (NY)	0	1
Widows Creek Fossil Plant, Tennessee Valley Authority (TVA) (AL)	0	1
Winyah Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	0	1
Wood River Power Station, Illinois Power Company (IL)	0	1
Yorktown Power Station, Virginia Electric Power and Power Company (VEPCO) (VA)	0	1
Total	**152**	**149**

Source: ERG, 2015m; U.S. EPA, 2014a through 2014e.

a – One case study or damage case may document impacts to both ground water and surface water.

b – The damage case source did not specifically identify the plant name; therefore, EPA used the name of the damage case.

c – EPA was unable to identify the steam electric power plant associated with this documented impact. For the purpose of counting the unique number of plants, these impacts were assumed to be associated with a plant not already identified elsewhere in this table.

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Allen Fossil Plant Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Manganese, TDS	X			
Allen Steam Generating Plant, Duke Power (NC)	Pond/Impoundment	Manganese, Iron, pH, Nitrate, Nickel	X			
Alma Off-site Fly Ash Landfill, Dairyland Power (WI)	Pond/Impoundment	Sulfate, Manganese, Boron, Selenium, Cadmium				
Asheville Steam Electric Plant, Progress Energy (NC)	Pond/Impoundment	Boron, Chromium, Iron, Manganese, Thallium, Nitrate, Sulfate, pH, TDS, Cadmium, Arsenic, Antimony	X	X		X
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	Pond/Impoundment, Landfill	Arsenic, Cadmium	X			
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X	X		
BC Cobb, Consumers Energy (MI)	Pond/Impoundment	Boron, Lithium, Manganese, Sulfate, Ammonia	X			
Belews Creek Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X	X	X	X
Big Bend Station, Tampa Electric Company (FL)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS	X		X	X
Big Cajun 2 Power Plant, NRG Energy/Louisiana Generating, LLC (LA)	Pond/Impoundment	Selenium, TDS, Barium, Arsenic	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Pond/Impoundment, Landfill	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X	X		X
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Aluminum, Cadmium, Iron, Sulfate, Arsenic, Cobalt, Calcium, Manganese, Molybdenum, Boron, Nickel	X			
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	Pond/Impoundment, Landfill	Selenium, Arsenic, Cadmium, Lead, Manganese, Vanadium, Nitrate, Iron, Sulfate, TDS, pH	X			
C.R. Huntley Flyash Landfill (NY)	Pond/Impoundment, Landfill	Arsenic, Iron, Manganese, Sulfate, TDS, Cadmium, Barium, Lead, TSS	X	X		
Canadys Plant, South Carolina Electric & Gas (SCE&E) (SC)	Pond/Impoundment	Arsenic, Nickel, Selenium	X			X
Cape Fear Steam Plant, Progress Energy (NC)	Pond/Impoundment	Lead, Chromium, Boron, Iron, Manganese, Sulfate, Selenium	X	X		
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Pond/Impoundment, Landfill	Arsenic, Boron, Molybdenum	X	X		
Cayuga Coal Ash Disposal Landfill, AES (NY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X	X	X	X
Cholla Steam Electric Generating Station, Arizona Public Service Company (AZ)	Pond/Impoundment	Sulfate, TDS, Chloride, Fluoride	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	Pond/Impoundment, Landfill	Boron, Manganese, Iron, Sulfate, Magnesium	X			
Coal Creek Station Surface Impoundments, Cooperative Power Association/United Power (ND)	Pond/Impoundment	Selenium, Arsenic, Sulfate, Chloride, Boron, Chromium, Iron, Sodium, TDS	X			
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Pond/Impoundment, Landfill	Cadmium, Antimony, Arsenic, Lead, Nitrate, Aluminum, Iron, Manganese, Boron, Molybdenum, Cobalt, Lithium, Sulfate, Chromium	X			
Coleto Creek Power Station, International Power (TX)	Pond/Impoundment	Arsenic, Lead, Boron, Cobalt, Nickel, Vanadium	X			
Colstrip Power Plant, PPL Montana (MT)	Pond/Impoundment, Landfill	Selenium, Boron, Sulfate, TDS, Molybdenum, Arsenic, Chloride	X			X
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment, Landfill	Arsenic, Cadmium, Chromium, Sodium, Sulfate, Iron, Aluminum, Chloride, TDS	X			
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X	X		
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Pond/Impoundment, Landfill	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH				
Dallman Station Ash and FGD Ponds, City Water, Light and Power (IL)	Pond/Impoundment, Landfill	Arsenic, Chromium, Sodium, Boron, Manganese, Iron, Sulfate, TDS	X X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Dan River Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Chromium, Iron, Lead, Manganese, Silver, Sulfate, Arsenic, Antimony, Boron, TDS, pH	X	X		
Dave Johnston Power Plant (WY)	Pond/Impoundment, Landfill	Cadmium, Manganese, Sulfate, Boron	X			
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Lead, Chloride, TDS, Sulfate, Iron, pH	X			
Duck Creek Station, Central Illinois Light Company (IL)	Pond/Impoundment	Sulfate, TDS, Chloride, Manganese, Iron, Boron				
E.J. Stoneman Generating Station, Dairyland Power Cooperative (WI)	Pond/Impoundment	Cadmium, Chromium, Sulfate, Manganese, Iron, Zinc, Boron, Barium	X			X
Edgewater 1-4 Ash Disposal Site, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment, Landfill	Boron, Sulfate, Iron, Chloride, TDS, Arsenic, Selenium	X			X
Fayette Power Project (Sam Seymour), Lower Colorado River Authority (TX)	Pond/Impoundment, Landfill	Selenium, Aluminum, Chloride, Cobalt, Manganese, Molybdenum, Sulfate, TDS, Vanadium	X			
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Pond/Impoundment, Landfill	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X	X		
Fly Ash Landfill, Coffeen/White & Brewer Trucking (IL)	Pond/Impoundment, Landfill	Sulfate, TDS, Manganese, Cadmium, Chromium, Thallium, Beryllium, Boron, Nickel, Barium, Iron, Zinc, Aluminum, Sodium	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Gallatin Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Boron, Beryllium, Cadmium, Iron, Manganese, Nickel, Sulfate, TDS, Arsenic, Mercury, Vanadium, Cobalt	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Pond/Impoundment, Landfill	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X	X		X
George Neal Station North Landfill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Landfill, Pond/Impoundment	Iron, Manganese, Sulfate, Arsenic	X			X
Gibson Generating Station, Duke Energy (IN)	Pond/Impoundment, Landfill, Cooling Reservoir	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X	X		X
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, pH	X			
Havana Power Plant, Illinois Power Company (IL)	Pond/Impoundment	Manganese, Sulfate, Boron				
Hennepin Power Station, Illinois Power Company (IL)	Pond/Impoundment, Landfill	Sulfate, TDS, Boron, Iron, Manganese	X			
Hunlock Power Station, UGI Development Company (PA)	Pond/Impoundment	Arsenic, Iron, Manganese	X		X	
Hutsonville Power Station, Central Illinois Public Service Company (IL)	Pond/Impoundment	Sulfate, TDS, Manganese, Boron				

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	Pond/Impoundment, Landfill	Cadmium, Iron, Lead, Manganese, pH, Sulfate, TDS, Arsenic, Chlorine	X			X
J.H. Campbell, Consumers Energy (MI)	Pond/Impoundment	pH, Antimony, Boron, Cadmium, Chromium, Iron, Lead, Selenium, Vanadium, Aluminum, Nickel, Thallium, Manganese, Zinc	X	X		
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Aluminum, Cadmium, Manganese, Boron, Strontium, Sulfate, Selenium, Hexavalent Chromium	X	X	X	X
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X	X	X	X
Joppa Steam Plant Ash Ponds, Ameren (Electric Energy) (IL)	Pond/Impoundment	Lead, Chromium, Cobalt, Boron, Manganese, Sulfate, Iron, TDS	X			
Karn/Weadock Generating Facility, Consumer Energy (MI)	Pond/Impoundment, Landfill	Arsenic, Boron, Lithium,	X			X
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Selenium, Manganese, Cobalt, Aluminum, Ammonia, Thallium, Iron	X	X		X
Lansing Smith Plant, Florida Power and Light (FL)	Pond/Impoundment	Aluminum, Cadmium, Chloride, Chromium, Fluoride, Sulfate, Manganese, Iron, Radium-226, Radium-228, TDS, Sodium	X			
Lee Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Lead, Boron, Manganese, Iron, Chromium, pH	X			X
Leland Olds Station, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Arsenic, Boron, Lead, Sulfate	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Lincoln Stone Quarry Landfill, Joliet Generating Station 29, Midwest Generation (IL)	Pond/Impoundment	Antimony, Manganese, Sulfate, Chloride, TDS	X			
Lincoln Stone Quarry Landfill, Joliet Generating Station 9, Midwest Generation (IL)	Pond/Impoundment, Landfill	Arsenic, Ammonia, Boron, Molybdenum, pH, Sulfate, TDS, Barium, Copper, Selenium, Cadmium	X			X
Little Blue Run Surface Impoundment, Bruce Mansfield Power Plant, First Energy (PA)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Antimony, Barium, Boron, Cadmium, Calcium, Chloride, Hexavalent Chromium, Fluoride, Iron, Lead, Manganese, pH, Sodium, Sulfate, TDS, TSS, Thallium, Turbidity	X	X		X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Pond/Impoundment, Landfill	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,	X			
Marion Plant, Southern Illinois Power Cooperative (IL)	Pond/Impoundment, Landfill	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X	X	X	X
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	Pond/Impoundment, Landfill	Chromium, Lead, Sulfate, Iron, TDS	X			
Mendosa Power Station Ash Ponds, Ameren Energy Generating Company, (IL)	Pond/Impoundment	Arsenic, Boron, Manganese, Chromium (?), Sulfate, TDS	X	X		
Michigan City Site (IN)	Pond/Impoundment	Arsenic, Lead	X			
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	Pond/Impoundment, Landfill	Arsenic, Chloride, Sulfate, TDS	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Mitchell Power Station, Allegheny Energy (PA)	Pond/Impoundment, Landfill	Arsenic, Boron, Iron, Molybdenum, Manganese, Nickel	X			X
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	Pond/Impoundment	Arsenic, Beryllium, Cadmium, Copper, Iron, Lead, Manganese, Nickel, pH, Zinc	X	X		X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Pond/Impoundment, Landfill	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X	X	X	X
Muskingum River Plant, American Electric Power (AEP)/ Ohio Power Company (OH)	Pond/Impoundment	Barium, Iron, Sulfate	X			X
Nelson Dewey Ash Disposal Facility, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment	Selenium, Arsenic, Sulfate, Boron, Fluoride, Cadmium (?), Iron				
Northeastern Station Ash Landfill, American Electric Power/Public Service Company Oklahoma (OK)	Landfill, Pond/Impoundment	Selenium, Arsenic, Barium, Chromium, Lead, Vanadium, Thallium, Sulfate, pH	X		X	X
Oak Ridge Y-12 Plant, Chestnut Ridge Operable Unit 2, Oak Ridge Reservation, Department of Energy (TN)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Iron, Zinc, Manganese, Thallium (?)	X		X	
Paradise Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment	Arsenic, Boron, Chromium, Copper, Manganese	X			
Parish Generating Station, NRG Energy/Texas Genco II (TX)	Pond/Impoundment, Landfill	Arsenic, Selenium, Barium, Boron, Chromium, Cobalt, Manganese, Molybdenum, Sulfate	X			
Pearl Station, Prairie Power Inc./Soyland Power Coop (IL)	Pond/Impoundment	Arsenic, Chromium, Boron, Manganese, Sulfate, Chlorine, Iron, TDS, Lead, Boron	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Pond/Impoundment, Landfill	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X	X	X	X
Prairie Creek Generating Station Ash Landfill, Interstate Power and Light (Alliant) (IA)	Pond/Impoundment, Landfill	Arsenic, Boron, Manganese, Sulfate, Iron	X	X		
R.M. Schahfer Generating Station (IN)	Landfill, Pond/Impoundment	Sulfate, Iron, Manganese, Molybdenum, Chlorine, Sodium, Boron				
Reid Gardner Generating Facility, Nevada Energy (NV)	Pond/Impoundment, Landfill	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X	X	X	X
Rock River Ash Disposal Facility, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment	Mercury, Arsenic, Sulfate, Iron, Selenium, Boron, TDS	X			
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Pond/Impoundment, Landfill	Arsenic, Lead, pH, TDS, Chloride, Sulfate	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Pond/Impoundment, Landfill	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X	X		X
Seward Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X	X		X

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium	X		X	X
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	Pond/Impoundment, Landfill	Arsenic, Cadmium, Lead, Sulfate, Selenium, Boron	X			
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	Pond/Impoundment, Landfill	Arsenic, Sulfate, TDS	X			X
Sutton Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Boron, Manganese, Iron, Thallium, Selenium, Antimony, Lead, Sulfate, TDS	X	X		X
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	Pond/Impoundment, Landfill	Arsenic, Nickel	X			
Venice Power Station Ash Ponds, Union Electric Company/Ameren Energy/AmerenUE (IL)	Pond/Impoundment	Arsenic, Boron, Cadmium, Iron, Manganese, TDS	X	X		X
Vermillion Power Station, Illinois Power (IL)	Pond/Impoundment	Sulfate, TDS, Boron, Iron, Manganese, Chloride				
W.C. Beckjord Station, Duke Energy (formerly Cinergy) (OH)	Pond/Impoundment	Selenium, Sulfate	X			
W.J. Neal Station Surface Impoundment, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Selenium, Arsenic, Chromium, Cadmium, Lead, Zinc, Aluminum	X		X	X
Wateree Station, SCE&G (SC)	Pond/Impoundment, Landfill	Arsenic, Chromium, Cadmium, Lead, Iron	X	X		X

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Waukegan Generating Station Ash Ponds, Midwest Generation (Edison International) (IL)	Pond/Impoundment, Landfill	Arsenic, Antimony, Boron, Manganese, Sulfate, TDS, Iron	X	X		
Weber Ash Disposal Site, AES Creative Resources (NY)	Pond/Impoundment, Landfill	Sulfate, TDS, Manganese, Iron, Aluminum, pH	X			
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Pond/Impoundment, Landfill	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X	X	X	
Widows Creek Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Pond/Impoundment	Lead, Cobalt, Boron, Iron, Manganese, Aluminum, Sulfate	X			
Winyah Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, Chromium, Sulfate, Iron, Chloride	X	X		
Wood River Power Station, Illinois Power Company (IL)	Pond/Impoundment	Sulfate, TDS, Chloride, Manganese, Iron, Boron				
Yorktown Power Station, Chisman Creek Disposal Site, Virginia Electric Power and Power Company (VEPCO) (VA)	Pond/Impoundment, Landfill	Sulfate, Nickel, Vanadium, Selenium	X			

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); MCL (Maximum Contaminant Level); TDS (Total Dissolved Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded MCLs or federal/state WQC/standards.

c – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

d – An “X” indicates that the ground water contaminated a source outside the plant property boundaries.

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
A.B. Brown Generating Station, Southern Indiana Gas and Electric Company (SIGECO) (IN)	FGD	Arsenic, Sodium, Boron, Sulfate, TDS, Chloride, pH	X			
Alma On-site Fly Ash Landfill, Dairyland Power (WI)	Fly Ash	Sulfate, Manganese				
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	Ash	Arsenic, Cadmium	X			
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Bottom Ash, Fly Ash, Other	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X	X		
Battlefield Golf Club, Chesapeake Energy Facility, Dominion Power (VA)	Fly Ash	Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Thallium, Zinc, Vanadium, Iron, Boron, Aluminum	X			
BBSS Sand and Gravel Quarries, Constellation Energy (MD)	Fly Ash, Bottom Ash	Arsenic, Selenium, Aluminum, Cadmium, Thallium, Manganese, Sulfate, Beryllium, Lead, Nickel	X			X
Belews Creek Steam Station, Duke Energy (NC)	Fly Ash, FGD	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X	X	X	X
Big Bend Station, Tampa Electric Company (FL)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS	X		X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Bottom Ash, Fly Ash	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X	X		X
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	Ash, FGD	Selenium, Arsenic, Cadmium, Lead, Manganese, Vanadium, Nitrate, Iron, Sulfate, TDS, pH	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
C.R. Huntley Flyash Landfill (NY)	Bottom Ash, Fly Ash, Other	Arsenic, Iron, Manganese, Sulfate, TDS, Cadmium, Barium, Lead, TSS	X	X		
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Bottom Ash, Fly Ash, FGD	Arsenic, Boron, Molybdenum	X	X		
Cayuga Coal Ash Disposal Landfill, AES (NY)	Bottom Ash, Fly Ash, Other	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X	X	X	X
CCW Landfill, Trans-Ash, Inc. (TN)	Bottom Ash, Fly Ash	Mercury, Iron, Boron, Sulfate, Arsenic, Chromium, Lead	X			X
Cedar-Sauk Landfill, Wisconsin Electric Power Company (WEPCO) (WI)	Fly Ash, Bottom Ash	Selenium, Sulfate, Boron	X			
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	Fly Ash, Other	Boron, Manganese, Iron, Sulfate, Magnesium	X			
Coal Ash Pit #3, Sheldon Station, Nebraska Public Power District (NE)	Fly Ash	Selenium, Sulfate	X			X
Coal Combustion Waste Landfill, Merom Generating Station, Hoosier Energy (IN)	Fly Ash, Bottom Ash	Barium, Chromium, Cadmium, Lead, Sulfate, Chloride, Sodium	X			
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Bottom Ash, Fly Ash, Other	Cadmium, Antimony, Arsenic, Lead, Nitrate, Aluminum, Iron, Manganese, Boron, Molybdenum, Cobalt, Lithium, Sulfate, Chromium	X			
Colstrip Power Plant, PPL Montana (MT)	Bottom Ash, Fly Ash, FGD	Selenium, Boron, Sulfate, TDS, Molybdenum, Arsenic, Chloride	X			X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Conesville Fixed FGD Sludge Landfill, American Electric Power (AEP) (OH)	Fly Ash, FGD	Arsenic, Cadmium, Chromium, Calcium, Magnesium, TDS, Sulfate, Iron, Selenium	X			
Crist Plant Ash Landfill, Gulf Power (Southern Company) (FL)	Fly ash, Bottom Ash, FGD	Arsenic, Cadmium, Manganese, Chromium, Sodium, Sulfate, Aluminum, Chlorine, Iron, pH, TDS	X			
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Bottom Ash, FGD	Arsenic, Cadmium, Chromium, Sodium, Sulfate, Iron, Aluminum, Chloride, TDS	X			
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash, FGD	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X	X		
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Bottom Ash, Other	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH		X		
Dallman Station Ash and FGD Ponds, City Water, Light and Power (IL)	Ash, FGD	Arsenic, Chromium, Sodium, Boron, Manganese, Iron, Sulfate, TDS	X			
Dan River Steam Station, Duke Energy (NC)	Bottom Ash, Fly Ash, Other	Chromium, Iron, Lead, Manganese, Silver, Sulfate, Arsenic, Antimony, Boron, TDS, pH	X	X		
Danskammer Waste Management Facility, Central Hudson Gas and Electric Corporation (NY)	Ash	Sulfate, Sulfide, TDS, Turbidity, Iron, Magnesium, Manganese, Sodium, Boron, pH				
Dave Johnston Power Plant (WY)	Fly Ash	Cadmium, Manganese, Sulfate, Boron	X			
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Bottom Ash, Fly Ash, FGD, Other	Selenium, Arsenic, Lead, Chloride, TDS, Sulfate, Iron, pH	X			
East Bend Scrubber Sludge Landfill, Cinergy (KY)	FGD	TDS, Iron, Sulfate, Manganese, Chloride				

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Edgewater 1-4 Ash Disposal Site, Alliant (formerly Wisconsin Power & Light) (WI)	Ash	Boron, Sulfate, Iron, Chloride, TDS, Arsenic, Selenium	X			X
Fair Station Ash Landfill, Central Iowa Power Cooperative (IA)	Ash	Selenium, Manganese, Sulfate, Iron	X			
Fayette Power Project (Sam Seymour), Lower Colorado River Authority (TX)	Bottom Ash, Fly Ash, FGD, Other	Selenium, Aluminum, Chloride, Cobalt, Manganese, Molybdenum, Sulfate, TDS, Vanadium	X			
Fern Valley Landfill, Orion Power Holdings, Inc. (a subsidiary of RRI Energy) (PA)	Fly Ash	Selenium, Aluminum, Boron, Chloride, Sulfate, TDS	X	X	X	X
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Bottom Ash, Fly Ash, Other	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X	X		
Fly Ash Landfill, Coffeen/White & Brewer Trucking (IL)	Fly Ash, FGD, Bottom Ash	Sulfate, TDS, Manganese, Cadmium, Chromium, Thallium, Beryllium, Boron, Nickel, Barium, Iron, Zinc, Aluminum, Sodium	X			
Fly Ash Landfill, Don Frame Trucking, Inc. (NY)	Bottom Ash, Fly Ash, Other	Lead, Sulfate, TDS, Manganese, Iron	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X	X		X
George Neal Station North Landfill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Fly Ash	Iron, Manganese, Sulfate, Arsenic	X			X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
George Neal Station South Ash Monofill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Bottom Ash, Fly Ash	Selenium, Arsenic, Barium, Zinc, Iron, Manganese, Sulfate	X			
Gibson Generating Station, Duke Energy (IN)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X	X		X
Hatfield's Ferry Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash, FGD	Arsenic, Aluminum, Boron, Chromium, Manganese, Molybdenum, Thallium, TDS, Sulfate, Selenium	X	X		X
Hennepin Power Station, Illinois Power Company (IL)	Fly Ash	Sulfate, TDS, Boron, Iron, Manganese	X			
Highway 59 Landfill, Wisconsin Electric Power Company (WEPCO) (WI)	Bottom Ash, Fly Ash	Selenium, Sulfate, Boron, Manganese, Chloride, Iron, Arsenic, Molybdenum, TDS		X		X
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	Bottom Ash, Fly Ash, Other	Cadmium, Iron, Lead, Manganese, pH, Sulfate, TDS, Arsenic, Chlorine	X			X
Indian River Generating Station, NRG Energy (DE)	Ash	Selenium, Mercury, Arsenic, Aluminum, Barium, Cadmium, Chromium, Copper, Lead, Nickel, Thallium, Zinc, Iron, Manganese	X	X		X
John Warden Ash Site (MI)	Ash, Other	Boron, Lithium				
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X	X	X	X
K.R. Rezendes South Main Street Ash Landfill, Salem Harbor and Brayton Point Plants, Pacific Gas and Electric (PG&E) (MA)	Ash	Selenium, Arsenic (?)	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Karn/Weadock Generating Facility, Consumer Energy (MI)	Ash, Fly Ash, Bottom Ash	Arsenic, Boron, Lithium,	X			X
Lincoln Stone Quarry Landfill, Joliet Generating Station 9, Midwest Generation (IL)	Ash	Arsenic, Ammonia, Boron, Molybdenum, pH, Sulfate, TDS, Barium, Copper, Selenium, Cadmium	X			X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Bottom Ash, Fly Ash, Other	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,	X			
Marion Plant, Southern Illinois Power Cooperative (IL)	Bottom Ash, Fly Ash, FGD	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X	X	X	X
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	Ash	Chromium, Lead, Sulfate, Iron, TDS	X			
Miamiview Landfill, Cincinnati Gas & Electric Company (OH)	FGD	Sulfate, Manganese				
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Chloride, Sulfate, TDS	X			
Mitchell Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash	Arsenic, Boron, Iron, Molybdenum, Manganese, Nickel	X			X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Bottom Ash, Fly Ash, Other	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X	X	X	X
Muscatine County Landfill (IA)	Ash	Selenium, Sulfate	X			
Muskegon County Type III Landfill (MI)	Fly Ash	Boron, Manganese		X		
North Lansing Landfill, Lansing Board of Water & Light (MI)	Ash, Other	Selenium, Boron, Lithium, Manganese, Sulfate, Lead	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Northeastern Station Ash Landfill, American Electric Power/Public Service Company Oklahoma (OK)	Bottom Ash, Fly Ash	Selenium, Arsenic, Barium, Chromium, Lead, Vanadium, Thallium, Sulfate, pH	X		X	X
Parish Generating Station, NRG Energy/Texas Genco II (TX)	Fly Ash, Bottom Ash, FGD (Emergency Only)	Arsenic, Selenium, Barium, Boron, Chromium, Cobalt, Manganese, Molybdenum, Sulfate	X			
Petersburg Generating Station, Indianapolis Power & Light (IN)	Not Specified	Sulfate, TDS	X			
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Ash, FGD	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X	X	X	X
Pine Hill Landfill, Marquette Board of Light & Power (MI)	Fly Ash	Boron, Lithium, Sodium		X		
Port Washington Facility, Wisconsin Electric Power Company (WEPCO) (WI)	Bottom Ash, Fly Ash	Selenium, Boron, Sulfate				X
Prairie Creek Generating Station Ash Landfill, Interstate Power and Light (Alliant) (IA)	Ash	Arsenic, Boron, Manganese, Sulfate, Iron	X	X		
Presque Isle Power Plant, WE Energies (WE) (MI)	Bottom Ash, Fly Ash	Boron, Molybdenum, Selenium, Sodium, Sulfate, Lithium				
Pulliam Ash Disposal Site, Wisconsin Power Supply Company (WPSC) (WI)	Bottom Ash, Fly Ash	Sulfate, Manganese, Iron, Boron, Zinc, Aluminum, Chlorine, TDS, pH				
R.M. Heskett Station, Montana-Dakota Utilities (ND)	Ash	Sulfate, Boron, Cadmium, Selenium, Nitrate	X			
R.M. Schahfer Generating Station (IN)	Ash, FGD	Sulfate, Iron, Manganese, Molybdenum, Chlorine, Sodium, Boron				

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Range Road Landfill, Detroit Edison (MI)	Ash	Boron, Lithium, Manganese		X		X
Reid Gardner Generating Facility, Nevada Energy (NV)	Fly Ash, FGD	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X	X	X	X
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Bottom Ash, Fly Ash, Other	Arsenic, Lead, pH, TDS, Chloride, Sulfate	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Fly Ash, FGD, Other	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X	X		X
Seward Generating Station, RRI Energy (PA)	Ash, Other	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X	X		X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium	X		X	X
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	Bottom Ash, Fly Ash, FGD	Arsenic, Cadmium, Lead, Sulfate, Selenium, Boron	X			
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	Bottom Ash, Fly Ash, FGD	Arsenic, Sulfate, TDS	X			X
Swift Creek Structural Fill, ReUse Technology, Inc./ Full Circle Solutions (NC)	Fly Ash	Arsenic, Lead, Sulfate	X	X		X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	Fly Ash, Bottom Ash, Other	Arsenic, Nickel	X			
Wateree Station, SCE&G (SC)	Bottom Ash, Fly Ash, FGD	Arsenic, Chromium, Cadmium, Lead, Iron	X	X		X
Waukegan Generating Station Ash Ponds, Midwest Generation (Edison International) (IL)	Ash	Arsenic, Antimony, Boron, Manganese, Sulfate, TDS, Iron	X	X		
Weber Ash Disposal Site, AES Creative Resources (NY)	Ash	Sulfate, TDS, Manganese, Iron, Aluminum, pH	X			
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Fly Ash	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X	X	X	
Yard 520 Landfill Site (Brown's Landfill),Northern Indiana Public Service Company (NIPSCO) (IN)	Fly Ash, Other	Arsenic, Manganese, Boron, Molybdenum, Lead, Selenium, Iron, Sulfate, Ammonium	X			X
Yorktown Power Station, Chisman Creek Disposal Site, Virginia Electric Power and Power Company (VEPCO) (VA)	Fly Ash	Sulfate, Nickel, Vanadium, Selenium	X			

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); MCL (Maximum Contaminant Level); TDS (Total Dissolved Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded MCLs or federal/state WQC/standards.

c – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

d – An “X” indicates that the ground water contaminated a source outside the plant property boundaries.

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Asheville Steam Electric Plant, Progress Energy (NC)	Pond/Impoundment	Boron, Chromium, Iron, Manganese, Thallium, Nitrate, Sulfate, pH, TDS, Cadmium, Arsenic, Antimony	X			X
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X			
Belews Creek Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X		X	X
Big Bend Station, Tampa Electric Company (FL)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS			X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Pond/Impoundment, Landfill	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X			X
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Aluminum, Cadmium, Iron, Sulfate, Arsenic, Cobalt, Calcium, Manganese, Molybdenum, Boron, Nickel				
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Pond/Impoundment, Landfill	Arsenic, Boron, Molybdenum	X			
Cayuga Coal Ash Disposal Landfill, AES (NY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X		X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Clinch River Plant, American Electric Power (AEP)/Appalachian Power (VA)	Pond/Impoundment	Aluminum, pH, Copper	X			X
Columbia Energy Center, Alliant Energy (WI)	Pond/Impoundment, Landfill	Cadmium, Copper, Barium, Aluminum, Iron, Zinc, Arsenic, Selenium, Lead, Manganese	X			X
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X			
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Pond/Impoundment, Landfill	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH	X			
Dan River Steam Station, Duke Energy (NC)	Pond/Impoundment	Arsenic, Copper, Iron, Aluminum	X	X		
Dave Johnston Power Plant (WY)	Pond/Impoundment, Landfill	Cadmium, Manganese, Sulfate, Boron				
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Pond/Impoundment, Landfill	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Pond/Impoundment, Landfill	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X			X
Gibson Generating Station, Duke Energy (IN)	Pond/Impoundment, Landfill, Cooling Reservoir	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X			X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Glen Lyn Plant, American Electric Power (AEP)/Appalachian Power (VA)	Pond/Impoundment	Selenium, Cadmium, Copper, Chromium, Zinc, pH, Nickel	X			X
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, pH				
J.H. Campbell, Consumers Energy (MI)	Pond/Impoundment	pH, Antimony, Boron, Cadmium, Chromium, Iron, Lead, Selenium, Vanadium, Aluminum, Nickel, Thallium, Manganese, Zinc	X			
J.R. Whiting Generating Plant, CMS/Consumers Energy (MI)	Pond/Impoundment	Selenium, Arsenic, Cobalt, Nickel, Bromine, Chromium				
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Aluminum, Cadmium, Manganese, Boron, Strontium, Sulfate, Selenium, Hexavalent Chromium	X		X	X
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X		X	X
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Selenium, Manganese, Cobalt, Aluminum, Ammonia, Thallium, Iron	X	X		X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Little Blue Run Surface Impoundment, Bruce Mansfield Power Plant, First Energy (PA)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Antimony, Barium, Boron, Cadmium, Calcium, Chloride, Hexavalent Chromium, Fluoride, Iron, Lead, Manganese, pH, Sodium, Sulfate, TDS, TSS, Thallium, Turbidity	X			X
Little Scary Creek Fly Ash Impoundment, John Amos Plant, American Electric Power (AEP)/Appalachian Power (WV)	Pond/Impoundment	Selenium, Mercury, Arsenic, Copper	X			
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Pond/Impoundment, Landfill	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,				
Marion Plant, Southern Illinois Power Cooperative (IL)	Pond/Impoundment, Landfill	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X		X	X
Martin's Creek Power Plant, PPL (PA)	Pond/Impoundment	Arsenic, Selenium, Lead, Aluminum, Copper, Chromium, Iron	X			X
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	Pond/Impoundment	Arsenic, Beryllium, Cadmium, Copper, Iron, Lead, Manganese, Nickel, pH, Zinc	X			X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Pond/Impoundment, Landfill	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X		X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Oak Ridge Y-12 Plant, Chestnut Ridge Operable Unit 2, Oak Ridge Reservation, Department of Energy (TN)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Iron, Zinc, Manganese, Thallium (?)			X	
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Pond/Impoundment, Landfill	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X		X	X
Plant Bowen, Georgia Power (GA)	Pond/Impoundment	Arsenic, Cadmium, Chromium, Lead, Mercury, Nickel, Copper	X			X
Reid Gardner Generating Facility, Nevada Energy (NV)	Pond/Impoundment, Landfill	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X		X	X
Savannah River Site, D-Area, Department of Energy (SC)	Pond/Impoundment	Cadmium, Chromium, Copper, Mercury, Selenium, Zinc, Iron, Aluminum	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Pond/Impoundment, Landfill	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X			X
Seward Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X			X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium			X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Sutton Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Boron, Manganese, Iron, Thallium, Selenium, Antimony, Lead, Sulfate, TDS	X			X
W.J. Neal Station Surface Impoundment, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Selenium, Arsenic, Chromium, Cadmium, Lead, Zinc, Aluminum			X	X
Wateree Station, SCE&G (SC)	Pond/Impoundment, Landfill	Arsenic, Chromium, Cadmium, Lead, Iron	X			X
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Pond/Impoundment, Landfill	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X		X	

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); TDS (Total Dissolved Solids); TOC (Total Organic Carbon); TOH (Total Organic Hydrocarbons); TSS (Total Suspended Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded federal/state WQC/standards.

c – An “X” indicates that the contaminated surface water was issued a fish consumption advisory.

d – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

e – An “X” indicates that the surface water contaminated a source outside the plant property boundaries.

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Bottom Ash, Fly Ash, Other	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X			
Battlefield Golf Club, Chesapeake Energy Facility, Dominion Power (VA)	Fly Ash	Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Thallium, Zinc, Vanadium, Iron, Boron, Aluminum				
Belews Creek Steam Station, Duke Energy (NC)	Fly Ash, FGD	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X		X	X
Big Bend Station, Tampa Electric Company (FL)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS			X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Bottom Ash, Fly Ash	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X			X
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Bottom Ash, Fly Ash, FGD	Arsenic, Boron, Molybdenum	X			
Cayuga Coal Ash Disposal Landfill, AES (NY)	Bottom Ash, Fly Ash, Other	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X		X	X
CCW Landfill, Trans-Ash, Inc. (TN)	Bottom Ash, Fly Ash	Mercury, Iron, Boron, Sulfate, Arsenic, Chromium, Lead				X
Coal Combustion Waste Landfill, Merom Generating Station, Hoosier Energy (IN)	Fly Ash, Bottom Ash	Barium, Chromium, Cadmium, Lead, Sulfate, Chloride, Sodium				
Columbia Energy Center, Alliant Energy (WI)	Bottom Ash, Fly Ash	Cadmium, Copper, Barium, Aluminum, Iron, Zinc, Arsenic, Selenium, Lead, Manganese	X			X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash, FGD	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X			
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Bottom Ash, Other	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH	X			
Dave Johnston Power Plant (WY)	Fly Ash	Cadmium, Manganese, Sulfate, Boron				
Fern Valley Landfill, Orion Power Holdings, Inc. (a subsidiary of RRI Energy) (PA)	Fly Ash	Selenium, Aluminum, Boron, Chloride, Sulfate, TDS	X		X	X
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Bottom Ash, Fly Ash, Other	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X			X
Gibson Generating Station, Duke Energy (IN)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X			X
Hatfield's Ferry Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash, FGD	Arsenic, Aluminum, Boron, Chromium, Manganese, Molybdenum, Thallium, TDS, Sulfate, Selenium	X			X
Indian River Generating Station, NRG Energy (DE)	Ash	Selenium, Mercury, Arsenic, Aluminum, Barium, Cadmium, Chromium, Copper, Lead, Nickel, Thallium, Zinc, Iron, Manganese	X			X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
John Warden Ash Site (MI)	Ash, Other	Boron, Lithium				
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X		X	X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Bottom Ash, Fly Ash, Other	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,				
Marion Plant, Southern Illinois Power Cooperative (IL)	Bottom Ash, Fly Ash, FGD	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X		X	X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Bottom Ash, Fly Ash, Other	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X		X	X
Oak Creek Power Plant, Wisconsin Energy (WE Energies (WE))/Wisconsin Electric Power Company (WI)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Chromium, TCE, Diesel Fuel	X			X
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Ash, FGD	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X		X	X
Range Road Landfill, Detroit Edison (MI)	Ash	Boron, Lithium, Manganese	X			X
Reid Gardner Generating Facility, Nevada Energy (NV)	Fly Ash, FGD	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X		X	X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Seminole Generating Station, Seminole Electric Cooperative (FL)	Fly Ash, FGD, Other	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X			X
Seward Generating Station, RRI Energy (PA)	Ash, Other	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X			X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium			X	X
Wateree Station, SCE&G (SC)	Bottom Ash, Fly Ash, FGD	Arsenic, Chromium, Cadmium, Lead, Iron	X			X
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Fly Ash	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X		X	

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); TDS (Total Dissolved Solids); TOC (Total Organic Carbon); TOH (Total Organic Hydrocarbons); TSS (Total Suspended Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded federal/state WQC/standards.

c – An “X” indicates that the contaminated surface water was issued a fish consumption advisory.

d – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

e – An “X” indicates that the surface water contaminated a source outside the plant property boundaries.

Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants

Species	Attractive Nuisance Site Description	Pollutant Concentrations in the Environment or Diet	Pollutant Concentrations in the Organism (µg/g)	Observed Effects	Study Type	Citation
Common Grackles (*Quiscalus quiscala*)	Nested in close proximity to a coal-fired power plant's fly ash pond.	Not measured in study	Eggs = 5.9 selenium	Histopathological	Field	Bryan *et al.*, 2003
Raccoons (*Procyon lotor*)	Lived in close proximity to a coal-fired power plant's ash pond.	Not measured in study	• Heart = 2.8 arsenic • Kidney = 3.2 cadmium, 0.43 strontium • Muscle = 0.95 chromium • Liver = 0.34 lead, 1.5 mercury	Histopathological	Field	Burger *et al.*, 2002
Interior Least Tern (*Sterna antillarum*)	Nested on a dike in a coal-fired power plant's ash pond.	Not measured in study	Not observed in study	Not observed in study	Field	Pruitt, 2000 and Duke Energy, 2007
Southern Toads (*Bufo terrestris*)	• Inhabited an ash basin and nearby swamp. • Reference (control) site organisms were transferred to contaminated locations.	Not measured in study	Not measured in study	Elevated corticosterone and testosterone levels	Outdoor mesocosm	Hopkins *et al.*, 1997
Southern Toads (*Bufo terrestris*)	• Inhabited an ash pond and nearby swamp. • Reference site organisms were transferred to contaminated locations.	Pond sediment = 39.64 µg/g arsenic, 4.38 µg/g selenium	Adult males = 1.58 arsenic, 17.40 selenium	Histopathological	Outdoor mesocosm	Hopkins *et al.*, 1998

Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants

Species	Attractive Nuisance Site Description	Pollutant Concentrations in the Environment or Diet	Pollutant Concentrations in the Organism (µg/g)	Observed Effects	Study Type	Citation
Larval Bullfrogs (*Rana catesbeiana*)	Inhabited bottom ash ponds near a coal-fired power plant.	Pond sediment = 49.39 µg/g arsenic, 0.72 µg/g cadmium, 23.85 µg/g chromium, 84.72 µg/g copper, 6.11 µg/g selenium, 106.39 µg/g strontium, 45.83 µg/g vanadium	Whole body concentration = 33.10 arsenic, 5.47 cadmium, 18.25 chromium, 116.72 copper, 20.25 selenium, 39.89 strontium, 17.32 vanadium	• Morphological • Decreased swimming speeds	Field	Hopkins *et al.*, 2000
Eastern Narrow-Mouth Toads (*Gastrophryne carolinensis)*	Inhabited a selenium-laden site located near a coal-fired power plant.	• Site water = 3.93 µg/L selenium • Soil = 38.25 µg/L selenium • Lab water = 0.28 µg/L selenium	• Females = 42.40 selenium • Eggs = 43.96 selenium	• Reproductive • Histopathological	Outdoor mescosm	Hopkins *et al.*, 2006
Barn Swallow (*Hirundo rustica*)	Nested near a selenium-laden pond associated with a coal-fired power plant.	Not provided in the literature	Eggs = 2.8 selenium	Histopathological	Field	King *et al.*, 1994
Slider Turtles (*Trachemys scripta*)	• Inhabited a selenium-laden basin that receives fly ash transport water near a coal-fired power plant. • Eggs were incubated in ash-contaminated soil.	Ash-contaminated soil = 2.56 µg/g selenium	Adult Females = 37.18 (mean concentration), selenium	Reproductive	Outdoor mescosm	Nagle *et al.*, 2001
Canada Geese (*Branta Canadensis*)	Inhabited pens near a vanadium-laden ash pond associated with an oil-fired power plant	Site water = 467,000 µg/L vanadium	• Liver = 57.3 vanadium • Kidney = 226 vanadium	• Lethal • Histopathological	Outdoor mesocosm	Rattner *et al.*, 2006

Acronyms: µg/g (Micrograms per Grams); µg/L (Micrograms per Liters).

Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants

Site Name, Location, and Contamination Source	Organism Affected	Documented Effects	Trace Pollutant Concentrations (ppm)	Citation
Kesterson Reservoir, CA Agricultural Runoff	California Vole (*Microtus californicus*)	Mean selenium concentrations in livers were significantly elevated.	Liver = 119 selenium	Clark *et al.*, 1987
Kesterson Reservoir, CA Agricultural Runoff	American Coot (*Fulica americana*), Mallard (*Anas platyrhynchos*)	Mean selenium concentrations in bird eggs and livers were elevated; organisms exhibited severe reproductive failure and deformities.	• Eggs = 2.2 – 110 selenium • Liver = 19 – 130 selenium • Water = 300,000 selenium	Ohlendorf *et al.*, 1986
Kesterson Reservoir, CA Agricultural Runoff	Pied-Billed Grebes (*Podilymbus podiceps*), Common Moorhen (*Gallinula chloropus*), Black-Necked Stilts (*Himantopus mexicanus*)	Selenium concentrations in livers were 10 times those found in nearby control areas; organisms exhibited severe lesions and embryonic deformities.	• Liver = 94.4 selenium • Water = 300,000 selenium	Ohlendorf *et al.*, 1988a
Kesterson Reservoir, CA Agricultural Runoff	Gopher Snakes (*Pituophis melanoleucus*), Bullfrogs (*Rana catesbeiana*)	Selenium concentrations in snake and frog livers were significantly elevated.	• Snake liver = 11.1 selenium • Frog liver = 45.0 selenium	Ohlendorf *et al.*, 1988b
Kesterson Reservoir, CA Agricultural Runoff	Eared Grebe (*podiceps nigricollis*), Mallard (*Anas platyrhynchos*), Cinnamon Teal (*Anas cyanoptera*), Gadwall (*Anas strepera*), American Coot (*Fulica americana*), Killdeer (*Charadrius vociferous*), Black-Necked Stilt (*Himantopus mexicanus*), American Avocet (*Recurvirostra americana)*	Hatchlings exhibited mortality, deformity, and lack of embryonic development.	Water = 300 selenium	Ohlendorf *et al.*, 1989
Kesterson Reservoir, CA Agricultural Runoff	Mosquitofish (*Gambusia affinis*), American Coot (*Fulica americana)*, Ducks (*Anas spp*.)	Selenium concentrations in livers, kidneys, and muscles were elevated; organisms exhibited reduced body weight.	• Fish = 120 – 140 selenium • Coot liver = 76.7 selenium • Duck liver = 25.2 selenium	Ohlendorf *et al.*, 1990
Liberty State Park, NJ Industrial and Urban Activities	House Wren (*troglodytes aedon*), American Robin (*Turdus migratorus*)	Lead, arsenic, chromium, copper, and iron concentrations in bird feathers were elevated.	Feather = 4,200 lead; 1,000 chromium; 6,200 copper; 600 arsenic	Hofer *et al.*, 2010

Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants

Site Name, Location, and Contamination Source	Organism Affected	Documented Effects	Trace Pollutant Concentrations (ppm)	Citation
Meadowlands, NJ Industrial and Urban Activities	Red-winged blackbird (*agelaius phoeniceus*), marsh wrens (*Cistothorus palustris*), tree swallow (*Tachycineta bicolor*)	Lead and chromium concentrations in blood were elevated; mercury and chromium concentrations in eggs were elevated.	• Swallow blood = 0.94 lead; 1.03 chromium • Wren eggs = 0.2 mercury • Blackbird eggs = 0.12 chromium	Tsipoura *et al.*, 2008

Acronym: ppm (parts per million).

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
Belews Creek Steam Station, Duke Energy (NC)	Striped bass (*Morone saxatilis*)	Consumed a selenium-laden diet by eating red shiners collected from a site receiving coal ash pond sluice water.	Red Shiners = 9.6 µg/g (average whole-body concentration), wet	Skeletal muscle = 3.8 (higher average concentration), wet	Modified behavior Decreased growth Histopathological Lethal	Laboratory (reservoir)	Coughlan and Velte, 1989
	Largemouth bass (*Micropterus salmoides*) [a] *Pomoxis spp*.	Inhabited a selenium-laden cooling water reservoir receiving both fly ash and bottom ash pond effluent from a coal-fired power plant.	Site water [d] = 10 µg/L	Biomass [e] = 0.1 – 1.0 (mean)	Lethal Reproductive	Field (reservoir)	Cumbie and Van Horn, 1978
	Lepomis spp. [b]			Body = 41.0 – 77.1 (54.6 mean concentration), wet			
	Lealurus spp. [c]			Body = 0.31 – 15.5 (6.32 mean concentration), wet			
	Largemouth bass (*Micropterus salmoides)*	Inhabited a selenium-laden cooling water reservoir receiving effluent from the coal ash pond.	Ash effluent = 100-200 µg/L Site water = 10 µg/L	Visceral tissue = 40+ (highest mean concentration), wet	Lethal	Field (reservoir)	Lemly, 1985a
	Green sunfish (*Lepomis cyanellus*)	Inhabited a selenium-laden lake receiving coal fly ash sluice water.	Site water = 13 µg/L Sediment = 5 – 14 µg/g, dry	Liver = 21.4, wet Skeletal muscle = 12.9, wet Hematocrit = 33, wet	Histopathological Hematological	Field (lake)	Sorensen *et al.*, 1984b
D-Area Coal-Fired Power Plant, Savannah River Site (SRS) (SC)	Banded water snakes (*Nerodia fasciata*)	Consumed a selenium-laden diet by eating prey collected from a contaminated site located near a coal-fired power plant.	Prey items [f] = 22.7 µg/g (geometric least squared mean), dry	Gonads = 17.64 (female), 19.06 (male) Kidney = 25.38 (female), 32.04 (male) Liver = 24.08 (female), 24.22 (male)	Reproductive Histopathological	Laboratory (not specified)	Hopkins *et al.*, 2002

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Eastern narrow-mouth toads (*Gastrophryne carolinensis)*	Inhabited a selenium-laden site located near a coal-fired power plant.	Site water = 3.93 µg/L Soil = 8.25 µg/L Lab water = 0.28 µg/L	Females = 42.40 Eggs = 43.96	Reproductive Histopathological	Outdoor mescosm (combustion residuals pond)	Hopkins *et al.*, 2006
	Slider turtles (*Trachemys scripta*)	Inhabited a selenium-laden pond receiving sluiced fly ash near a coal-fired power plant. Eggs were incubated in ash-contaminated soil.	Ash-contaminated soil = 2.56 µg/g, dry	Adult females = 37.18 (mean concentration), dry	Reproductive	Outdoor mescosm (combustion residuals pond)	Nagle *et al.*, 2001
Roxboro Plant, Progress Energy (NC)	Largemouth bass (*Micropterus salmoides*)	Inhabited a selenium-laden cooling water reservoir receiving ash pond effluent from a coal-fired power plant.	Not provided in the literature.	Carcass = 2.86 (mean, female), 2.63 (mean, male) Gonad = 4.40 (mean, female), 2.38 (mean, male)	Reproductive Histopathological	Field (reservoir)	Baumann and Gillespie, 1986
	Bluegill (*Lepomis macrochirus*)			Carcass = 2.74 (mean, female), 4.64 (mean, male) Gonad = 4.63 (mean, female), 3.35 (mean, male)			
	Bluegill (*Lepomis macrochirus*)	Inhabited a selenium-laden reservoir receiving coal ash pond effluent.	Not provided in the literature	Not provided in the literature	Lethal	Field (reservoir) [g]	Crutchfield and Ferguson, 2000a
	Green sunfish [h] (*Lepomis cyanellus)*	Inhabited a selenium-laden reservoir receiving coal ash pond effluent.	Site water [i] = 7 – 14 µg/L	Biomass [j] = 2,744 – 3,793 (mean)	Lethal Reproductive	Field (reservoir)	Crutchfield, 2000b

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Bluegill (*Lepomis macrochirus*)	Inhabited a selenium-laden cooling water reservoir of a coal-fired power plant.	Site water [k] = 9 – 12 µg/L	Testes = 4.37 (mean concentration) Ovaries = 6.96 (mean concentration)	Reproductive	Laboratory (reservoir)	Gillepsie *et al.*, 1986
	Bluegill [l] (*Lepomis macrochirus*)	Inhabited a selenium-laden cooling water reservoir of a coal-fired power plant.	Site water = <10–20 µg/L	Liver = 34 (mean concentration), wet Gonad = 12.1 (mean, female), 5.4 (mean, male), wet Muscle = 13 (mean concentration), wet	Histopathological	Field (reservoir)	Sager and Colfield, 1984
	Largemouth bass [m] (*Micropterus salmoides*)			Liver = 10.2 (mean concentration), wet Gonad = 10.3 (mean, female), wet Muscle = 6.7 (mean concentration), wet			
Martin Lake Steam Station, Texas Utilities Electric Service Company (TX)	Green sunfish (*Lepomis cyanellus*)	Inhabited a selenium-laden lake receiving coal fly ash, scrubber sludge, and coal bottom ash.	Not provided in the literature	Hepatopancreas = 1.31 – 9.30, wet	Histopathological	Field (lake)	Sorensen *et al.*, 1982
	Redear sunfish (*Lepomis microlophus*)			Hepatopancreas = 2.8 – 11.03, wet			
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake receiving coal fly ash, scrubber sludge, and coal bottom ash.	Not provided in the literature	Liver = 20	Histopathological	Field (lake)	Sorensen *et al.*, 1983

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake receiving coal ash pond wastewater.	Not provided in the literature	Hepatopancreas = 8.4 – 27.2 µg/L Kidney = 11.4 – 115.7 µg/L Ovaries = 0 – 5.9 µg/L Testes = 0 – 54.2 µg/L	Increased weight loss	Field (lake)	Sorensen and Bauer, 1984a
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake located near a coal-fired power plant.	Not provided in the literature	Liver = 7.63 (mean concentration)	Histopathological Reproductive	Field (lake)	Sorensen, 1988

Acronyms: kg/ha (kilogram per hectacre); µg/L (micrograms per liter); µg/g (micrograms per gram).

a – Multiple fish species were studied; however, as presented by the report, the largemouth bass and *pomoxis spp.* had the lowest documented selenium biomass concentrations.

b – Multiple fish species were studied; however, as presented by the report, the *Lepomis spp.* had the highest documented selenium skeletal muscle concentrations.

c – Multiple fish species were studied; however, as presented by the report, the *Letalurus spp.* had the lowest documented selenium body concentrations.

d – This selenium concentration is dissolved.

e – This concentration is measured in the units kg/ha. The range of selenium concentrations was reported annually from 1982 to 1989, before the steam electric power plant converted to dry ash handling. Both fish species had the same range of selenium concentrations.

f – The banded water snakes were fed weekly combinations of previously frozen prey items inhabiting the coal ash-contaminated site.

g – The data used in this study were census data collected from routine biological monitoring undertaken by the steam electric power plant.

h – Multiple fish species were studied; however, as presented by the report, the green sunfish had the highest documented selenium biomass concentrations.

i – These are the selenium water concentrations detected prior to the conversion to a dry fly ash handling system.

j – This concentration is measured in the units kg/ha. The range of selenium concentrations was reported annually from 1982 to 1989, before the steam electric power plant converted to dry ash handling.

k – This concentration was not measured for this study but was reported in a previous study conducted at the same site.

l – Multiple fish species were studied; however, as presented by the report, the bluegills had the highest documented selenium liver tissue concentration.

m – Multiple fish species were studied; however, as presented by the report, the largemouth bass had the lowest documented selenium liver tissue concentration.

APPENDIX B
PROXIMITY ANALYSES SUPPORTING TABLES

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Algal Growth	Algal Growth		
Algal Growth	Chlorophyll-A		
Cause Unknown	Cause Unknown		
Cause Unknown - Impaired Biota	Benthic Macroinvertebrates Bioassessments		
Cause Unknown - Impaired Biota	Fish Bioassessments		
Dioxins	2,3,7,8-Tetrachlorodibenzo-P-Dioxin (Only)		
Dioxins	Dioxin		
Dioxins	Dioxins		
Fish Consumption Advisory	Fish Consumption Advisory		
Flow Alteration(s)	Flow Alteration(s)		
Habitat Alterations	Habitat Alterations		
Mercury	Fish Consumption Advisory - Mercury	✓	✓
Mercury	Mercury	✓	✓
Mercury	Mercury In Fish Tissue	✓	✓
Metals (Other Than Mercury)	Aluminum	✓	✓
Metals (Other Than Mercury)	Arsenic	✓	✓
Metals (Other Than Mercury)	Cadmium	✓	✓
Metals (Other Than Mercury)	Chromium, Total	✓	✓
Metals (Other Than Mercury)	Copper	✓	✓
Metals (Other Than Mercury)	Iron	✓	✓
Metals (Other Than Mercury)	Lead	✓	✓
Metals (Other Than Mercury)	Manganese	✓	✓
Metals (Other Than Mercury)	Metals (Other Than Mercury)	✓	✓
Metals (Other Than Mercury)	Selenium	✓	✓
Metals (Other Than Mercury)	Silver	✓	✓
Metals (Other Than Mercury)	Zinc	✓	✓
Noxious Aquatic Plants	Macrophytes		
Nutrients	Eutrophication	✓	✓
Nutrients	Nitrogen, Total	✓	✓
Nutrients	Nutrient/Eutrophication Biological Indicators	✓	✓
Nutrients	Nutrients	✓	✓
Nutrients	Phosphorus	✓	✓
Nutrients	Phosphorus, Total	✓	✓

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Oil And Grease	Oil	✓	
Oil And Grease	Oil And Grease	✓	
Organic Enrichment/Oxygen Depletion	Dissolved Oxygen	✓	
Organic Enrichment/Oxygen Depletion	Dissolved Oxygen Saturation	✓	
Pathogens	Bacteria		
Pathogens	Coliforms		
Pathogens	Enterococcus Bacteria		
Pathogens	Escherichia Coli (*E. Coli*)		
Pathogens	Fecal Coliform		
Pathogens	Indicator Bacteria		
Pathogens	Pathogens		
Pesticides	Atrazine		
Pesticides	Chlordane		
Pesticides	Chlorpyrifos		
Pesticides	DDD		
Pesticides	DDE		
Pesticides	DDT		
Pesticides	Dieldrin		
Pesticides	Mirex		
Pesticides	Organochlorine Pesticides		
pH/Acidity/Caustic Conditions	pH	✓	
pH/Acidity/Caustic Conditions	pH, Low	✓	
Polychlorinated Biphenyls (PCBs)	Fish Consumption Advisory - PCBs		
Polychlorinated Biphenyls (PCBs)	PCBs In Fish Tissue		
Polychlorinated Biphenyls (PCBs)	Polychlorinated Biphenyls (PCBs)		
Salinity/Total Dissolved Solids/Chlorides/Sulfates	Salinity/Total Dissolved Solids/Chlorides	✓	✓
Salinity/Total Dissolved Solids/Chlorides/Sulfates	Total Dissolved Solids (TDS)	✓	✓
Sediment	Sedimentation/Siltation	✓	
Sediment	Siltation	✓	
Sediment	Solids (Suspended/Bedload)	✓	
Sediment	Suspended Sediment	✓	
Taste, Color, And Odor	Taste and Odor		
Temperature	Temperature		
Toxic Inorganics	Boron	✓	✓
Toxic Organics	Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)		

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Turbidity	Total Suspended Solids (TSS)	✓	
Turbidity	Turbidity	✓	

Source: U.S. EPA, 2014i. National 303(d) Listed Impaired Waters National Hydrography Data (NHD) Indexed Dataset. Reach Address Database (RAD). Extracted on August 4. Available online at: http://www.epa.gov/waters/data/downloads.html. DCN SE04544.

Note: A surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat). In even-numbered years, states submit their lists of impaired waters (known as the “303(d) list”) to EPA. These state-submitted, Geographic Information System (GIS) datasets are collected by EPA and indexed to the National Hydrography Dataset (NHDPlus) at 1:100K resolution (*i.e.*, 303(d) impaired waters proximity database). For this EA, EPA reviewed the 303(d) impaired waters proximity database to identify steam electric power plant immediate receiving waters identified as impaired for a pollutant associated with the evaluated wastestreams (*i.e.*, FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate).

Table B-2. Immediate Receiving Waters Fish Consumption Advisory Listing

Pollutant	Found in Combustion Wastewater	Evaluated in the EA
Chlordane		
Chlorinated pesticides		
DDT		
Dieldrin		
Dioxin		
Lead	✓	✓
Mercury	✓	✓
Mirex		
Not Specified		
PCBs (Total)		
Perfluorooctane sulfonate		
Toxaphene		

Source: U.S. EPA, 2014h. National Fish Consumption Advisories NHD Indexed Dataset. RAD. Extracted on July 7. Available online at: http://epamap32.epa.gov/radims/. DCN SE04545.

APPENDIX C
WATER QUALITY MODULE METHODOLOGY

This appendix presents the model equations, input variables, pollutant benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model water quality module.

The IRW water quality module equations are organized by the methodology for nonvolatile pollutants (*i.e.*, arsenic, cadmium, chromium (VI), copper, lead, nickel, selenium, thallium, and zinc) and volatile pollutants (*i.e.*, mercury). 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. Model input requirements for the equations presented in Appendix C can be divided into four major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; and 4) site-specific assumption variable based on predetermined data. The following tables in Appendix C describe the input requirements and data sources used in the water quality module:

- Table C-1. Site-Specific Model Input Variables.
- Table C-2. Model Assumption Input Variables.
- Table C-3. Site-Specific Assumption Input Variables.
- Table C-4. Surface Water 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 Level (MCL) Benchmarks.

EPA calculated pollutant loadings from the evaluated wastestreams as part of its engineering analysis (see Section 10 of the Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD) [EPA 821-R-15-007]). The IRW water quality module performs calculations on a per immediate-receiving-water basis. For steam electric power plants that discharge to multiple receiving waters, EPA divided the plant-specific pollutant loadings accordingly among the receiving waters based on water diagrams provided in the Questionnaire for the Steam Electric Power Generating Effluent Guidelines (Steam Electric Survey) responses. EPA used the IRW model to evaluate the environmental impacts from 188 steam electric power plants in the receiving water quantitative analysis (209 unique immediate receiving waters).

EPA modeled chromium (VI) in the water quality module, but did not take into consideration arsenic or mercury speciation. EPA included 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). EPA used total selenium loadings in the water quality module; however, due to the partition coefficients available, EPA assumed the dominant form of selenium in the receiving water was selenate (*i.e.*, selenium (VI)). Although selenium speciation likely occurs within combustion residual surface impoundments prior to discharge, EPA selected the selenate partition coefficient because it is expected to be the predominant form present in well-oxygenated alkaline surface waters and the rate of conversion between selenate and selenite (*i.e.*, selenium (IV)) is reported to be slow in most natural waters [U.S. EPA, 2004].

IRW Model: Water Quality Module Equations

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}); and
Total pollutant concentration in sediment (C_{bs}).

EPA used the equations presented below to calculate receiving water concentrations for arsenic, cadmium, chromium (VI), 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 steam effluent (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 NHD Plus (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 steam effluent (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 NHD Plus (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])	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption 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)	Model assumption value of 0.03 m (see Table C-2)

EQUATION C-6

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

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)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption 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])	Model assumption value of 0.6 cm^3/cm^3 (see Table C-2)
Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)

bsc	=	Bed sediment particle concentration (gram per cubic centimeter [g/cm^3]) or (kilogram per liter [kg/L])	Model assumption value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic layer (m)	Model assumption 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 NHD Plus (see Table C-1)
v	=	Receiving water velocity (m/s)	Site-specific value from NHD Plus (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 NHD Plus (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)	Model assumption 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)	Model assumption 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)	Model assumption value of 0/day (see Table C-2)
k_{vol}	=	Water column volatilization loss rate constant (1/day)	Model assumption 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 NHD Plus (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)	Site-specific value from NHD Plus (see Table C-1)
$d_{z,lake}$	=	Depth of the lake (m)	Site-specific value (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)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption 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)	Model assumption value of 0 m/day (see Table C-2)

d_b	=	Depth of upper benthic sediment layer (m)	Model assumption value of 0.03 m (see Table C-2)

EQUATION C-15

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

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)	Model assumption value of 0.6 cm^3/cm^3 (see Table C-2)
Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)
bsc	=	Bed sediment particle concentration (g/cm^3) or (kg/L)	Model assumption value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic sediment layer (m)	Model assumption 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)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption 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)

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}). 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)	Model assumption 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)	Model assumption 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)	Model assumption value of 1.026 (see Table C-2)
T_w	=	Temperature of the waterbody (degrees Kelvin [°K])	River or stream: site-specific assumption value (see Table C-3 and Table C-6) Lake, pond, or reservoir: model assumption value (see Table C-3 and Table C-6)
T_{hlc}	=	Temperature of HLC (°K)	Default model 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: model assumption 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]	Known value of 0.0113 atm-m^3/mol (see Table C-2)
R	=	Universal gas constant (atm-m^3/°K-mole)	Known value of 0.00008205 atm-m^3/°K-mole (see Table C-2)

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 NHD Plus (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])	Known value of 200.59 g/mol for mercury (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-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)	Model assumption value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Site-specific assumption value (see Table C-3)
ρ_a	=	Density of air corresponding to water temperature (g/cm^3)	Model assumption value of 0.0012 g/cm^3 (see Table C-2)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Model assumption value of 1 g/cm^3 (see Table C-2)
k	=	Von Karman’s constant (unitless)	Known value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Model assumption 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)	Model assumption value of 0.0169 g/cm-s (see Table C-2)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Model assumption 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)	Model assumption value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Site-specific assumption value (see Table C-3)
k	=	Von Karman's constant (unitless)	Known value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Model assumption 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	Site-specific assumption value (see Table C-3)
MW	=	Molecular weight (g/mol)	Known value of 200.59 g/mol for mercury (see Table C-2)

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 benchmarks presented in Table C-7.

IRW Model: Water Quality Module Inputs

Table C-1. Site-Specific Input Variables

Input Variable	Input Category and Description	Data Source
L_{total}	Plant-specific effluent characteristic Total waterbody loading	EPA estimated the pollutant discharge loadings using the methodology presented in Section 10 of the TDD.
Q_{cool}	Plant-specific effluent characteristic Total cooling water effluent flow by receiving water	EPA determined the estimated cooling water flow for each plant by outfall based an assessment of industry survey results using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
Q_{river}	Receiving water characteristic for rivers and streams Waterbody annual flow	EPA extracted average annual flow values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset includes estimated mean annual flow values for each stream reach within the network using the Vogel Method [Vogel *et al.*, 1999] and the Unit Runoff Method.
v	Receiving water characteristic for rivers and streams Receiving water velocity	EPA extracted average annual velocity values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset 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	EPA estimated the stream reach length based on outfall locations using the methodology described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
Q_{lake}	Receiving water characteristic for lakes, ponds, and reservoirs Average discharge flow exiting the lake/pond system	EPA extracted average annual flow values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset includes estimated mean annual flow values for the stream reach exiting the lake using the Vogel Method [Vogel *et al.*, 1999] and the Unit Runoff Method.
Area	Receiving water characteristic for lakes, ponds, and reservoirs Surface area of the lake, pond, or reservoir	EPA estimated the lake surface area based on NHD Plus data or site-specific sources as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
$d_{z,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs Depth of the lake, pond, or reservoir	EPA estimated the depth of the lake, pond, or reservoir based on site-specific data as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
$d_{w,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs Depth of the water column	EPA estimated the depth of the lake, pond, or reservoir based on site-specific data as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].

Table C-2. Model Assumption Input Variables and Known Variables

Input Variable	Description	Assumed/ Known Value	Assumption 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 0.8 and 0.4 [U.S. EPA, 1998b]. EPA selected an average value to use for this input variable.
bsc	Bed sediment particle concentration	1 g/cm^3	Bed sediment particle concentrations typically range between 0.5 to 1.5 g/cm^3 [U.S. EPA, 1998d]. 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, 1998b]. EPA selected an average value to use for this input variable.
k_{sw}	Degradation rate for water column	0/day	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	EPA selected a volatilization rate of 0 for nonvolatile pollutants (*i.e.*, all pollutants except mercury).
k_{sed}	Degradation rate for sediment	0/day	EPA assumed no loss from pollutant degradation in the sediment, as an environmentally conservative assumption.
WB	Rate of burial	0/day	EPA assumed no pollutant loss from burial within the waterbody sediments, as an environmentally conservative assumption.
Θ_{water}	Temperature correction	1.026 (unitless)	EPA selected the temperature correction factor based on the value provided in U.S. EPA, 1998b.
$K_{g(Rivers)}$	Gas phase transfer coefficient for rivers or streams	36,500 m/yr (100 m/day)	EPA selected the gas phase transfer coefficient for rivers and streams based on the value provided in U.S. EPA, 1998b.
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)	EPA selected the drag coefficient based on the value provided in U.S. EPA, 1998b.
ρ_a	Density of air corresponding to water temperature	0.0012 g/cm^3	EPA selected the density of air corresponding to water temperature based on the value provided in U.S. EPA, 2005b.
ρ_w	Density of water corresponding to water temperature	1 g/cm^3	EPA selected the density of water corresponding to water temperature based on the value provided in U.S. EPA, 2005b.
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. Model Assumption Input Variables and Known Variables

Input Variable	Description	Assumed/ Known Value	Assumption Rationale/Data Source
Kd_{sw}	Suspended sediment- surface water partition coefficient	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. 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	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. EPA identified U.S. EPA, 2005a as the primary source for the pollutant-specific bed sediment partition coefficients.
λ_2	Dimensionless viscous sublayer thickness	4 (unitless)	EPA selected the viscous sublayer thickness value based on the value provided in U.S. EPA, 2005b.
μ_w	Viscosity of water corresponding to water temperature	0.0169 g/cm-s	EPA selected the viscosity of water value based on the value provided in U.S. EPA, 2005b.
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. Site-Specific Assumption Input Variables

Input Variable	Description	Assumed Value	Data Source
TSS	Total suspended solids	Table C-5	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, 2014g].

Table C-3. Site-Specific Assumption Input Variables

Input Variable	Description	Assumed Value	Data Source
W_{10}	Wind velocity 10 m above the water surface	Table C-1	National Climatic Data Center national mean annual wind speed GIS coverage (downloaded 05/12/2011 from http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl?directive=quick_search&subrnum). EPA selected, as an environmentally conservative estimate, the lower of the wind speed range values for the analysis.
T_a	Air temperature	Table C-2	National Climatic Data Center national mean annual temperature GIS coverage (downloaded 05/12/2011 from http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl?directive=quick_search&subrnum). 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	Table C-6	EPA used the regional surface temperatures determined as part of the *Human and Ecological Risk Assessment of Coal Combustion Residuals* [U.S. EPA, 2014g].

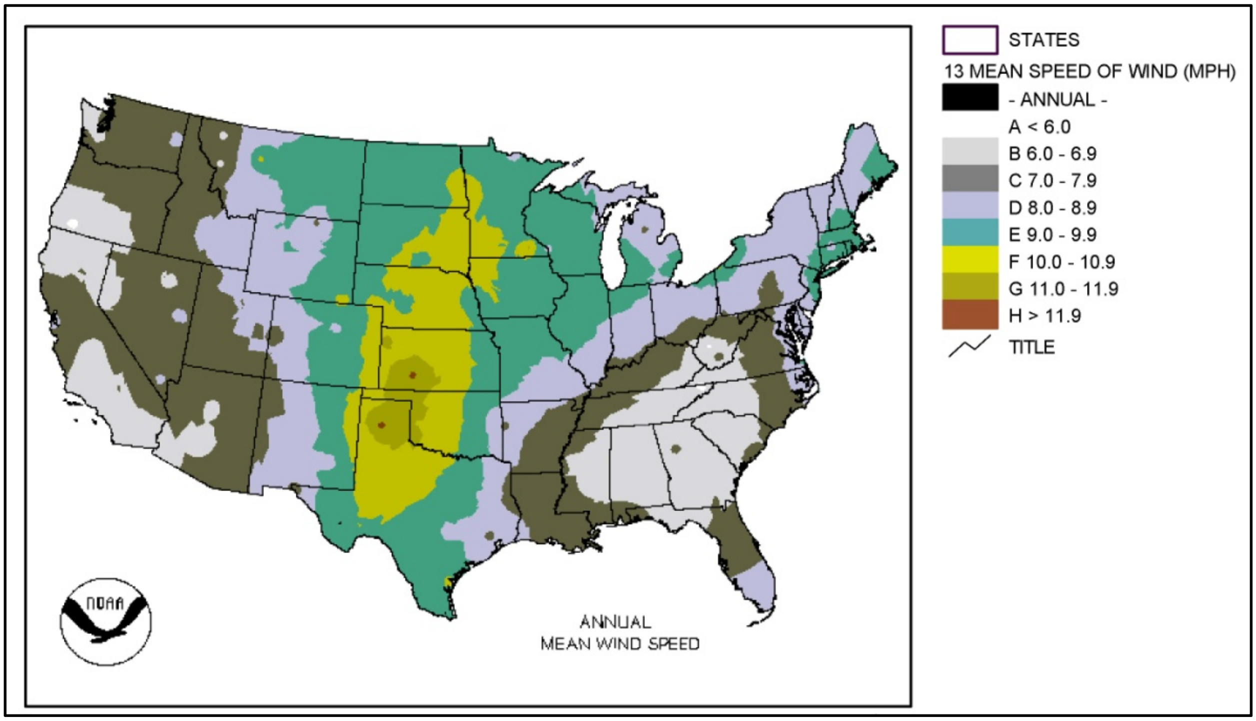


Figure C-1. National Climatic Data Center National Mean Annual Wind Speed

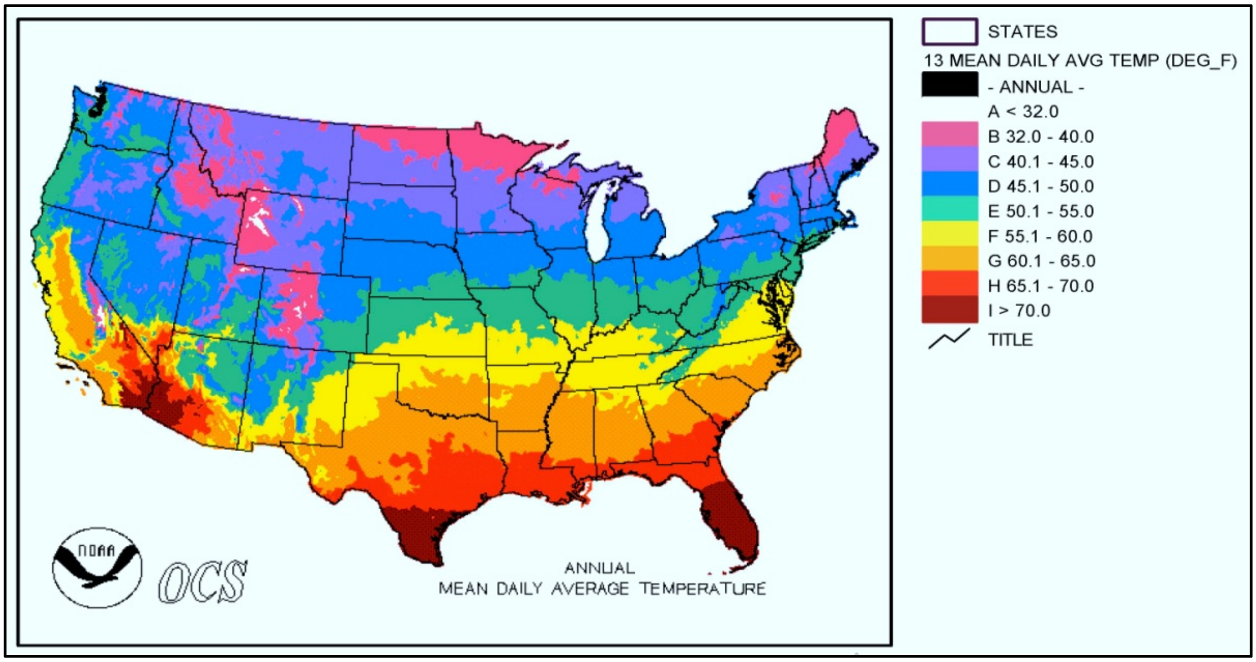


Figure C-2. National Climatic Data Center National Mean Annual Temperature

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
Chromium (VI)	16,000	50
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	Geometric Mean	Weighted Geometric Mean
1	9,007	33	3.2	40	8	6
2	47,202	38	10	316	32	40
3	43,395	36	6.3	79	25	25
4	29,577	37	6.3	794	25	25
5	39,900	38	4	100	25	25
6	4,137	28	5	316	16	20
7	34,494	37	32	1,585	63	100
8	46,231	38	50	316	158	126
9	3,254	35	13	3,162	32	63
10	62,791	38	10	398	126	126
11	48,969	38	25	794	200	126
12	7,280	35	40	1,995	79	126
13	13,974	37	32	79,433	200	398
14	26,699	38	16	5,012	158	251
15	9,162	37	20	19,953	200	398
16	19,965	33	4	2,512	16	25
17	173,136	37	2	316	6	10
18	42,022	37	13	398	63	50
Lakes (national)	4,360	99	1	398	25	25

Source: U.S. EPA, 2010b; Legacy STORET database.

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

Table C-6. Regional Surface Water Temperatures

Hydrologic Region	Climate	Surface Water Temperature (°C)	Surface Water Temperature (°K)
1	North	14 (Northern Median)	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

Table C-6. Regional Surface Water Temperatures

Hydrologic Region	Climate	Surface Water Temperature (°C)	Surface Water Temperature (°K)
11	South	17	290
12	South	21	294
13	South	17 (Southern Median)	290
14	South	9	282
15	South	17	290
16	South	9	282
17	North	14 (Northern Median)	287
18	South	15	288

Source: U.S. EPA, 2010b; Legacy STORET database.

Table C-7. NRWQC and MCL Benchmarks

Pollutant	FW Acute NRWQC Benchmark [a,b] (mg/L)	FW Chronic NRWQC Benchmark [a,b] (mg/L)	HH WO NRWQC Benchmark [a,b] (mg/L)	HH O NRWQC Benchmark [a,b] (mg/L)	MCL Benchmark [a,c] (mg/L)
Arsenic	0.34 (d)	0.15 (d)	0.000018 (f)	0.00014 (f)	0.01
Cadmium	0.002 (d)	0.00025 (d)	--	--	0.005
Chromium (VI)	0.016 (d)	0.011 (d)	--	--	0.1 (g)
Copper	0.013 (d,e)	0.009 (d,e)	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 (f)
Nickel	0.47 (d)	0.052 (d)	0.61	4.6	-
Selenium	--	0.005	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); NRWQC (National Recommended Water Quality Criteria).

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

b – National Recommended Water Quality Criteria. Washington, D.C. [U.S. EPA, 2009d]. 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.

c – National Primary Drinking Water Regulations. EPA 816-F-09-004. May. Washington, D.C. [U.S. EPA, 2009e].

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

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

f – Benchmark is for inorganic form of pollutant.

g – MCL is for total chromium.

h – Secondary (nonenforceable) drinking water standard.

IRW Model: Water Quality Module Methodology Limitations and Assumptions

The limitations and assumptions in the IRW water quality module are as follows:

- The module is based on annual-average pollutant loadings, normalized effluent flow rates from the steam electric 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). The result of this limitation on the water quality module outputs is unknown.
- The module represents only the waterbody concentration within the immediate discharge zone (*i.e.*, approximately 1 to 10 kilometers [km] from the outfall) and does not calculate pollutant concentrations in downstream waters. This limitation results in a potential underestimation of the extent of surface waters with environmental and human health impacts under baseline conditions and improvements under the regulatory options.
- 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 benchmarks 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 bed 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 does not account for the accumulation of pollutant concentrations in bottom sediments and pore water that occur over prolonged discharge periods.
- The module assumes that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a partition coefficient. 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). 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 unknown because of unknown 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 benthic 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 benthic 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, 1998b]. EPA had neither measured values nor the data to determine burial rates for each immediate receiving water. The pollutants with more than 10 percent immediate receiving waters showing impacts to sediment receptors include cadmium, mercury, and nickel (see Table 6-4). This assumption results in a potential overestimation of impacts in the benthic 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 steam electric power plants, as there are several waste streams that are not included in the analysis (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). Because of this approach, the module potentially underestimates the number and magnitude of benchmark exceedances at baseline and under the regulatory options. The module also potentially underestimates the number of environmental and human health improvements under the regulatory options (*i.e.*, a higher number of exceedances under baseline conditions creates additional opportunities for improvement under the regulatory options). The results of EPA's case study modeling, which does take into account ambient background pollutant concentrations and contributions from other point and nonpoint sources, support this assessment of the water quality module's limitations (see Section 8).

APPENDIX D
WILDLIFE MODULE METHODOLOGY

This appendix presents the model equations, input variables, pollutant benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model wildlife module. Wildlife impacts include 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 steam electric power plants.
- Wildlife (minks and eagles)[1] that consume fish from receiving waters in the immediate discharge zone of steam electric power plants.

EPA estimated pollutant concentrations in the immediate receiving water and sediment using the IRW model water quality module (see Appendix C). The wildlife module uses these concentrations as inputs.

Model input requirements for the equations presented in Appendix D can be divided into four major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; and 4) pollutant-specific variable. The following tables in Appendix D describe the input requirements and data sources used in the wildlife module and impacts analysis:

- Table D-1. Chemical Stressor Concentration Limits (CSCLs) 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 Concentration (NEHC) Benchmarks for Minks and Bald Eagles.

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

Impact to Aquatic Life Receptors from Direct Contact with Sediment. 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 CSCL benchmarks 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 benchmark) indicates a potential impact to the exposed organism. EPA used Equation D-1 to calculate the HQ for sediment biota.

---

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

EQUATION D-1

$$HQ_{sed} = \frac{C_{bs}}{CSCL_{sed}}$$

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 Equation C-5
$CSCL_{sed}$	=	Ecological benchmark for sediment (milligrams per kilograms [mg/kg])	Receptor-specific benchmark (see Table D-1)

Adverse Effects to Piscivorous Wildlife. 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 ecological benchmarks. Equation D-2 calculates pollutant concentrations in fish for the evaluated pollutants, except for mercury. Because the more toxic form of mercury is methylmercury, 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.

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 Equation C-3
C_{dw}	=	Dissolved pollutant concentration in water (mg/L)	Water quality module output Equation C-4
0.15	=	Fraction of dissolved total mercury as dissolved methylmercury (unitless)	Model assumption 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)

EPA compared the calculated T3 fish tissue concentration to the ecological benchmark for minks and the calculated T4 fish tissue concentration to the ecological benchmark for eagles. EPA selected NEHC benchmarks for minks and eagles (Table D-3) as the ecological benchmarks for piscivorous wildlife. The wildlife module expresses this comparison as an HQ. EPA used Equation D-4 to calculate HQ values for arsenic, cadmium, chromium (VI), copper, lead, mercury (as methylmercury), nickel, selenium, thallium, and zinc.

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. CSCL Benchmarks for Sediment Biota [a]

Pollutant in Wildlife Impact Assessment	CSCL Benchmark Value (mg/kg)	Notes
Arsenic	5.90	
Cadmium	0.596	
Chromium (VI)	37.3	No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.
Copper	35.7	
Lead	35	
Mercury	0.174	EPA compares the mercury, not methylmercury, concentration in the sediment to the benchmark.
Nickel	18.0	
Selenium	None identified	EPA could not complete the analysis for this pollutant – no benchmark for comparison.
Thallium	None identified	
Zinc	123	

Source: MacDonald, D.D.; C. G. Ingersoll; and T. A. Berger. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 2000, 39(1)20 (as cited in NOAA, 2008).

a – The benchmarks used for the analysis are threshold effect levels (TELs).

Table D-2. Bioconcentration Factors (BCFs) and Bioaccumulation Factors (BAFs) for Trophic Level 3 (T3) and Trophic Level 4 (T4) Fish

Pollutant	BCF or BAF	Factor for Trophic Level 3 (T3) Fish (L/kg)	Factor for Trophic Level 4 (T4) Fish (L/kg)	Source
Arsenic	BCF	4.00E+00	4.00E+00	Barrows *et al.*, 1980
Cadmium	BCF	2.70E+02	2.70E+02	Kumada *et al.*, 1972
Chromium (VI)	BCF	6.00E-01	6.00E-01	Stephan, 1993
Copper [a]	BCF	3.60E+01	3.60E+01	U.S. EPA, 1980
Lead	BAF	4.60E+01	4.60E+01	Stephan, 1993
Methylmercury	BAF	1.60E+06	6.80E+06	U.S. EPA, 1997a
Nickel [b]	BCF	0.8	0.8	Stephan, 1993
Selenium	BAF	4.90E+02	1.70E+03	Lemly, 1985a
Thallium	BCF	3.40E+01	1.30E+02	Barrows *et al.*, 1980 and Stephan, 1993
Zinc	BCF	3.50E+02	3.50E+02	Murphy *et al.*, 1978

a – BCF not specific to a particular trophic level; applies to fish consumed by humans.
b – Nickel (soluble salts).

Table D-3. NEHC Benchmarks for Mink and Bald Eagles

Pollutant in Wildlife Impact Assessment	NEHC Benchmark Value for Mink (T3 Fish) (µg/g)	NEHC Benchmark Value for Eagle (T4 Fish) (µg/g)	Notes
Arsenic	7.65	22.4	
Cadmium	5.66	14.7	
Chromium (VI)	17.7	26.6	No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.
Copper	41.2	40.5	
Lead	34.6	16.3	
Methylmercury	0.37	0.5	No benchmark for methylmercury. EPA used the total mercury benchmark, which may underestimate the impact to wildlife.
Nickel,	12.5	67.1	
Selenium	1.13	4	
Thallium	None identified	None identified	EPA could not complete the analysis for this pollutant – no benchmark for comparison.
Zinc	904	145	

Source: USGS, 2008.

IRW Model: Wildlife Module Methodology Limitations and Assumptions

EPA was required to make assumptions about various inputs, resulting in limitations with respect to the wildlife module output and interpretation. Variability occurs from heterogeneous characteristics, such as body weight differences within a population or the contaminant levels in the environment. Uncertainty represents a lack of knowledge about factors such as the adverse effects from exposure to pollutants. The assumptions and limitations of the wildlife module include the following:

- ***Additive Risks Across Pathways.*** The wildlife module does not consider additive risks across 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 large amounts of 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 since it is likely the dose from the food source dominates the dose from water ingestion.
- ***Use of BCFs and BAFs***. Where available, EPA used BAFs to represent the accumulation of pollutants in fish tissue *(e.g.,* for selenium and methylmercury). Otherwise, 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.[2] 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 environmental assessment (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 unknown due to site-specific considerations.
- ***Receptor Populations Evaluated.*** EPA considered the limitations and made multiple assumptions in choosing receptor populations to evaluate. First, 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, EPA considered a limited number of species for use as receptors. For the wildlife receptors, 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. EPA attempts to address this

---

[2] EPA Office of Water Health and Ecological Criteria Division agrees that all the routes (*e.g.,* 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, 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. EPA is working to develop BAF/BCF distributions for several pollutants to better represent the bioaccumulation in aquatic organisms.

limitation in the impact assessment by presenting a proximity analysis of steam electric power plants to habitats of threatened and endangered species (see Section 3.4.5 of this report) and an evaluation of the ecological risk to aquatic organisms and avian receptors from selenium contamination (see Section 5.2 of this report).

- ***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. EPA believes this assumption is reasonable based on the following two factors: 1) It is possible that in some habitats the dietary composition for both minks and eagles consists largely of fish and 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; and 2) With respect to home ranges, the case study water quality modeling results (see Section 8) demonstrate that pollutants discharged from steam electric 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.
- ***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 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 strata; 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 species and concentrations of pollutants. Due to the complexity of these relationships and necessity for site-specific data, none of the impact analyses considered stratification of receiving waters. The result of this limitation on the wildlife module outputs is unknown.

- ***Multiple Pollutant Exposures.*** According to EPA's *Steam Electric Power Generating Point Source Category: Final Detailed Study Report* [U.S. EPA, 2009b], 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, EPA did not consider the impact of mercury on the uptake or toxicity of selenium. There is evidence in the literature that these two compounds interact with each other in the environment and may decrease the level of impact of each pollutant on a receptor; conversely, the interaction of other pollutants may increase the impact to a receptor. However, because benchmarks 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.*** EPA used ecological benchmarks as described above to determine impacts to aquatic organisms from direct contact with contaminated sediment. The benchmarks represent threshold effect levels TELs. If an organism ingests chemical concentration above the TEL, some effect (or response) will be produced. If the concentration ingested is below the TEL, no effect (or response) will occur. The TEL represents the concentration of a chemical that would result in "no effect," therefore the results presented in EA report are a more environmentally protective impact estimate [USGS, 2008].

APPENDIX E
HUMAN HEALTH MODULE METHODOLOGY

This appendix presents the model equations, input variables, benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model human health module. Human health impacts include the following receptor groups:

- Child cohorts (recreational) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Child cohorts (subsistence) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Adult cohorts (recreational) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Adult cohorts (subsistence) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.

In addition to the national-scale cohorts evaluated as part of the environmental assessment (EA), EPA also estimated annual-average daily dose of pollutants for human receptors based on race and Hispanic origin as an environmental justice analysis.

EPA estimated pollutant concentrations in fish tissue using the IRW model wildlife module (see Appendix D). The human health module uses these concentrations as inputs.

Model input requirements for the equations presented in Appendix E can be divided into five major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; 4) receptor cohort-specific variable; and 5) pollutant-specific variable. The following tables in Appendix E 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. Model Assumption Input Variables for the Human Health Module.
- Table E-3. Receptor Cohort-Specific Input Variables for the Human Health Module.
- Table E-4. Environmental Justice Analysis: Receptor Cohort-Specific Consumption Rate by Race or Hispanic Origin for the Human Health Module.
- Table E-5. Pollutant-Specific Input Variables in the Human Health Module.

IRW Model: Human Health Module Equations

EPA estimated the pollutant concentrations in fish fillets consumed by humans (*i.e.*, dose) using an assumed consumption ratio of T3 and T4 fish and site-specific pollutant concentrations in fish. For each cohort, EPA calculated the average daily dose (ADD) of the pollutant from eating fish and compared this ADD to non-cancer human health benchmarks (*i.e.*, 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 benchmark) indicates a potential non-cancer threat to the human cohort. EPA also calculated a lifetime average daily dose (LADD) and a corresponding lifetime excess cancer risk (LECR) for each cohort. This study used the 1-in-a-million cancer risk benchmark as an acceptable risk threshold when evaluating exposures associated with fish consumption.

EPA used the equations presented below to calculate the pollutant concentration in the fish fillet; the ADD for arsenic, cadmium, chromium (VI), 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 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 Equation D-2 and Equation D-3
F_{T3}	=	Fraction of trophic level 3 fish intake (unitless)	Model assumption value of 0.36 (see calculation below)
F_{T4}	=	Fraction of trophic level 4 fish intake (unitless)	Model assumption value of 0.64 (see calculation below)

To determine the fraction of T3 and T4 fish intake for human cohorts, EPA started with the data presented in the 2011 Emissions Factor Handbook, Table 10-74 [U.S. EPA, 2011b]. 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. 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.

Table E-1. Calculation of Consumption Ratio for Trophic Level 3 (F_{T3}) and Trophic Level 4 (F_{T4}) Fish

Species	Trophic Level	Ice Fishing		Lakes and Ponds		Rivers and Streams	
		Count of Fish Consumed	Mass Consumed (kg)	Count of Fish Consumed	Mass Consumed (kg)	Count of Fish Consumed	Mass Consumed (kg)
Landlocked salmon	4	832	290	928	340	305	120
Atlantic salmon	4	3	1.1	33	9.9	17	11
Togue (Lake trout)	4	483	200	459	160	33	2.7
Brook trout	4	1,309	100	3,294	210	10,185	420
Brown trout	4	275	54	375	56	338	23
Yellow perch	3	235	9.1	1,649	52	188	7.4
White perch	3	2,544	160	6,540	380	3,013	180
Bass (Smallmouth and largemouth)	4	474	120	73	5.9	787	130
Pickerel	3	1,091	180	553	91	303	45
Lake whitefish	3	111	20	558	13	55	2.7
Hornpout (Catfish and bullheads)	3	47	8.2	1,291	100	180	7.8
Bottom fish (Suckers, carp and sturgeon)	3	50	81	62	22	100	6.7
Chub	3	0	0	252	35	219	130
Smelt	3	7,808	150	428	4.9	4,269	37
Other	4	201	210	90	110	54	45
TOTALS		**15,463**	**1,583**	**16,587**	**1,590**	**20,046**	**1,168**
Totals by Trophic Level							
	T3 Total	11,886	608	11,333	698	8,327	417
	T4 Total	3376	765.1	5162	781.8	11665	751.7
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, 2011b.

Bold indicates factors selected for the human health model.

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

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). EPA assumed the exposure durations (ED) for use in the LADD calculation are equal to the length of time in that cohort range. 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-2

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

Where:

ADD	=	Daily dose of pollutant from fish ingestion (mg/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 ww/day)	Receptor cohort-specific value (see Table E-3 and Table E-4)
F_{fish}	=	Fraction of fish intake from contaminated source	Model assumption value of 1
1,000	=	Conversion factor (grams per kilograms [g/kg])	Conversion factor
BW	=	Body weight (kg)	Receptor cohort-specific value (see Table E-3)

EQUATION E-3

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

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)	Receptor cohort-specific value (assumed value) (see Table E-3)
EF	=	Exposure frequency (days/yr)	Model assumption value of 350
AT	=	Averaging time (yr)	Model assumption value of 70 [U.S. EPA, 2011b]
365	=	Conversion factor (days/yr)	

EQUATION E-4

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

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 reference dose (mg/kg BW/day)	Pollutant-specific value (see Table E-5)

EQUATION E-5

$$\text{LECR} = \text{LADD} \times \text{CSF}$$

Where:

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

IRW Model: Human Health Module Inputs and Benchmarks

Table E-2. Model Assumption Input Variables for the Human Health Module

Input Variable	Description	Assumed Value	Assumption Rationale/Data Source
F_{T3}	Fraction of trophic level 3 fish intake	0.36	U.S. EPA, 2011b
F_{T4}	Fraction of trophic level 4 fish intake	0.64	U.S. EPA, 2011b
F_{fish}	Fraction of fish intake from contaminated source	1	EPA assumed that all fish consumed by the receptor is from the contaminated surface water.
EF	Exposure frequency (days/yr)	350	EPA assumed that the fisher 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, 2011b

For the EA and benefits analyses,[1] 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 waterbody compared to both recreational fishers and the general population. Because of the focus of human exposure to a subset of the general population that more frequently consume local fish, 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, 2015g].

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 benefits analysis (see the Benefits and Cost Analysis), EPA only evaluates impacts to a subset of the population living near the immediate and downstream receiving waters.

The EPA document, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (Table 5-1) determined protective fish intake rates using the following percentiles by fisher type: 1) general population and recreational fisher: 90th percentile of per capita data and 2) subsistence fisher: 99th 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, EPA used best professional judgment and using the following percentiles by fisher type: 1) recreational fisher: mean of consumer-only data and 2) subsistence fisher: 95th percentile of consumer-only data.

---

[1] See the *Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category* (EPA-821-R-15-005) (Benefits and Cost Analysis).

Table E-3. Receptor Cohort-Specific Input Variables for the Human Health Module

Receptor	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	121.7	5
Adult Recreational Fisher [c]		80	0.665	53.2	49
Adult Subsistence Fisher [c]		80	2.05	164	49

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

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

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

b – 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, 2011b]. EPA used consumer-only fish consumption rates: mean values for recreational fishers and 95th percentile values for subsistence fishers. EPA converted the listed consumption rate (g/kg-day) to g/day by multiplying by mean body weight for each cohort as listed in U.S. EPA, 2008b [ERG, 2015g]. Fish intake rates provided in the reference [U.S. EPA, 2011b] 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, 2011b] presented multiple adult groups. 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: Receptor Cohort-Specific Input Consumption Rate by Race or Hispanic Origin for the Human Health Module

Receptor	Race or Hispanic Origin	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, 2011b.

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

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

b – Consumption rates provided as single value by race and Hispanic origin (as g/kg-day). 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 or Hispanic origin are less statistically reliable due to the comparatively smaller data set.

Table E-5. Pollutant-Specific Benchmarks for the Human Health Module

Pollutant in Human Health Impact Assessment	RfD (mg/kg-day)	CSF $(\text{mg/kg-day})^{-1}$	Notes [a]
Arsenic, inorganic	3.00E-04	1.50E+00	RfD and CSF for drinking water ingestion
Cadmium, total	1.00E-03		RfD for food consumption
Chromium (VI)	3.00E-03		RfD for drinking water ingestion
Copper	1.00E-02		Used the intermediate oral minimal risk level (MRL) as the reference dose [ATSDR, 2010a]
Lead, total	None available		
Methylmercury	1.00E-04		RfD for fish consumption only
Nickel, total	2.00E-02		RfD for soluble salts; used for food consumption
Selenium, total	5.00E-03		RfD for food consumption
Thallium, total	1.00E-05		Used value cited in U.S. EPA, 2010a for thallium chloride as the reference dose; used for chronic oral exposure
Zinc, total	3.00E-01		RfD for food consumption

Acronyms: mg/kg-day (milligrams per kilogram body weight per day)

a – References include ATSDR, 2010a for copper; U.S. EPA, 2010a for thallium, and U.S. EPA, 2011c for all other pollutants.

IRW Model: Human Health Module Limitations and Assumptions

The human health module limitations and assumptions include the following:

- ***Additive Risks Across Pathways.*** The human health module does not consider additive risks across 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 combustion wastewater.
- ***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, 2009b], 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 benchmarks 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 receptors, 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).[2]
- ***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. EPA used the most current data regarding exposure assumptions, and these values represent EPA's current guidance on exposure data [U.S. EPA, 2008a; U.S. EPA, 2011b].
- ***Human Health Benchmarks.*** Uncertainties generally associated with human health benchmarks are discussed in detail in EPA's *Guidelines for Carcinogen Risk Assessment* [U.S. EPA, 2005c] and Integrated Risk Information System (IRIS) [U.S. EPA, 2011c]. IRIS defines the 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." 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, 2011c]. 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, 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, 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, 2011b].

---

[2] For the benefits analysis, EPA further defined the affected population (*i.e.*, individuals potentially exposed to steam electric power plant pollutants via consumption of contaminated fish) as recreational and subsistence fishers who fish reaches that are affected by steam electric power plant discharges (including immediate receiving waters and downstream reaches), as well as their household members. EPA estimated the number of people who are likely to fish affected reaches based on typical travel distances to a fishing site, presence of substitute fishing locations, data on the locations and status of fish consumption advisories for affected reaches, and information on anglers' awareness and adherence to those advisories. See the Benefits and Cost Analysis.

APPENDIX F
OVERVIEW OF ECOLOGICAL RISK MODELING SETUP AND OUTPUTS

This appendix summarizes the inputs, outputs, and methodology limitations/assumptions for the ecological risk modeling that EPA used to evaluate reproductive risks associated with dietary exposure to selenium. EPA performed ecological risk modeling for two sets of water quality outputs:

- Dissolved selenium concentrations in the immediate receiving waters of all modeled steam electric power plants, based on the outputs from the water quality module of the national-scale immediate receiving water (IRW) model (see Appendix C).
- Dissolved selenium concentrations in the immediate receiving water and downstream reaches of Black Creek, Mississippi, based on the outputs from the Black Creek case study water quality model (see Appendix G).

Model input requirements for the ecological risk model can be divided into four major categories: 1) dissolved selenium concentrations; 2) site-specific enrichment factors (EFs), which represent the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water; 3) species-specific trophic transfer factors (TTFs), which describe subsequent bioaccumulation by higher trophic-level aquatic organisms such as fish and birds; and 4) exposure-response (ER) functions, which translate the modeled selenium concentrations in fish and birds into the associated reduction in reproductive success.

The ecological risk modeling methodology is described in Section 5.2 of the EA report. This modeling approach is consistent with the approach taken in developing the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2014f] (referred to as the draft selenium criterion) and is based on the same data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish}. For this EA, EPA expanded the model to include data sets for $TTF_{mallard}$ and $ER_{mallard}$.

The following sections describe these inputs and their sources; summarize the ecological risk modeling results; and discuss the limitations and assumptions associated with this modeling.

Dissolved Selenium Concentrations

As described above, the dissolved selenium concentrations for the national-scale and case study ecological risk models are derived from the IRW water quality module and the Black Creek case study water quality model, respectively. Dissolved selenium concentrations used in the national-scale ecological risk model are provided in DCN SE04612.[1] Dissolved selenium concentrations used in the case study ecological risk model are provided in DCN SE04615. Prior to use as inputs for the Black Creek case study ecological risk model, EPA calculated three-month rolling averages of the dissolved selenium concentration output from the Black Creek case study water quality model. This resulted in one average concentration for each calendar month

---

[1] EPA removed identifying information, such as the immediate receiving water name and the steam electric power plant name, from this reference to prevent disclosure of confidential business information (CBI).

throughout the entire modeling period after the assumed compliance date for the Morrow Generating Site (2019-2036). Use of a three-month rolling average avoided the calculation of significantly elevated reproductive risks in response to short-term (*e.g.*, daily or weekly) fluctuations in the dissolved selenium concentration.

Enrichment Factors

As discussed in Section 5.2 of the EA report, the EFs used in the ecological risk modeling effort are consistent with those used in developing the draft selenium criterion [U.S. EPA, 2014f]. This effort produced EF distributions for lentic systems (*e.g.*, lakes, reservoirs, and ponds) and lotic systems (*e.g.*, rivers, creeks, and streams). These distributions are well described by lognormal distributions with means (standard deviations) of 1,738 (2,499)[2] for lentic systems and 692 (787) for lotic systems. These EF distributions are illustrated in Figure F-1 and Figure F-2.

Trophic Transfer Factors

As discussed in Section 5.2 of the EA report, the TTFs used to represent selenium bioaccumulation in invertebrates and fish in the national-scale ecological risk model are also consistent with those used in developing the draft selenium criterion [U.S. EPA, 2014f]. This resulted in a TTF_{invert} distribution with a mean (standard deviation) of 2.84 (2.49)[3] and a TTF_{fish} distribution with a mean (standard deviation) of 1.6 (1.08). These TTF distributions are illustrated in Figure F-1.

Based on a review of Ohlendorf [2003], EPA developed a TTF distribution for mallards. The resulting $TTF_{mallard}$ distribution is best described by a triangular distribution, with a likeliest value of 2.5, a minimum value of 0.4, and a maximum value of 4.1. This TTF distribution is illustrated in Figure F-1.

For the Black Creek case study ecological risk model, EPA refined the TTF_{invert} and TTF_{fish} datasets to include only invertebrate and fish species that are representative of those collected during surveys of Black Creek and other nearby rivers and streams as part of EPA's National Aquatic Resource Survey (NARS). This resulted in smaller distributions that are more likely to reflect bioaccumulation patterns within the species that actually inhabit Black Creek. These TTF distributions are illustrated in Figure F-2.

Exposure Response Functions

To estimate the risk of negative reproductive effects among fish, EPA used the same extensively peer-reviewed ER function (*i.e.*, curve) as was used in the draft selenium criterion [U.S. EPA, 2014f]. This ER function is illustrated in Figure F-3.

---

[2] The EF for a given waterbody is the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water, multiplied by 1,000. A mean EF of 1,738 for lentic systems indicates that, on average, the concentration of selenium at the base of the food web is 1.738 times greater than the dissolved concentration in water.

[3] The TTF for a given trophic level is the ratio of the concentration in the organism to the concentration in the consumed material or lower-trophic-level organism. A mean TTF of 2.84 for invertebrates indicates that, on average, the concentration of selenium in the tissues of invertebrates is 2.84 times greater than the concentration in particulates consumed by invertebrates.

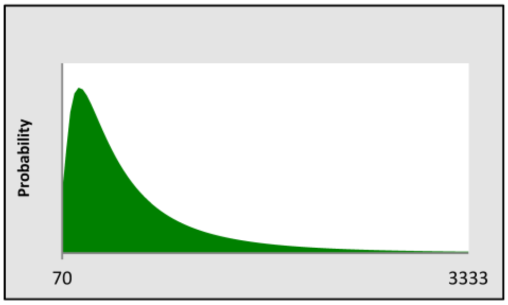
To develop the ER function for mallards, EPA fit a logistic curve to the combined, control normalized data from six different laboratory studies that evaluated the effect of selenium on mallard egg hatchability [Heinz *et al.*, 1987, 1989; Heinz and Hoffman, 1996, 1998; Stanley *et al.*, 1994, 1996]. This ER function is illustrated in Figure F-4.

Lotic EF Distribution

Lognormal distribution with parameters:

Location	33.00
Mean	692.00
Std. Dev.	787.00

Selected range is from 70.00 to 3,333.00

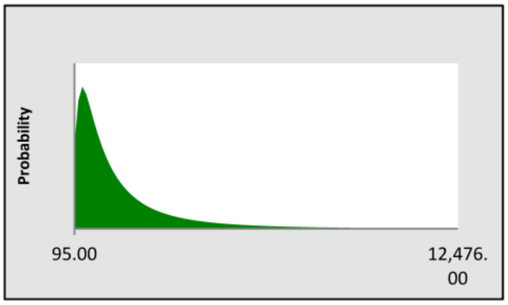


Lentic EF Distribution

Lognormal distribution with parameters:

Location	21.00
Mean	1,738.00
Std. Dev.	2,499.00

Selected range is from 95.00 to 12,476.00

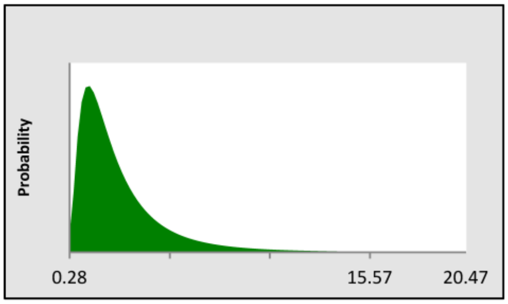


Invertebrate TTF (TTF_{invert}) Distribution

Lognormal distribution with parameters:

Location	0.12
Mean	2.84
Std. Dev.	2.49

Selected range is from 0.13 to 20.47

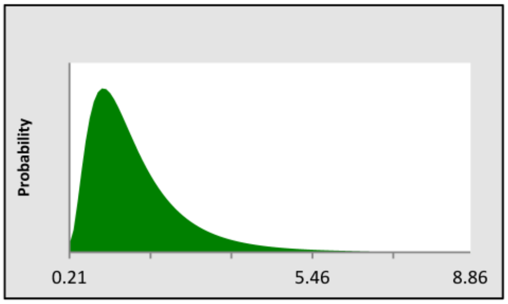


Fish TTF (TTF_{fish}) Distribution

Lognormal distribution with parameters:

Location	0.04
Mean	1.63
Std. Dev.	1.08

Selected range is from 0.08 to 58.00



Mallard TTF ($TTF_{mallard}$) Distribution

Triangular distribution with parameters:

Minimum	0.36
Likeliest	2.50
Maximum	4.10

Selected range is from 0.36 to 4.10

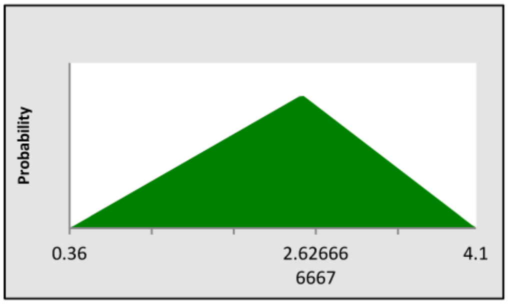


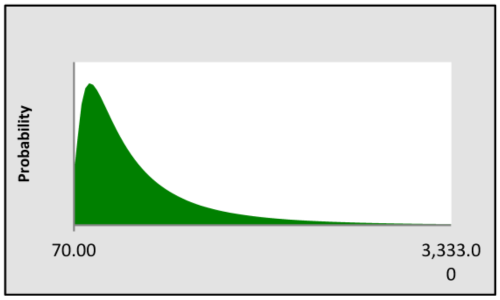
Figure F-1. Input EF and TTF Distributions for National-Scale Ecological Risk Model – Baseline and Final Rule (Option D)

Lotic EF Distribution

Lognormal distribution with parameters:

Location	33.00
Mean	692.00
Std. Dev.	787.00

Selected range is from 70.00 to 3,333.00

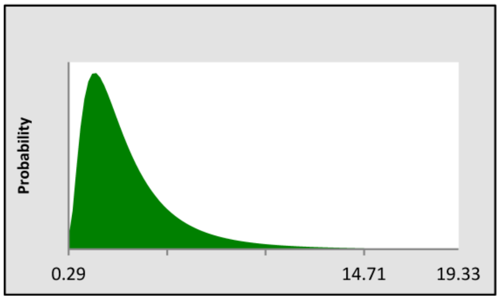


Invertebrate TTF (TTF_{invert}) Distribution

Lognormal distribution with parameters:

Location	0.05
Mean	3.21
Std. Dev.	2.52

Selected range is from 0.24 to 19.33

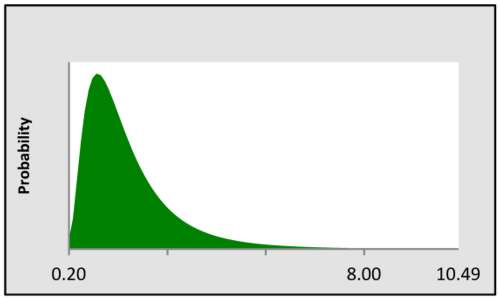


Fish TTF (TTF_{fish}) Distribution

Lognormal distribution with parameters:

Location	0.04
Mean	1.76
Std. Dev.	1.25

Selected range is from 0.13 to 58.00

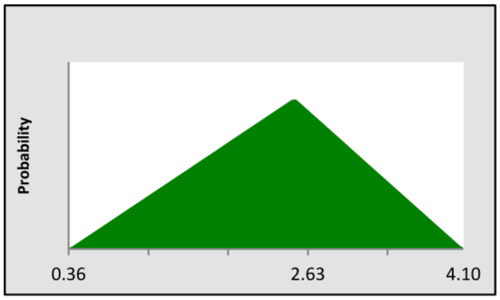


Mallard TTF ($TTF_{mallard}$) Distribution

Triangular distribution with parameters:

Minimum	0.36
Likeliest	2.50
Maximum	4.10

Selected range is from 0.36 to 4.10

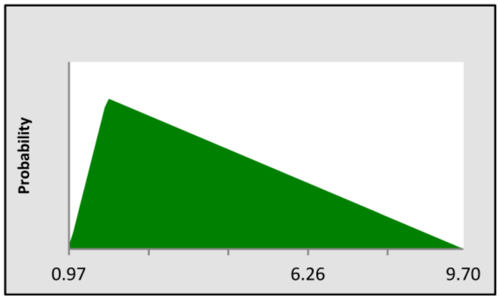


Dissolved Selenium (ug/L) Distribution - Baseline

Triangular distribution with parameters:

Minimum	0.97
Likeliest	1.82
Maximum	9.70

Selected range is from 0.97 to 9.70



Dissolved Selenium (ug/L) Distribution - Final Rule

Triangular distribution with parameters:

Minimum	0.01
Likeliest	0.05
Maximum	0.28

Selected range is from 0.01 to 0.28

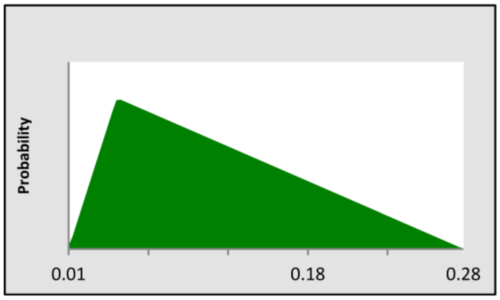


Figure F-2. Input EF, TTF, and Dissolved Selenium Distributions for Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) Ecological Risk Model – Baseline and Final Rule (Option D)

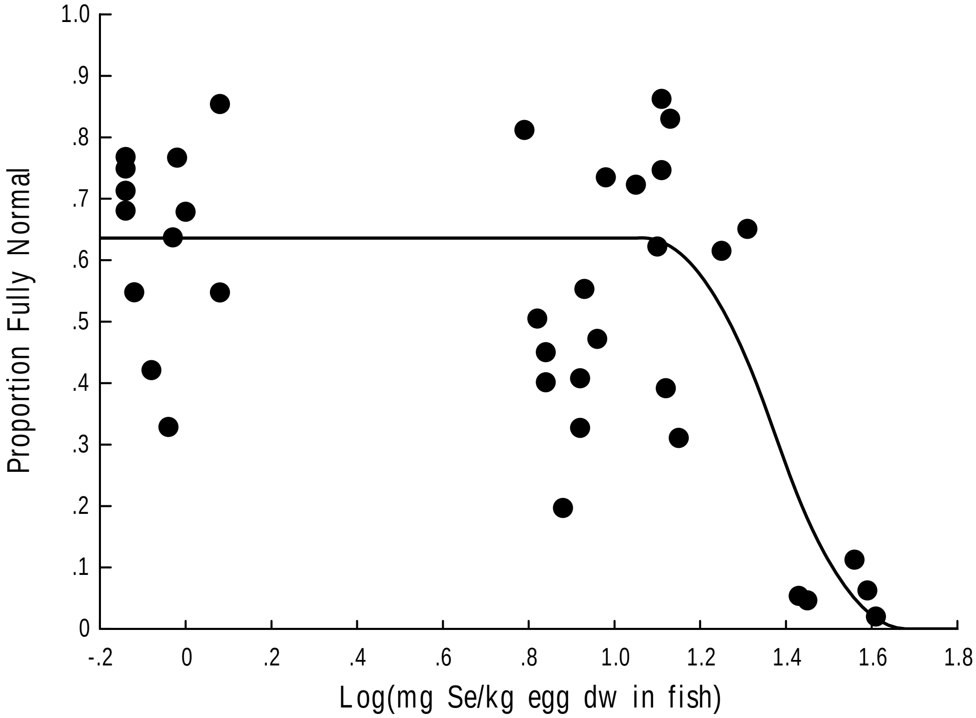


Figure F-3. Exposure-Response Function for Fish Reproductive Success

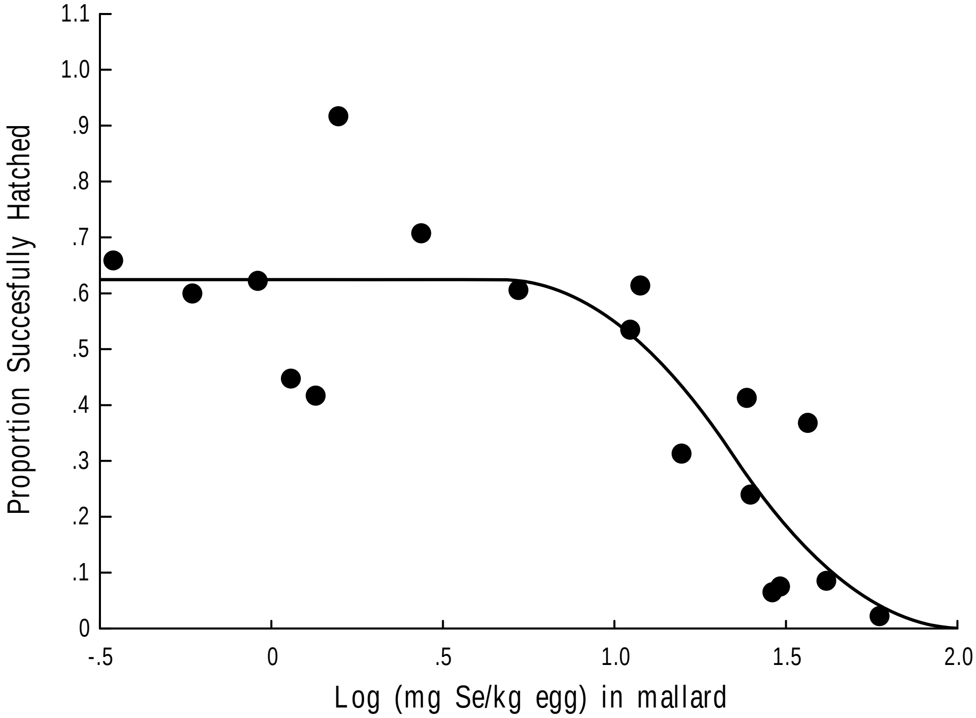


Figure F-4. Exposure-Response Function for Mallard Egg Hatchability

Ecological Risk Model Outputs

Table F-1 and Table F-2 summarize the results of the national-scale ecological risk model for fish under baseline conditions and the final rule, respectively.

Table F-3 and Table F-4 summarize the results of the national-scale ecological risk model for mallards under baseline conditions and the final rule, respectively.

Table F-5 and Table F-6 summarize the results of the case study ecological risk model for birds and mallards, respectively, under baseline conditions. Under the final rule, none of the modeled stream segments resulted in a modeled risk of greater than 0.1 percent for either fish or mallards.

Table F-1. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Fish – Baseline

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	14 (7.7%)	14 (6.7%)
25th:	2 (7.7%)	17 (9.3%)	19 (9.1%)
Median:	4 (15%)	24 (13%)	28 (13%)
75th:	6 (23%)	32 (17%)	38 (18%)
90th:	8 (31%)	36 (20%)	44 (21%)
95th:	8 (31%)	42 (23%)	50 (24%)
10 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	12 (6.6%)	12 (5.7%)
25th:	1 (3.8%)	14 (7.7%)	15 (7.2%)
Median:	4 (15%)	20 (11%)	24 (11%)
75th:	6 (23%)	29 (16%)	35 (17%)
90th:	7 (27%)	35 (19%)	42 (20%)
95th:	8 (31%)	39 (21%)	47 (22%)
50 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	14 (7.7%)	14 (6.7%)
Median:	3 (12%)	17 (9.3%)	20 (9.6%)
75th:	5 (19%)	27 (15%)	32 (15%)
90th:	6 (23%)	34 (19%)	40 (19%)
95th:	8 (31%)	35 (19%)	43 (21%)
75 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	14 (7.7%)	14 (6.7%)
Median:	3 (12%)	17 (9.3%)	20 (9.6%)
75th:	5 (19%)	26 (14%)	31 (15%)
90th:	6 (23%)	31 (17%)	37 (18%)
95th:	7 (27%)	34 (19%)	41 (20%)
90 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	9 (4.9%)	9 (4.3%)
25th:	0 (0%)	13 (7.1%)	13 (6.2%)
Median:	2 (7.7%)	17 (9.3%)	19 (9.1%)
75th:	5 (19%)	22 (12%)	27 (13%)
90th:	6 (23%)	29 (16%)	35 (17%)
95th:	6 (23%)	34 (19%)	40 (19%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-2. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Fish – Final Rule (Option D)

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	5 (2.7%)	5 (2.4%)
Median:	0 (0%)	11 (6%)	11 (5.3%)
75th:	0 (0%)	16 (8.7%)	16 (7.7%)
90th:	1 (3.8%)	21 (11%)	22 (11%)
95th:	1 (3.8%)	25 (14%)	26 (12%)
10 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	8 (4.4%)	8 (3.8%)
75th:	0 (0%)	15 (8.2%)	15 (7.2%)
90th:	0 (0%)	19 (10%)	19 (9.1%)
95th:	1 (3.8%)	23 (13%)	24 (11%)
50 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	6 (3.3%)	6 (2.9%)
75th:	0 (0%)	12 (6.6%)	12 (5.7%)
90th:	0 (0%)	19 (10%)	19 (9.1%)
95th:	0 (0%)	20 (11%)	20 (9.6%)
75 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	5 (2.7%)	5 (2.4%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	15 (8.2%)	15 (7.2%)
95th:	0 (0%)	19 (10%)	19 (9.1%)
90 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	4 (2.2%)	4 (1.9%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	15 (8.2%)	15 (7.2%)
95th:	0 (0%)	19 (10%)	19 (9.1%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-3. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Mallards – Baseline

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Mallard Population Experiencing Hatching Failure			
10th:	3 (12%)	18 (9.8%)	21 (10%)
25th:	5 (19%)	26 (14%)	31 (15%)
Median:	6 (23%)	34 (19%)	40 (19%)
75th:	8 (31%)	38 (21%)	46 (22%)
90th:	9 (35%)	47 (26%)	56 (27%)
95th:	13 (50%)	52 (28%)	65 (31%)
10 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	14 (7.7%)	14 (6.7%)
25th:	3 (12%)	17 (9.3%)	20 (9.6%)
Median:	5 (19%)	26 (14%)	31 (15%)
75th:	6 (23%)	32 (17%)	38 (18%)
90th:	8 (31%)	36 (20%)	44 (21%)
95th:	8 (31%)	42 (23%)	50 (24%)
50 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	13 (7.1%)	13 (6.2%)
Median:	2 (7.7%)	17 (9.3%)	19 (9.1%)
75th:	4 (15%)	22 (12%)	26 (12%)
90th:	6 (23%)	28 (15%)	34 (16%)
95th:	6 (23%)	34 (19%)	40 (19%)
75 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	7 (3.8%)	7 (3.3%)
25th:	0 (0%)	10 (5.5%)	10 (4.8%)
Median:	0 (0%)	14 (7.7%)	14 (6.7%)
75th:	3 (12%)	17 (9.3%)	20 (9.6%)
90th:	5 (19%)	22 (12%)	27 (13%)
95th:	6 (23%)	27 (15%)	33 (16%)
90 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	8 (4.4%)	8 (3.8%)
Median:	0 (0%)	12 (6.6%)	12 (5.7%)
75th:	1 (3.8%)	14 (7.7%)	15 (7.2%)
90th:	4 (15%)	18 (9.8%)	22 (11%)
95th:	5 (19%)	22 (12%)	27 (13%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-4. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Mallards – Final Rule (Option D)

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	7 (3.8%)	7 (3.3%)
25th:	0 (0%)	12 (6.6%)	12 (5.7%)
Median:	0 (0%)	19 (10%)	19 (9.1%)
75th:	0 (0%)	23 (13%)	23 (11%)
90th:	0 (0%)	26 (14%)	26 (12%)
95th:	2 (7.7%)	26 (14%)	28 (13%)
10 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	6 (3.3%)	6 (2.9%)
Median:	0 (0%)	12 (6.6%)	12 (5.7%)
75th:	0 (0%)	17 (9.3%)	17 (8.1%)
90th:	0 (0%)	21 (11%)	21 (10%)
95th:	0 (0%)	25 (14%)	25 (12%)
50 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	5 (2.7%)	5 (2.4%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	14 (7.7%)	14 (6.7%)
95th:	0 (0%)	18 (9.8%)	18 (8.6%)
75 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	3 (1.6%)	3 (1.4%)
75th:	0 (0%)	6 (3.3%)	6 (2.9%)
90th:	0 (0%)	9 (4.9%)	9 (4.3%)
95th:	0 (0%)	13 (7.1%)	13 (6.2%)
90 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	1 (0.55%)	1 (0.48%)
25th:	0 (0%)	2 (1.1%)	2 (0.96%)
Median:	0 (0%)	3 (1.6%)	3 (1.4%)
75th:	0 (0%)	3 (1.6%)	3 (1.4%)
90th:	0 (0%)	6 (3.3%)	6 (2.9%)
95th:	0 (0%)	9 (4.9%)	9 (4.3%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-5. Risk of Selenium-Driven Reproductive Effects in Fish Downstream from Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) – Baseline

Percentile [a]	**Black Creek WASP Model Segment ID** [b,c]												
	39	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**	**29**	**28**	**27**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	0.381%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	83.0%	17.8%	18.9%	8.00%	6.25%	3.46%	5.70%	8.80%	<0.1%	<0.1%	<0.1%	1.62%	1.46%
90th:	>99.9%	98.7%	98.3%	94.6%	93.4%	87.7%	95.2%	94.4%	40.8%	36.3%	20.5%	82.6%	79.6%
95th:	>99.9%	>99.9%	>99.9%	>99.9%	>99.9%	99.8%	>99.9%	>99.9%	94.2%	92.8%	80.6%	99.7%	99.6%
	26	**25**	**24**	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**	**15**	**14**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	1.11%	0.226%	2.42%	2.39%	2.14%	1.82%	1.81%	2.41%	0.723%	0.330%	0.345%	0.331%	0.323%
90th:	80.9%	57.1%	86.5%	87.8%	83.9%	80.1%	81.0%	84.1%	73.4%	66.5%	64.6%	60.3%	58.4%
95th:	99.7%	97.8%	99.8%	99.7%	99.7%	99.5%	99.6%	99.7%	99.1%	98.9%	98.7%	97.9%	97.7%
	13	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	0.237%	0.273%	0.266%	0.993%	0.509%	0.303%	0.312%	0.273%	0.313%	0.375%	0.375%	0.292%	0.421%
90th:	57.9%	60.3%	59.2%	72.3%	66.7%	59.1%	59.7%	56.3%	58.4%	63.1%	63.1%	59.5%	59.5%
95th:	97.6%	98.5%	97.9%	98.9%	97.8%	97.5%	97.8%	97.8%	97.4%	98.4%	98.4%	97.9%	98.3%

Note: Percentages are rounded to three significant figures.

a – Percentile refers to the risk percentile. For example, based on the values in the 75th percentile row for Segment 39, there is a 25 percent probability that selenium concentrations in fish eggs/ovaries are high enough to cause negative reproductive effects in 83 percent of the exposed fish population inhabiting that segment of Black Creek.

b – Segment 39 is the immediate receiving water for Morrow Generating Site. Segment 1 is farthest downstream from the immediate receiving water. The 39 segments comprise a total of 95 miles of Black Creek.

c – >0 to 5 percent risk; 5 to 35 percent risk; 35 to 65 percent risk; 65 to 95 percent risk; >95 percent risk.

Table F-6. Risk of Selenium-Driven Reproductive Effects in Mallards Downstream from Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) – Baseline

Percentile [a]	Black Creek WASP Model Segment ID [b,c]												
	39	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**	**29**	**28**	**27**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	0.872%	0.268%	0.253%	0.153%	0.155%	0.139%	0.117%	0.167%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	9.18%	3.46%	3.21%	2.33%	2.27%	1.90%	1.92%	2.33%	0.463%	0.451%	0.298%	1.17%	1.10%
75th:	37.3%	19.4%	18.6%	15.0%	14.8%	12.6%	13.7%	14.6%	5.33%	4.81%	3.57%	9.98%	9.13%
90th:	71.1%	49.5%	47.4%	41.4%	40.5%	38.3%	40.5%	41.6%	22.1%	21.2%	17.6%	33.6%	32.0%
95th:	86.1%	68.0%	66.7%	60.5%	58.6%	57.2%	59.7%	60.6%	38.4%	37.2%	33.2%	52.5%	51.7%
	26	**25**	**24**	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**	**15**	**14**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	0.11%	0.109%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	1.14%	1.66%	1.53%	1.51%	1.57%	1.12%	1.12%	1.55%	1.12%	0.911%	0.698%	0.698%	0.698%
75th:	9.46%	11.5%	11.2%	11.5%	10.9%	10.0%	10.7%	10.9%	9.28%	7.76%	7.53%	7.06%	7.32%
90th:	33.2%	35.3%	35.6%	36.0%	34.5%	32.9%	33.5%	33.9%	31.1%	27.2%	27.4%	26.6%	26.5%
95th:	53.1%	53.7%	54.7%	55.3%	53.5%	52.5%	51.2%	52.4%	50.2%	44.9%	44.9%	44.9%	44.4%
	13	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	0.698%	0.698%	0.698%	1.09%	0.986%	0.750%	0.750%	0.75%	0.789%	0.750%	0.898%	<0.1%	0.900%
75th:	7.20%	7.12%	6.63%	8.59%	7.89%	7.35%	7.42%	7.17%	7.21%	7.03%	7.65%	6.75%	7.20%
90th:	25.5%	26.1%	25.4%	31.0%	26.8%	26.5%	26.0%	25.9%	26.9%	26.1%	27.0%	27.2%	27.3%
95th:	44.3%	44.4%	44.2%	48.6%	45.7%	44.3%	43.4%	43.6%	44.9%	43.6%	44.8%	45.6%	45.5%

Note: Percentages are rounded to three significant figures.

a – Percentile refers to the risk percentile. For example, based on the values in the 75th percentile row for Segment 39, there is a 25 percent probability that selenium concentrations in mallard eggs are high enough to cause negative reproductive effects in 37.3 percent of the exposed mallard population inhabiting that segment of Black Creek.

b – Segment 39 is the immediate receiving water for Morrow Generating Site. Segment 1 is farthest downstream from the immediate receiving water. The 39 segments comprise a total of 95 miles of Black Creek.

c – >0 to 5 percent risk; 5 to 35 percent risk; 35 to 65 percent risk; 65 to 95 percent risk; >95 percent risk.

Ecological Risk Model Methodology Limitations and Assumptions

The limitations and assumptions of the ecological risk modeling methodology include the following:

- ***Water Quality Inputs.*** The assumptions listed for the IRW model water quality module in Appendix C apply to the dissolved selenium concentrations that support the national-scale ecological risk model. The assumptions listed for the case study water quality model in Appendix G apply to the Black Creek case study ecological risk model. As discussed in Section 8 of the EA report, the case study models do incorporate available data regarding background pollutant concentrations and pollutant loading contributions from non-steam-electric point sources. For the Black Creek case study, however, EPA did not identify sufficient STORET monitoring data to represent upstream pollutant contributions, and did not identify any upstream non-steam-electric point sources with loadings for the modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area. This results in a potential underestimation of dissolved selenium concentrations (and the associated risk of negative reproductive effects among fish and mallards) within the Black Creek modeling area.
- ***Receptor Populations Evaluated.*** EPA assumed that the receptor species and receiving water occur together (*i.e.*, all receiving waters evaluated in the national-scale and case study ecological risk models are habitat for fish and mallards even though that may not always be the case). This results in a potential overestimation of the number of immediate receiving waters whose elevated selenium concentrations are causing negative reproductive impacts among exposed fish and mallards.
- ***Species Represented by Exposure-Response Functions.*** EPA used exposure-response functions that are based on vetted functions from the literature for brown trout (representative of fish) and mallard (representative of avian). Brown trout are amongst the most sensitive fish species to selenium [U.S. EPA, 2014f]. EPA selected the mallard as the representative avian species, which may not reflect potential impacts to other species that consume primarily fish rather than invertebrates, and that may show differential sensitivity. The literature suggests that mallards are among the most sensitive bird species to selenium [Chapman *et al.*, 2009]. Therefore, use of these exposure-response functions results in an environmentally protective estimate of reproductive risk among the fish and avian species found at any given waterbody.
- ***Multiple Pollutant Exposures.*** According to EPA's *Steam Electric Power Generating Point Source Category: Final Detailed Study Report* [U.S. EPA, 2009b], receptors will be exposed to multiple constituents simultaneously. However, the ecological risk model examines the impact of only selenium to receptors and does not take into account how the interaction of multiple pollutants impacts the receptors. For example, EPA did not consider the impact of mercury on the uptake or toxicity of selenium. There is evidence in the literature that these two compounds interact with each other in the environment and may decrease the level of impact of selenium on a receptor;[4] conversely, the interaction of other pollutants may increase the impact to a receptor. It

---

[4] In a notable but unexplained exception to this general rule, Heinz and Hoffman (1998) found that selenium and mercury interact to create additive or synergistic toxic effects in mallard embryos.

is beyond the scope of this analysis to include the effects of multiple pollutant interactions on receptors; however, the consideration of only selenium-driven impacts in this analysis likely results in an underestimation of the overall negative reproductive impacts among fish and mallards resulting from exposure to the variety of pollutants in steam electric power plant wastewater discharges.

- ***Composition of Fish and Mallard Diet.*** In this analysis, EPA assumed that mallard diets consisted entirely of invertebrates, which potentially overestimates the dietary intake of selenium (because invertebrates tend to bioaccumulate selenium to a higher degree than submerged aquatic vegetation, another component of mallard diets). EPA also assumed that the diets of fish and mallards consisted entirely of aquatic organisms that inhabit the modeled waterbodies. These assumptions result in an environmentally protective estimation of dietary selenium uptake if fish and mallards also consume organisms from other waterbodies that are not contaminated with selenium.

APPENDIX G
OVERVIEW OF CASE STUDY MODELING SETUP AND OUTPUTS

This appendix presents additional information about the model development, input variables, pollutant benchmarks, and methodology limitations/assumptions applicable to case study modeling performed using EPA's Water Quality Analysis Simulation Program (WASP). This appendix also presents additional information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, U.S. Geological Survey (USGS) time series flow data, steam electric power plant pollutant loadings), and model settings (*e.g.*, solids constants and sediment transport parameters) for each of the WASP models. For additional documentation regarding the selection of case study locations, development of the case study models, and outputs produced by the WASP models, refer to the ERG memorandum, "Technical Approach for Case Study Water Quality Modeling of Aquatic Systems in Support of the Final Steam Electric Power Generating Industry Environmental Assessment" (DCN SE05570) (*Case Study Water Quality Modeling Memorandum*).

CASE STUDY MODEL SETUP – ALL MODELS

This section of the appendix focuses on the development of the case study models, including the limitations/assumptions, input parameters, and methodologies that are applicable to all of the case study models.

Model Development & Input Variables

WASP Model Default Parameters. The Simple Toxicant module within WASP groups reaches of the modeled receiving water (*i.e.*, the individual COMIDs as defined in NHDPlus Version 1) into segments based on the hydrologic characteristics. The WASP model calculates the water column and benthic pollutant concentrations of the eight modeled pollutants using user-defined parameters and default assumption values. Table G-1 presents the WASP default parameters and values that EPA used for all the case study models.

Benthic Sediment Depth. All of the case study models are designed with two layers of segments representing the upper and lower benthic sediment layer, except for the Lake Sinclair model where benthic layers are not simulated. For each model, the depth of the upper and lower benthic sediment layers are 0.03m and 0.25m, respectively.

Pollutant Partition Coefficients & Densities. The Simple Toxicant module within WASP applies pollutant-specific partition coefficients to estimate the degree to which pollutants in the water column will adsorb to benthic sediments and suspended solids. EPA selected the suspended sediment-water (Kd_{SW}) partition coefficient for each of the eight modeled pollutants. Refer to Table C-4 in Appendix C of the *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-861-R-15-006), hereafter referred to as the "EA Report," for the suspended sediment water partition coefficients used for each modeled pollutant. Additionally, the Simple Toxicant module requires the user to input a density for each modeled pollutant. Table G-2 presents the density values EPA used for each pollutant, based on published values from literature.

Table G-1. Solids Constants and Sediment Transport Parameters – All Models

Input Parameter	Description	Value Used	Units
Silts and Fines Density	WASP default density for silts/fines	2.650	g/cm^3
Sand Density	WASP default density for sand	2.650	g/cm^3
Organic Solids Density	WASP default density for organic solids	1.350	g/cm^3
fcritcoh	Critical cohesive sediment fraction; above which sediment bed acts cohesively	0.200	(fraction)
vRCohMult	Shear stress multiplier for cohesive resuspension	2.500	g/m^2/sec
vRCohExp	Shear stress exponent for cohesive resuspension	2.500	(unitless)
vRNonCohEx	Shear stress exponent for noncohesive resuspension	1.500	(unitless)
D50_silt	Particle diameter for silt	0.025	mm
D50_sand	Particle diameter for sand	0.250	mm
D50_POM	Particle diameter for organic solids	0.012	mm
vDexp_silt	Shear stress exponent for silt deposition	1.000	(unitless)
vD_exp_san	Shear stress exponent for sand deposition	1.000	(unitless)
vD_exp_POM	Shear stress exponent for organic solids deposition	1.000	(unitless)
TAUcritcoh [a]	Critical shear stress for erosion of cohesive bed	3.500 or 5.000	N/m^2
TAU_cD1_si [b]	Lower critical shear stress for silt; below which deposition is maximum	3.500 or 5.000	N/m^2
TAU_cD2_si [b]	Upper critical shear stress for sand; above which deposition is zero	7.000 or 10.000	N/m^2
TAU_cD1_sa	Lower critical shear stress for sand; below which deposition is maximum	4.000	N/m^2
TAU_cD2_sa	Upper critical shear stress for sand; above which deposition is zero	5.000	N/m^2
TAU_cD1_PO [b]	Lower critical shear stress for organic solids; below which deposition is maximum	3.500 or 5.000	N/m^2
TAU_cD2_PO [b]	Upper critical shear stress for organic solids; above which deposition is zero	7.000 or 10.000	N/m^2

Acronyms: g/cm^3 (grams per cubic centimeter); g/m^2/sec (grams per square meter per second); mm (millimeter); N/m^2 (newton per square meter)

a – The value of this input parameter varies the critical sheer stress values for sediment transport. The value specified for this parameter, which can be set between 0.5 and 8.0 N/m^2, was determined as a result of calibration performed for each case study model. EPA determined that for all WASP models except for the Mississippi River site, a value of 3.5 N/m^2 was reasonable and resulted in modeled solids output comparable to the actual monitoring data results. For the Mississippi River WASP model, a value of 5.0 N/m^2 was deemed more appropriate based on model calibration.

b – WASP uses default values for these input parameters based on the value specified for 'TAUcritcoh.'

Table G-2. Pollutant Densities - All Models

Pollutant	Density (g/cm^3)
Arsenic	5.75
Cadmium	8.70
Copper	8.96
Lead	11.34
Nickel	8.91
Selenium	4.80
Thallium	11.85
Zinc	7.14

Organic Solids, Sands, and Silts/Fines. To define initial concentrations for the organic solids, sands, and silts/fines parameters, EPA used total organic carbon (TOC) and total suspended solids (TSS) concentrations derived from STORET monitoring data collected within the WASP modeling area. EPA calculated the concentrations of organic solids (OS), sands, and silts/fines using Equation G-1, **Error! Reference source not found.** Equation G-2, and Equation G-3 below.

EQUATION G-1

$$C_{os} = TOC \times f_{os}$$

EQUATION G-2

$$C_{sand} = (TSS - C_{os}) \times f_{sand}$$

EQUATION G-3

$$C_{sf} = (TSS - C_{os}) \times f_{sf}$$

Where:

C_{os}	=	Initial concentration of organic solids (mg/L)	Output from Equation G-1
C_{sand}	=	Initial concentration of sands (mg/L)	Output from Equation G-2
C_{sf}	=	Initial concentration of silts/fines (mg/L)	Output from Equation G-3
TOC	=	Total organic carbon (mg/L)	Site-specific value derived from STORET monitoring data
TSS	=	Total suspended solids (mg/L)	Site-specific value derived from STORET monitoring data
f_{os}	=	Fraction of total organic carbon that is organic solids (unitless)	Model assumption value of 0.5
f_{sand}	=	Fraction of total suspended solids composed of sands	Model assumption value of 0.05
f_{sf}	=	Fraction of total suspended solids composed of silts/fines	Model assumption value of 0.95

Calibration of Sediment Transport Parameters. The concentrations of the modeled pollutants are influenced by sediment transport; therefore, EPA calibrated specific sediment transport parameters where possible. EPA calibrated the model outputs by manipulating one sediment transport parameter, 'Critical Shear Stress for Erosion of Cohesive Bed' (defined as 'TAUcritcoh' in WASP), until the modeled TSS concentrations in the water column segments (represented by the sum of organic matter, sands, and silts/fines) closely matched the available TSS STORET monitoring data. The 'Critical Shear Stress for Erosion of Cohesive Bed' value used for each case study model is presented in the case study model-specific sections of this appendix.[1]

Calibration of Initial Concentration of Sediment in Benthic Segments. In some cases, the initial concentration of sediment in the benthic segments was adjusted during the calibration process, as very large spikes in total solids concentration were sometimes observed during high

---

[1] If EPA observed a significant difference between the modeled TSS concentrations and actual observed TSS concentrations, the sediment transport calibration values were given further review; however, those differences, when they occurred, were often attributable to the pollutant contributions flowing in from the model boundaries.

flow events near the beginning of the simulation period. These large spikes were an indication that too much sediment was present in the modeled benthic segments at the start of the simulation, indicating that calibration of the sediment concentration was necessary. Where monitored pollutant data were available, the total concentration of pollutant was plotted alongside the actual observed results from STORET monitoring data as another check in the calibration process. The initial concentrations of the organic solids, sands, and silts/fines in the benthic sediment used for each case study model are presented in the case study model-specific sections of this appendix.

Steam Electric Power Plant Pollutant Loadings. EPA calculated pollutant loadings from the evaluated wastestreams as part of its engineering analysis (see Section 10 of the *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD) [EPA 821-R-15-007]). The baseline and regulatory option pollutant loadings used for each case study are presented in the case study model-specific sections of this appendix. The *Case Study Water Quality Modeling Memorandum* further describes the methodology for calculating and incorporating steam electric power plant loadings data into the WASP models.

Non-Steam Electric Loadings. EPA incorporated pollutant loadings and/or concentrations data from Discharge Monitoring Reports (DMR), the Toxics Release Inventory (TRI), and EPA’s STORET monitoring database to represent pollutant contributions from non-steam-electric point sources and nonpoint sources that may impact the case study water quality model. EPA incorporated pollutant loadings data from DMR and TRI data for each of the eight pollutants to account for the pollutant contributions within the modeling area. STORET monitoring data were incorporated to account for contributions upstream of the modeling boundaries and for use in calibration. For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration or annual load to a daily mass loading.[2] Each case study model-specific section of this appendix presents the non-steam electric pollutant loadings incorporated into the model. The *Case Study Water Quality Modeling Memorandum* further describes the methodology for collecting, assessing, and incorporating DMR and TRI pollutant loadings data into the WASP models.

WASP Output Analysis Methodology

The WASP models generate output data for pollutant concentration (total, dissolved, and sorbed) in each water column and benthic segment on a daily output time step. For the purposes of assessing the baseline impacts and the improvements under the final rule, EPA used the baseline and regulatory option WASP model outputs from the period after the steam electric power plant’s assumed compliance date.[3] Using this period of water quality output ensures that the baseline and regulatory option analyses are both based on the same underlying flow data, meaning that the differences in modeled pollutant concentrations are solely attributable to the pollutant loading reductions under the final rule.

---

[2] EPA converted the average concentration calculated from the STORET monitoring data to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

[3] For case studies with pollutant loadings from multiple steam electric power plants (Ohio River and Mississippi River), EPA used the later of the two assumed compliance dates.

Water Quality Assessment. The WASP models generate daily pollutant concentrations in the water column of all water column segments within the models. EPA quantified the water quality impacts as the percent of days where the water column concentration, total or dissolved, exceed the National Recommended Water Quality Criteria (NRWQC) or Maximum Contaminant Level (MCL) benchmarks listed in Table C-7 in Appendix C. EPA also quantified the total river miles exhibiting exceedances and the distance downstream of the steam electric power plant(s) that showed any exceedances of these benchmarks at any point during the modeling period.

Wildlife Assessment. The WASP models generate daily pollutant concentrations in the upper and lower benthic sediment segments within the models. EPA quantified the impact to benthic organisms as the percent of days where the total sediment concentration in the upper benthic segments exceed the Chemical Stressor Concentration Limit (CSCL) benchmarks for sediment biota listed in Table D-1 in Appendix D. EPA also quantified the total number of river miles exhibiting exceedances and the distance downstream of the steam electric power plant(s) that showed any exceedances of these CSCLs at any point during the modeling period.

EPA calculated the annual average pollutant concentrations in the water column (averaged over the entire modeling period) of all water column segments. To determine negative impacts to piscivorous wildlife (*i.e.*, wildlife that consume fish) from the ingestion of contaminated fish, EPA compared the calculated annual average water column concentrations to “threshold” water concentrations that would result in exceedances of no effect hazard concentrations (NEHCs) for minks and eagles developed by the USGS.[4] Since minks are estimated to have a four-year life expectancy, EPA completed this analysis using four-year rolling average water concentration values. EPA quantified the total river miles with NEHC exceedances and how far downstream of the plant these impacts are observed.

Refer to Appendix F regarding the methodology for performing ecological risk modeling using water quality outputs from the Black Creek WASP model.

Human Health Assessment. EPA calculated the annual average pollutant concentrations in the water column (averaged over the entire modeling period) of all water column segments. To determine negative impacts to human receptors from the ingestion of contaminated fish, EPA compared the calculated annual average concentrations to “threshold” water concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR) benchmark for selected cohorts.[5] EPA quantified the total river miles with LECR benchmark exceedances and how far downstream of the plant these impacts are observed.

Case Study Modeling Methodology Limitations and Assumptions

The case study modeling methodology shares the following limitations and assumptions with the IRW model water quality module (see Appendix C for further discussion):

---

[4] Refer to the memorandum “Downstream EA Modeling Methodology and Supporting Documentation” (DCN SE04455) for the water column concentrations that result in exceedances of the NEHC benchmarks.

[5] Refer to the memorandum “Downstream EA Modeling Methodology and Supporting Documentation” (DCN SE04455) for the water column concentrations that result in exceedances of the non-cancer reference doses or LECR benchmark for selected cohorts.

- The models are based on annual-average pollutant loadings and normalized flow rates from the steam electric power plants. Unlike the water quality module, however, the case study models do account for temporal variability in the receiving water flow rates.
- The models do not take into consideration pollutant speciation within the receiving stream.
- The models assume that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a single partition coefficient.
- The pollutant loadings included in the models are not representative of the total pollutant loadings from steam electric power plants, as there are several waste streams that are not included in the analysis (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). Unlike the water quality module, however, the case study models do take into account ambient background pollutant concentrations and contributions from other point and nonpoint sources.

In addition to the above, the case study modeling methodology incorporates the following limitations and assumptions:

- The models assume that pollutant contributions from background sources and other point and nonpoint sources are constant over the entire modeling period. This assumption reduces the variability in modeled pollutant concentrations over time and results in a potential underestimation of periods with elevated pollutant concentrations above benchmark levels (under both baseline conditions and the regulatory options).
- The models incorporate DMR and TRI loadings data to represent other point source dischargers. In DMR, facilities are required to report loadings only for the pollutants that are listed in the facility's National Pollutant Discharge Elimination System (NPDES) permit. This limitation results in a potential underestimation of the pollutant loadings from point sources that discharge a modeled pollutant but are not required to report wastewater monitoring data as part of their NPDES permit. TRI collects facility-reported estimates of wastewater loadings data for both direct and indirect dischargers. The TRI releases database does not include loadings from facilities with total annual chemical releases of less than 500 lbs and incorporates assumptions regarding plants with annual releases of less than 1,000 lbs. This limitation results in a potential underestimation of pollutant loadings from smaller point sources. Other limitations of the data collected in TRI include the following: small establishments are not required to report, nor are facilities that do not meet reporting thresholds; releases reported are based on estimates, not measurements; certain chemicals are reported as a class, not as individual compounds; facilities are identified by NAICS code, not point source category; and TRI requires facilities to report only certain chemicals, therefore all pollutants discharged from a facility may not be captured. The effect of these limitations on the case study model outputs is unknown.
- In cases where STORET monitoring data results are reported as below the quantitation limit, EPA assumed the result was equal to one-half the low-level analytical method detection limit for purposes of averaging the monitoring data results. The effect of this assumption on the case study model outputs is unknown and

depends on whether actual background concentrations at the time and location of monitoring were higher or lower than the assumed concentration.

- The models assume that stream flow conditions throughout the modeling period can be represented by selected ranges of historical stream flow data. The effect of this assumption on the case study model outputs is unknown and depends on whether actual stream flow rates are higher or lower than those used in the models.
- For each steam electric power plant, EPA assumed a plant-specific date (derived from the plant’s permitting cycle) upon which the plant would achieve compliance with the final rule. The selection of the assumed compliance date influences the timing of when the modeled baseline impacts and improvements under the final rule would occur, but does not affect the magnitude of these impacts and improvements.
- By incorporating wildlife, human health, and ecological risk analyses, the models incorporate all of the limitations and assumptions described for those analyses (see Appendices D, E, and F).

CASE STUDY MODEL SETUPS AND OUTPUTS – BLACK CREEK, MS

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Black Creek case study model.

Model Development & Input Variables

WASP Model Design. The Black Creek WASP model starts at the R.D. Morrow, Sr. (Morrow) Generating Site's immediate receiving water (COMID 18104316), as defined by the IRW model, and extends approximately 95 miles downstream to just upstream of where Big Black Creek converges with Red Creek (COMID 18106998).

The Black Creek WASP model consists of 174 modeled segments. Segment IDs 1-39 represent the surface water of Black Creek with Segment ID 1 being the most downstream segment and Segment ID 39 being the most upstream segment and immediate receiving water. The remaining model segments represent tributary surface waters (Segment IDs 40-58), the upper benthic layers (Segment IDs 59-116), and the lower benthic layers (Segment IDs 117-174). Figure G-1 illustrates the segmentation of the Black Creek WASP model.

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on Morrow Generating Site's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Black Creek WASP model. EPA scaled the Black Creek stream gage data from Gage ID 02479130 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one USGS stream gage to represent inflow from Cypress Creek, a significant tributary to the Black Creek WASP modeling area. EPA scaled the Cypress Creek stream gage data from Gage ID 0247155 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-1 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-3 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-4 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

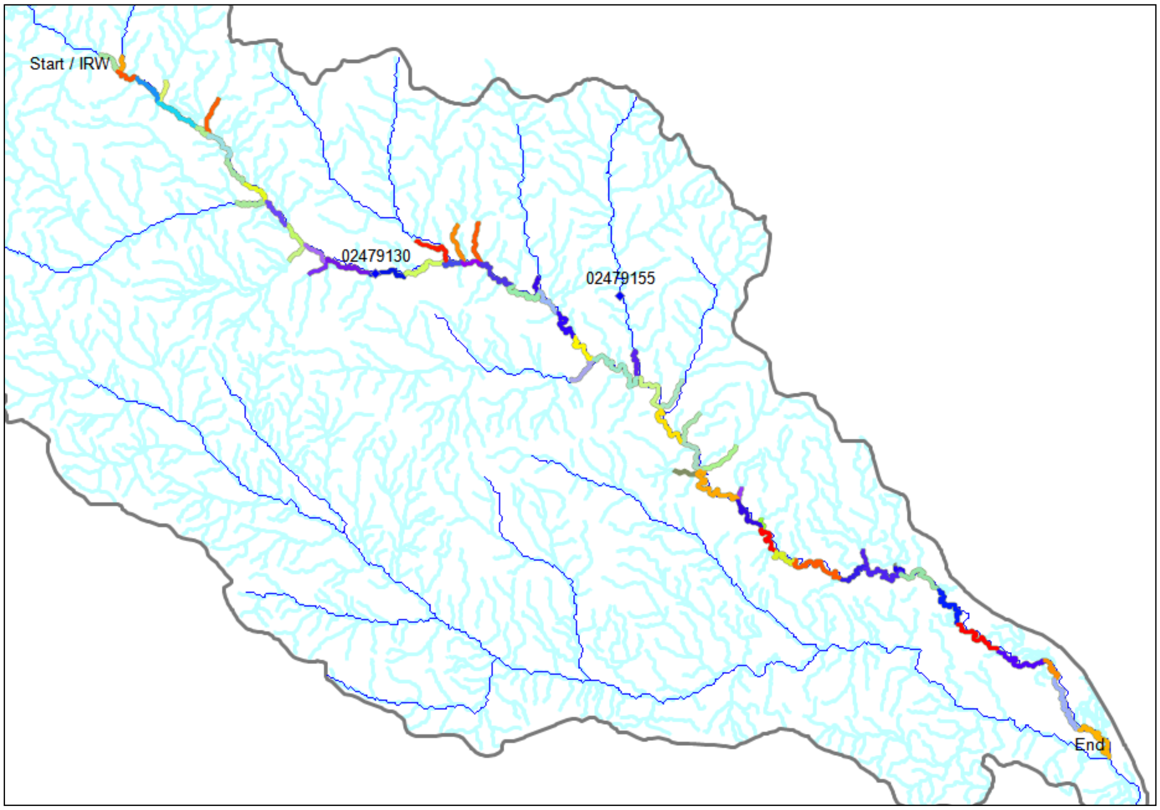


Figure G-1. Geographic Extent and Segmentation – Black Creek WASP Model

Model Input Variables. Table G-5 presents the pollutant loadings modeled from Morrow Generating Plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Black Creek case study model.

Table G-6 presents the pollutant contributions flowing into the Black Creek WASP model boundaries calculated using available STORET monitoring data.

Table G-7 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 3.43 mg/L, 0.78 mg/L, and 14.74 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-8 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 10,000 mg/L each.

Model Results

Case study modeling of Black Creek revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, selenium, and thallium. Figure G-2, Figure G-3, and Figure G-4 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[6]

Case study modeling of Black Creek revealed that average water column concentrations of three pollutants (cadmium, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of wildlife and/or human health benchmarks. Table G-9 and Table G-10 illustrate the average modeled pollutant concentration in each water column segment downstream of Morrow Generating Site (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-11 and Table G-12 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

Refer to Appendix F regarding the results of ecological risk modeling using water quality outputs from the Black Creek WASP model.

---

[6] To improve clarity, Figure G-2, Figure G-3, and Figure G-4 present the baseline water column concentrations leading up to the assumed compliance date of Morrow Generating Station. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-3. USGS Stream Gages with Flow Data Used in Black Creek WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
2479130	Black Creek near Brooklyn, MS	Full Record from 10/01/1970 - 04/14/2014	929	Black Creek	379	0.408
2479155	Cypress Creek near Janice, MS	Full Record from 10/01/1966 - 04/15/2014	138	Cypress Creek	158	1.143

Acronyms: USGS (U.S. Geological Survey).

Table G-4. Stream Flow Data Periods – Black Creek WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Black Creek (Gage ID 2479130)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Cypress Creek (Gage ID 2479155)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012

Table G-5. Pollutant Loadings - Morrow Generating Site

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	6.87	101.88	19.68	794.50	4.22	1,057.22	12.43	1,259.97
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	3.68	1.02	4.50	16.93	3.39	1.87	17.26	13.83
Combustion Residual Leachate	6.29	1.66	1.24	7.61	--	18.19	0.19	34.52
Total	**16.84**	**104.56**	**25.42**	**819.03**	**7.61**	**1,077.27**	**29.88**	**1,308.32**
Final Rule [b]								
FGD Wastewater	5.28	3.81	3.42	5.70	3.07	5.18	8.87	18.07
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	6.29	1.66	1.24	7.61	--	18.19	0.19	34.52
Total	**11.57**	**5.47**	**4.66**	**13.32**	**3.07**	**23.37**	**9.06**	**52.59**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2036).

Table G-6. Pollutant Contributions from STORET Monitoring Data – Black Creek WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Clear Creek	18104458	NLA06608-2010 (31.20,-89.30)	TOC	4,420.00	--
Little Black Creek	18104706	PA361 (31.09,-89.49)	TOC	7,400.00	--
			TSS	4,642.86	--
Big Creek [c]	18104940	PA043 (31.07,-89.27)	TOC	10,000.00	--
			TSS	7,000.00	--
Big Creek [c]	18104992	PA240 (31.07,-89.17) PA360 (31.14,-89.24)	TOC	10,333.33	--
			TSS	4,666.67	--
Cypress Creek	18108034	OWW04440-HBN8 (31.02,-89.01) PA056 (31.03,-89.02)	TSS	10,000.00	--
			TOC	18,000.00	--
Hickory Creek	18106316	112D33 (30.97,-88.97)	TOC	3,000.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

c – There are two distinct tributary systems that are identified as “Big Creek” in the National Hydrography Dataset Plus (NHDPlus Version 1) database.

Table G-7. Organic Solids, Sands, and Silts/Fines Inputs – Black Creek WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Black Creek [d]	18104316	3.43	0.78	14.74
Clear Creek	18104458	2.21	*	*
Little Black Creek	18104706	3.70	0.23	4.41
Big Creek [e]	18104940	5.00	0.35	6.65
Big Creek [e]	18104992	5.17	0.23	4.43
Cypress Creek	18108034	5.00	0.90	17.10
Hickory Creek	18106316	1.50	*	*
All Other Inflows [f]	N/A	3.76	0.43	8.14

Acronyms: N/A (Not Applicable).

* – No TSS results available. The 'All Other Inflows' concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1and the STORET monitoring data presented in Table G-6.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-6.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-6.

d – The organic solids, sands, and silts/fines concentrations presented for this segment were used as the initial surface water conditions.

e – There are two distinct tributary systems that are identified as "Big Creek" in the National Hydrography Dataset Plus (NHDPlus Version 1) database.

f – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-8. Sediment Transport Parameters – Black Creek WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si [a]	3.5	N/m^2
TAU_cD2_si [a]	7.0	N/m^2
TAU_cD1_PO [a]	3.5	N/m^2
TAU_cD2_PO [a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the 'TAUcritcoh' parameter.

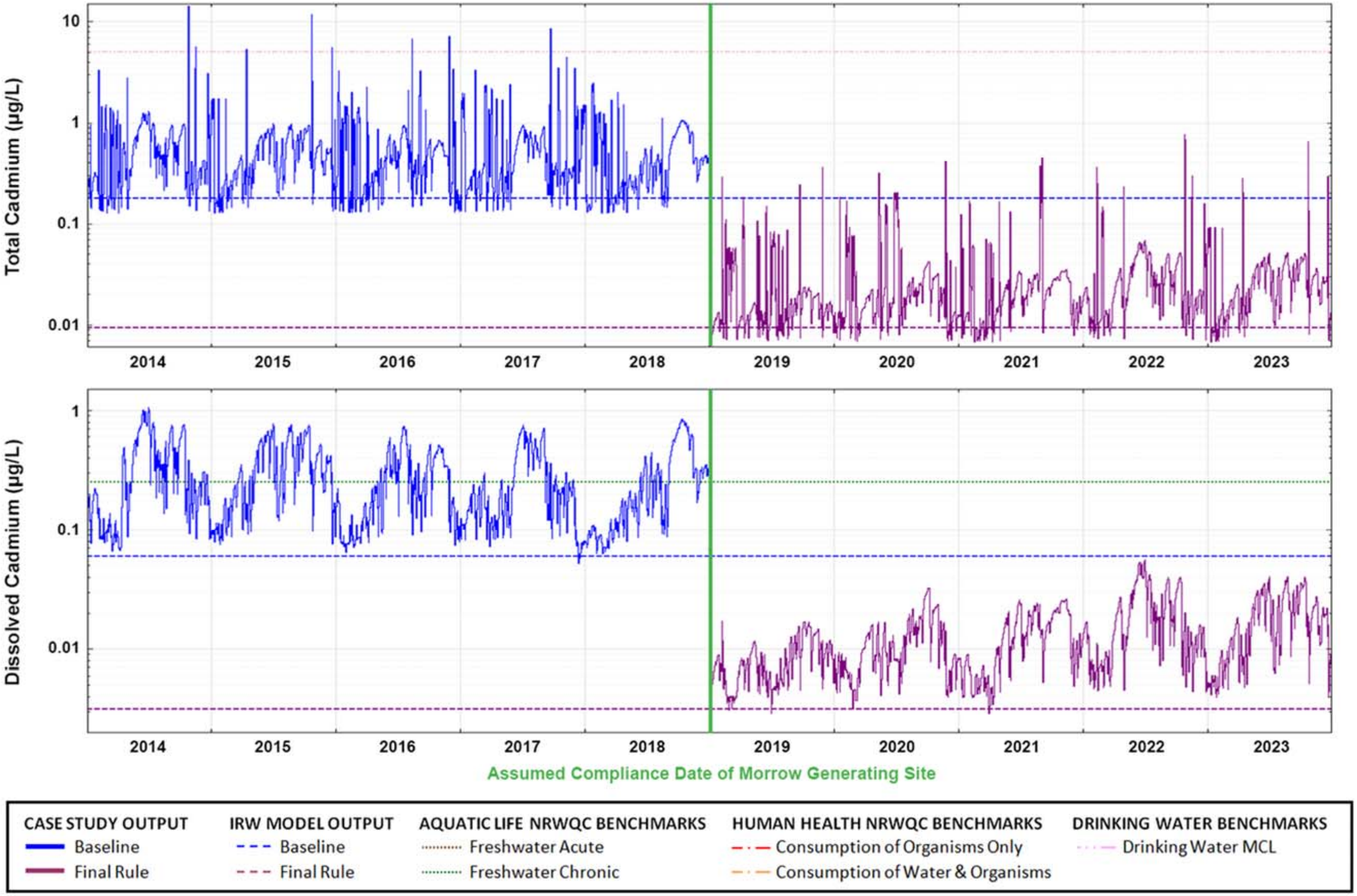


Figure G-2. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Cadmium, Dissolved Cadmium)

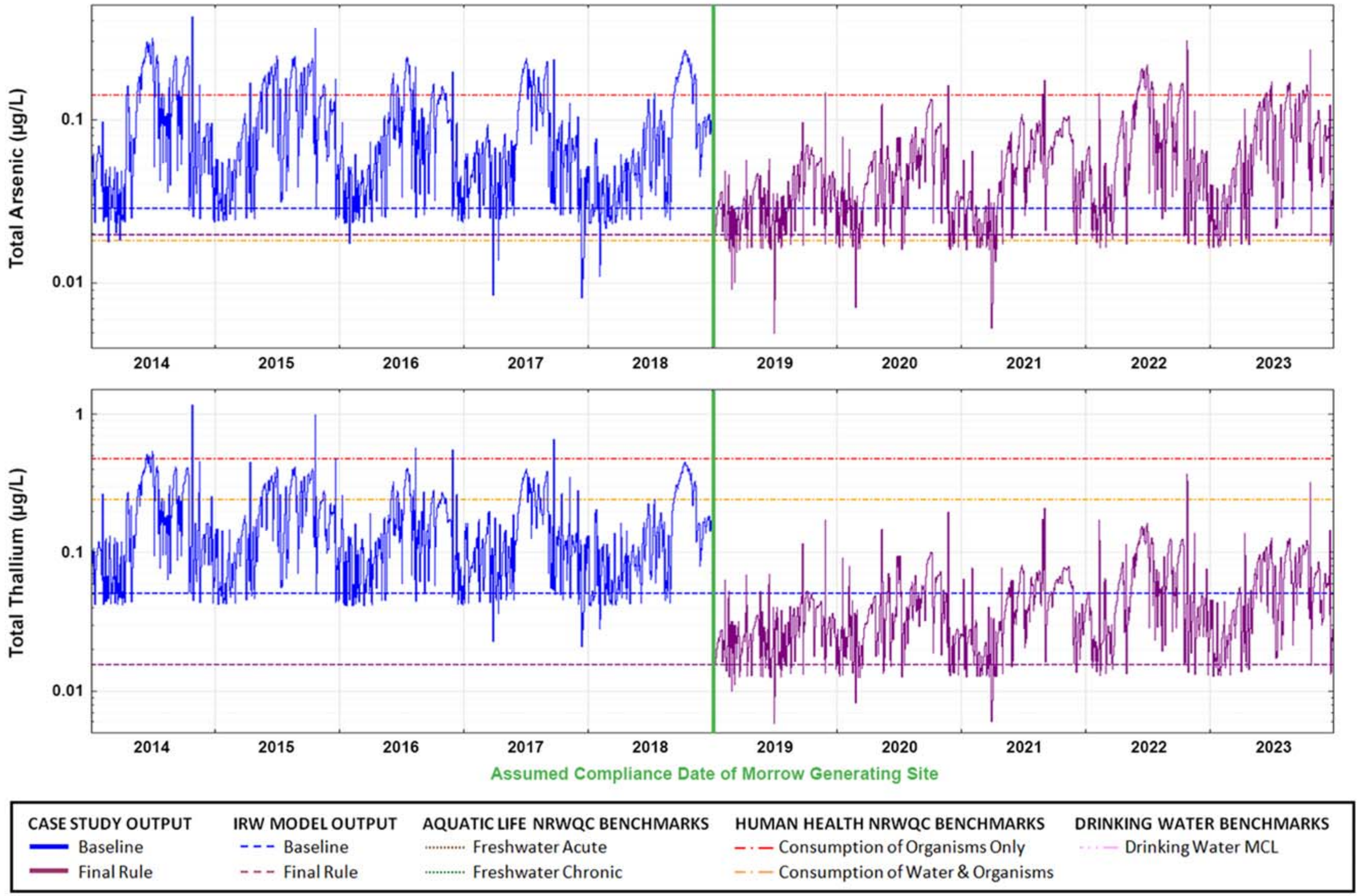


Figure G-3. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Arsenic, Total Thallium)

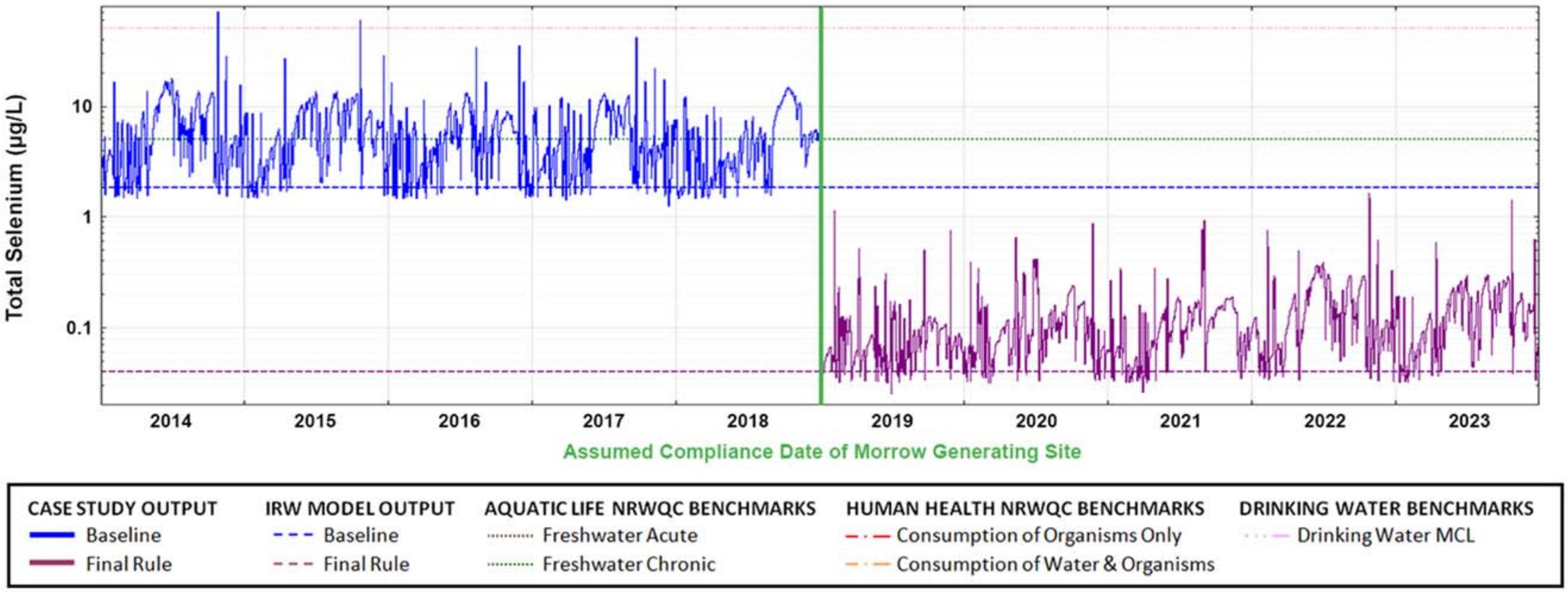


Figure G-4. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Selenium)

Table G-9. Average Water Column Concentrations Downstream of Morrow Generating Site at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (μg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
39	Black Creek/ IRW	1.64	1.64	0.0833	0.6045	0.1407	0.0498	4.2330	5.6497	0.1510	7.7217
38	Black Creek	1.44	3.08	0.0543	0.4095	0.0942	0.0346	2.7890	3.7362	0.0989	5.2410
37	Black Creek	2.23	5.31	0.0521	0.3172	0.0774	0.0226	2.5298	3.3195	0.0926	3.9426
36	Black Creek	2.68	7.99	0.0445	0.2883	0.0693	0.0218	2.2009	2.9067	0.0798	3.6359
35	Black Creek	0.93	8.92	0.0450	0.3114	0.0735	0.0249	2.2628	3.0074	0.0812	3.9689
34	Black Creek	2.10	11.01	0.0420	0.2960	0.0696	0.0240	2.1255	2.8291	0.0760	3.7863
33	Black Creek	1.89	12.90	0.0483	0.6251	0.1220	0.0625	3.0284	4.2797	0.0988	6.3651
32	Black Creek	1.68	14.58	0.0476	0.6712	0.1307	0.0694	3.1224	4.4510	0.1000	7.4057
31	Black Creek	1.84	16.43	0.0313	0.5851	0.1074	0.0619	2.3412	3.4341	0.0695	6.2251
30	Black Creek	1.48	17.90	0.0282	0.3999	0.0783	0.0400	1.8857	2.6870	0.0597	4.5225
29	Black Creek	1.44	19.35	0.0241	0.3275	0.0650	0.0324	1.5902	2.2546	0.0509	3.7426
28	Black Creek	2.64	21.99	0.0396	0.9409	0.1816	0.1095	3.4735	5.2132	0.0969	12.6119
27	Black Creek	2.09	24.08	0.0364	0.7642	0.1489	0.0866	3.0067	4.4546	0.0868	9.9344
26	Black Creek	2.66	26.74	0.0348	0.6855	0.1344	0.0764	2.7946	4.1124	0.0821	8.7650
25	Black Creek	1.31	28.05	0.0398	1.1003	0.2131	0.1383	3.8927	5.9734	0.0951	14.4045
24	Black Creek	1.07	29.12	0.0413	1.2014	0.2311	0.1532	4.1371	6.3833	0.0999	15.7678
23	Black Creek	2.86	31.98	0.0425	1.3070	0.2498	0.1688	4.3820	6.7989	0.1045	17.2212
22	Black Creek	3.02	35.00	0.0425	1.3056	0.2499	0.1690	4.3861	6.8023	0.1048	17.2252
21	Black Creek	1.59	36.59	0.0382	1.1168	0.2147	0.1431	3.8483	5.9276	0.0931	14.6726
20	Black Creek	2.50	39.09	0.0396	1.2133	0.2319	0.1569	4.0771	6.3200	0.0977	15.9712
19	Black Creek	1.98	41.07	0.0399	1.2327	0.2352	0.1596	4.1222	6.3956	0.0986	16.2267
18	Black Creek	4.21	45.29	0.0349	1.1106	0.2114	0.1451	3.6660	5.7048	0.0873	14.5811
17	Black Creek	2.62	47.91	0.0315	0.9820	0.1872	0.1276	3.2730	5.0823	0.0783	12.8610
16	Black Creek	2.75	50.66	0.0299	0.9354	0.1780	0.1218	3.1087	4.8313	0.0743	12.2591
15	Black Creek	2.09	52.75	0.0309	1.0301	0.1945	0.1357	3.3126	5.1842	0.0782	13.5792

Table G-9. Average Water Column Concentrations Downstream of Morrow Generating Site at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
14	Black Creek	4.55	57.30	0.0305	1.0067	0.1903	0.1325	3.2498	5.0822	0.0769	13.2571
13	Black Creek	2.35	59.65	0.0300	0.9822	0.1860	0.1290	3.1903	4.9820	0.0756	12.9326
12	Black Creek	2.14	61.79	0.0194	0.2514	0.0569	0.0208	1.4524	2.0605	0.0409	3.0507
11	Black Creek	2.01	63.80	0.0192	0.2467	0.0558	0.0211	1.4283	2.0254	0.0402	2.9991
10	Black Creek	4.00	67.80	0.0269	0.5034	0.1033	0.0565	2.2124	3.2481	0.0604	6.4548
9	Black Creek	1.80	69.61	0.0282	0.6248	0.1242	0.0747	2.4762	3.6902	0.0655	8.1467
8	Black Creek	3.50	73.10	0.0265	0.5620	0.1125	0.0662	2.2782	3.3875	0.0610	7.3174
7	Black Creek	3.02	76.12	0.0261	0.5480	0.1099	0.0642	2.2346	3.3201	0.0600	7.1365
6	Black Creek	3.33	79.45	0.0261	0.5551	0.1109	0.0650	2.2472	3.3481	0.0603	7.2115
5	Black Creek	3.16	82.61	0.0260	0.5475	0.1096	0.0639	2.2301	3.3199	0.0599	7.1144
4	Black Creek	3.36	85.97	0.0263	0.5658	0.1129	0.0666	2.2768	3.3970	0.0609	7.3715
3	Black Creek	1.90	87.87	0.0248	0.4646	0.0947	0.0517	2.0354	2.9817	0.0557	5.9687
2	Black Creek	3.66	91.54	0.0241	0.4279	0.0877	0.0462	1.9406	2.8222	0.0536	5.4496
1	Black Creek/ End	3.85	95.38	0.0247	0.4799	0.0943	0.0492	2.0362	2.9758	0.0556	5.7478

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-10. Average Water Column Concentrations Downstream of Morrow Generating Site Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
39	Black Creek/ IRW	1.64	1.64	0.0575	0.0322	0.0261	0.0204	0.0702	0.1250	0.0460	0.3167
38	Black Creek	1.44	3.08	0.0375	0.0218	0.0175	0.0141	0.0464	0.0828	0.0301	0.2153
37	Black Creek	2.23	5.31	0.0360	0.0169	0.0144	0.0092	0.0419	0.0734	0.0282	0.1615
36	Black Creek	2.68	7.99	0.0308	0.0153	0.0129	0.0089	0.0366	0.0644	0.0243	0.1485
35	Black Creek	0.93	8.92	0.0311	0.0166	0.0136	0.0102	0.0378	0.0669	0.0247	0.1629
34	Black Creek	2.10	11.01	0.0290	0.0158	0.0129	0.0098	0.0355	0.0629	0.0232	0.1555
33	Black Creek	1.89	12.90	0.0335	0.0532	0.0273	0.0274	0.1016	0.1766	0.0309	0.6420
32	Black Creek	1.68	14.58	0.0330	0.0545	0.0286	0.0301	0.0972	0.1717	0.0312	0.6460
31	Black Creek	1.84	16.43	0.0217	0.0469	0.0233	0.0269	0.0778	0.1392	0.0217	0.5689
30	Black Creek	1.48	17.90	0.0196	0.0335	0.0171	0.0174	0.0635	0.1107	0.0187	0.3883
29	Black Creek	1.44	19.35	0.0167	0.0274	0.0142	0.0140	0.0534	0.0927	0.0159	0.3143
28	Black Creek	2.64	21.99	0.0272	0.0639	0.0358	0.0460	0.0916	0.1718	0.0301	0.7238
27	Black Creek	2.09	24.08	0.0249	0.0536	0.0300	0.0366	0.0823	0.1518	0.0270	0.6070
26	Black Creek	2.66	26.74	0.0239	0.0491	0.0274	0.0323	0.0784	0.1434	0.0255	0.5566
25	Black Creek	1.31	28.05	0.0279	0.1061	0.0442	0.0607	0.1996	0.3454	0.0313	1.3552
24	Black Creek	1.07	29.12	0.0289	0.1205	0.0486	0.0675	0.2233	0.3880	0.0330	1.5491
23	Black Creek	2.86	31.98	0.0298	0.1339	0.0530	0.0746	0.2437	0.4253	0.0347	1.7278
22	Black Creek	3.02	35.00	0.0298	0.1349	0.0534	0.0748	0.2467	0.4305	0.0348	1.7427
21	Black Creek	1.59	36.59	0.0268	0.1214	0.0469	0.0639	0.2291	0.3976	0.0311	1.5701
20	Black Creek	2.50	39.09	0.0278	0.1276	0.0500	0.0697	0.2351	0.4099	0.0325	1.6503
19	Black Creek	1.98	41.07	0.0280	0.1291	0.0507	0.0709	0.2370	0.4137	0.0329	1.6710
18	Black Creek	4.21	45.29	0.0245	0.1176	0.0458	0.0643	0.2143	0.3747	0.0291	1.5246
17	Black Creek	2.62	47.91	0.0221	0.1029	0.0404	0.0565	0.1881	0.3285	0.0261	1.3331

Table G-10. Average Water Column Concentrations Downstream of Morrow Generating Site Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
16	Black Creek	2.75	50.66	0.0209	0.0988	0.0386	0.0540	0.1821	0.3154	0.0248	1.2784
15	Black Creek	2.09	52.75	0.0217	0.1092	0.0422	0.0602	0.1951	0.3423	0.0261	1.4175
14	Black Creek	4.55	57.30	0.0214	0.1085	0.0416	0.0590	0.1937	0.3421	0.0257	1.4070
13	Black Creek	2.35	59.65	0.0210	0.1068	0.0408	0.0574	0.1921	0.3385	0.0253	1.3864
12	Black Creek	2.14	61.79	0.0136	0.0236	0.0118	0.0090	0.0729	0.1176	0.0134	0.2752
11	Black Creek	2.01	63.80	0.0134	0.0232	0.0116	0.0095	0.0716	0.1157	0.0132	0.2737
10	Black Creek	4.00	67.80	0.0187	0.0514	0.0223	0.0249	0.1231	0.2037	0.0200	0.6375
9	Black Creek	1.80	69.61	0.0197	0.0652	0.0271	0.0330	0.1485	0.2420	0.0218	0.8157
8	Black Creek	3.50	73.10	0.0185	0.0585	0.0245	0.0291	0.1352	0.2222	0.0203	0.7296
7	Black Creek	3.02	76.12	0.0182	0.0571	0.0240	0.0282	0.1322	0.2181	0.0200	0.7113
6	Black Creek	3.33	79.45	0.0183	0.0580	0.0242	0.0286	0.1333	0.2201	0.0201	0.7222
5	Black Creek	3.16	82.61	0.0182	0.0568	0.0239	0.0281	0.1314	0.2174	0.0200	0.7066
4	Black Creek	3.36	85.97	0.0184	0.0582	0.0245	0.0292	0.1329	0.2204	0.0203	0.7233
3	Black Creek	1.90	87.87	0.0173	0.0510	0.0211	0.0228	0.1250	0.2041	0.0186	0.6233
2	Black Creek	3.66	91.54	0.0169	0.0469	0.0195	0.0204	0.1196	0.1936	0.0186	0.5720
1	Black Creek/ End	3.85	95.38	0.0173	0.0497	0.0208	0.0217	0.1233	0.1998	0.0186	0.5997

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-11. Total Miles of Black Creek with Wildlife And Human Health Impacts at Baseline

Wildlife & Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	89.79	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	89.79	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	95.38	89.79	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	12.75	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	37.64	0.00	No RfD	0.00	95.38	95.38	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o) [b]	0.00	0.00	0.00	No RfD	0.00	89.79	58.53	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	89.79	58.53	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	11.43	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-12. Total Miles of Black Creek with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	**Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)**							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	58.53	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – ETOWAH RIVER, GA

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Etowah River case study model.

Model Development & Input Variables

WASP Model Design. The Etowah River WASP model starts at Plant Bowen's immediate receiving water (COMID 6499098), as defined by the IRW model, and extends approximately 35 miles downstream to just upstream of where the Etowah River converges with Silver Creek (COMID 6500350).

The Etowah River WASP model consists of 96 modeled segments. Segment IDs 1-18 represent the surface water of the Etowah River with Segment ID 1 being the most downstream segment and Segment ID 18 being the most upstream segment and immediate receiving water. The remaining model segments represent tributary surface waters (Segment IDs 19-32), the upper benthic layers (Segment IDs 33-64), and the lower benthic layers (Segment IDs 65-96). Figure G-5 illustrates the segmentation of the Etowah River WASP model.

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2032, covering a period of 51 years. Based on Plant Bowen's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2021.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Etowah River WASP model. EPA scaled the Etowah River stream gage data from Gage ID 02395000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one USGS stream gage to represent inflow from Two Run Creek, a significant tributary to the Etowah River WASP modeling area. EPA scaled the Two Run Creek stream gage data from Gage ID 02395120 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-5 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-13 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-14 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

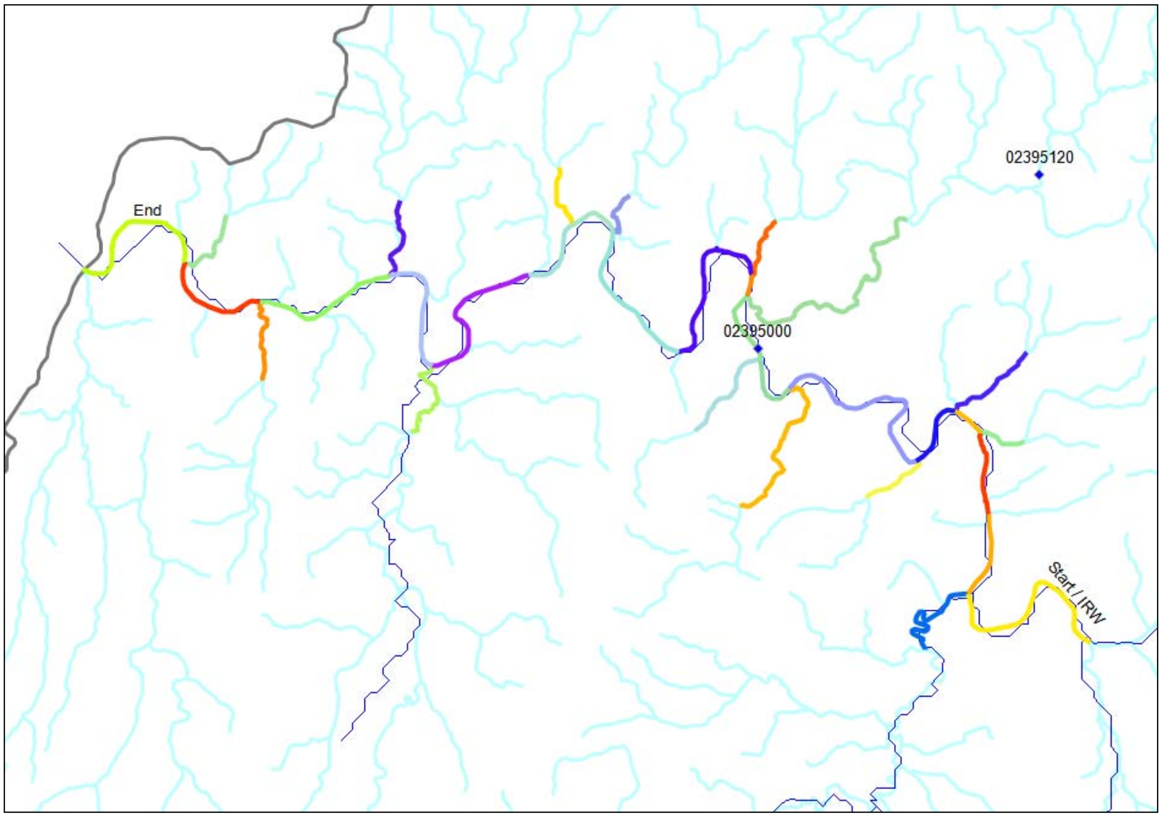


Figure G-5. Geographic Extent and Segmentation – Etowah River WASP Model

Model Input Variables. Table G-15 presents the pollutant loadings modeled from Plant Bowen at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Etowah River case study model and could not be accounted for using STORET monitoring data.

Table G-16 presents the pollutant contributions flowing into the Etowah River WASP model boundaries calculated using available STORET monitoring data.

Table G-17 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 2.56 mg/L, 0.90 mg/L, and 17.19 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-18 presents the sediment transport parameters resulting from EPA’s calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 500 mg/L each.

Model Results

Case study modeling of the Etowah River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, selenium, and thallium.[7] Figure G-6 and Figure G-7 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[8]

Case study modeling of the Etowah River revealed that average water column concentrations of three pollutants (arsenic, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Table G-19 and Table G-20 illustrate the average modeled pollutant concentration in each water column segment downstream of Plant Bowen (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-21 and Table G-22 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

---

[7] Case study modeling also revealed isolated downstream exceedances of water quality benchmarks for lead.

[8] To improve clarity, Figure G-6 and Figure G-7 present the baseline water column concentrations leading up to the assumed compliance date of Plant Bowen. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-13. USGS Stream Gages with Flow Data Used in Etowah River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
02395000	Etowah River near Kingston, GA	Partial Record from 07/18/2928 – 09/30/2013 (Missing Data between 10/24/1995 – 10/01/2008)	4,239	Etowah River	3,683	0.869
02395120	Two Run Creek near Kingston, GA	Full Record from 05/02/1980 – 09/30/2013	85	Two Run Creek	130	1.52

Acronyms: USGS (U.S. Geological Survey).

Table G-14. Stream Flow Data Periods – Etowah River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Etowah River (Gage ID 02395000)	
01/01/1982 - 10/23/1995	01/01/1982 - 10/23/1995
10/24/1995 - 09/30/2008	10/24/1967 - 09/30/1980
10/01/2008 - 9/30/2013	10/01/2008 - 9/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1994 - 10/23/2007	01/01/1982 - 10/23/1995
10/24/2007 - 09/30/2020	10/24/1967 - 09/30/1980
10/01/2020 - 9/30/2025	10/01/2008 - 9/30/2013
10/01/2025 – 12/31/2032	10/01/2005 – 12/31/2012
Two Run Creek (Gage ID 02395120)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1994 - 09/30/2025	01/01/1982 - 09/30/2013
10/01/2025 – 12/31/2032	10/01/2005 – 12/31/2012

Table G-15. Pollutant Loadings – Plant Bowen

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	27.56	408.74	78.96	3187.42	16.93	4241.43	49.87	5054.84
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	13.79	3.81	16.86	63.46	12.69	6.99	64.69	51.86
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**41.35**	**412.55**	**95.82**	**3,250.88**	**29.62**	**4,248.42**	**114.56**	**5,106.71**
Final Rule [b]								
FGD Wastewater	21.18	15.28	13.71	22.89	12.31	20.77	35.60	72.51
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**21.18**	**15.28**	**13.71**	**22.89**	**12.31**	**20.77**	**35.60**	**72.51**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2032).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2021 through 12/31/2032).

c - In estimating the historical pollutant loadings associated with Plant Bowen's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 2008 and 2011. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Bowen's first FGD system.

Table G-16. Pollutant Contributions from STORET Monitoring Data – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Etowah River	6499098	14310011 (34.15,-84.77) 1404130102 (34.15,-84.77) 1404130103 (34.15,-84.77) 1404130105 (34.12,-84.82)	As	--	9,993.11
			Cd	--	1,279.89
			Cu	--	5,103.32
			Ni	--	2,909.40
			Pb	--	2,631.57
			Tl	--	5,004.55
			Zn	--	7,666.84
			TOC	3,531.41	--
			TSS	8,775.41	--
Euharlee Creek	6497752	1404140704 (34.13,-84.94) 1404140701 (34.12,-84.95)	Pb	--	1,480.69
			TOC	6,734.53	--
			TSS	16,323.08	--
Two Run Creek	6497374	14340201 (34.22,-84.97)	As	--	693.96
			Cd	--	86.75
			Cu	--	346.98
			Ni	--	173.49
			Pb	--	138.79
			Tl	--	346.98
			Zn	--	693.96
			TOC	7,996.03	--
			TSS	12,847.83	--
Connesena Creek	6497306	1404150501 (34.24,-84.97)	TOC	4,191.06	--
			TSS	4,640.00	--
Toms Creek	6499778	1404160201 (34.26,-84.99)	TOC	9,465.83	--

Table G-16. Pollutant Contributions from STORET Monitoring Data – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Spring Creek	6499820	1404160301 (34.21,-85.07) 14340991 (34.21,-85.07)	As	--	541.04
			Cd	--	67.63
			Cu	--	270.52
			Ni	--	202.89
			Pb	--	54.10
			Tl	--	270.52
			Zn	--	270.52
			TOC	8,526.71	--
			TSS	14,434.78	--
Dykes Creek	6499782	1404160401 (34.25,-85.08) 1404160402 (34.26,-85.09)	TOC	2,350.53	--
			TSS	3,661.11	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-17. Organic Solids, Sands, and Silts/Fines Inputs – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Etowah River	6499098	1.77	0.44	8.33
Euharlee Creek	6497752	3.37	0.82	15.50
Two Run Creek	6497374	4.00	0.64	12.20
Connesena Creek	6497306	2.10	0.23	4.41
Toms Creek	6499778	4.73	*	*
Spring Creek	6499820	4.26	0.72	13.71
Dykes Creek	6499782	1.18	0.18	3.48
All Other Inflows [d]	N/A	3.06	0.51	9.61

Acronyms: N/A (Not Applicable).

* – No TSS results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-16.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-16.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-16.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-18. Sediment Transport Parameters – Etowah River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

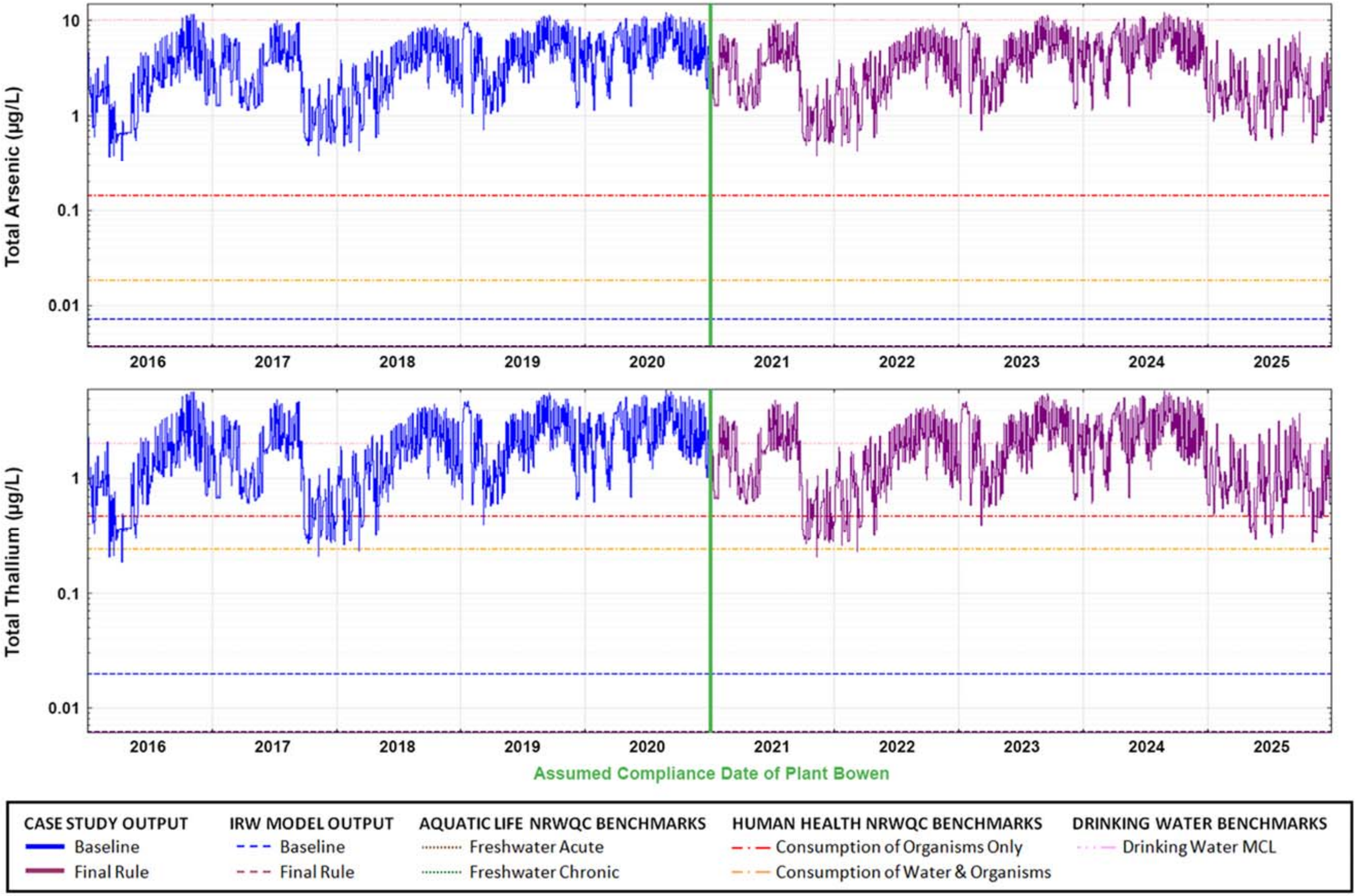


Figure G-6. Modeled Concentrations in Etowah River Water Column at Plant Bowen Immediate Receiving Water (Total Arsenic, Total Thallium)

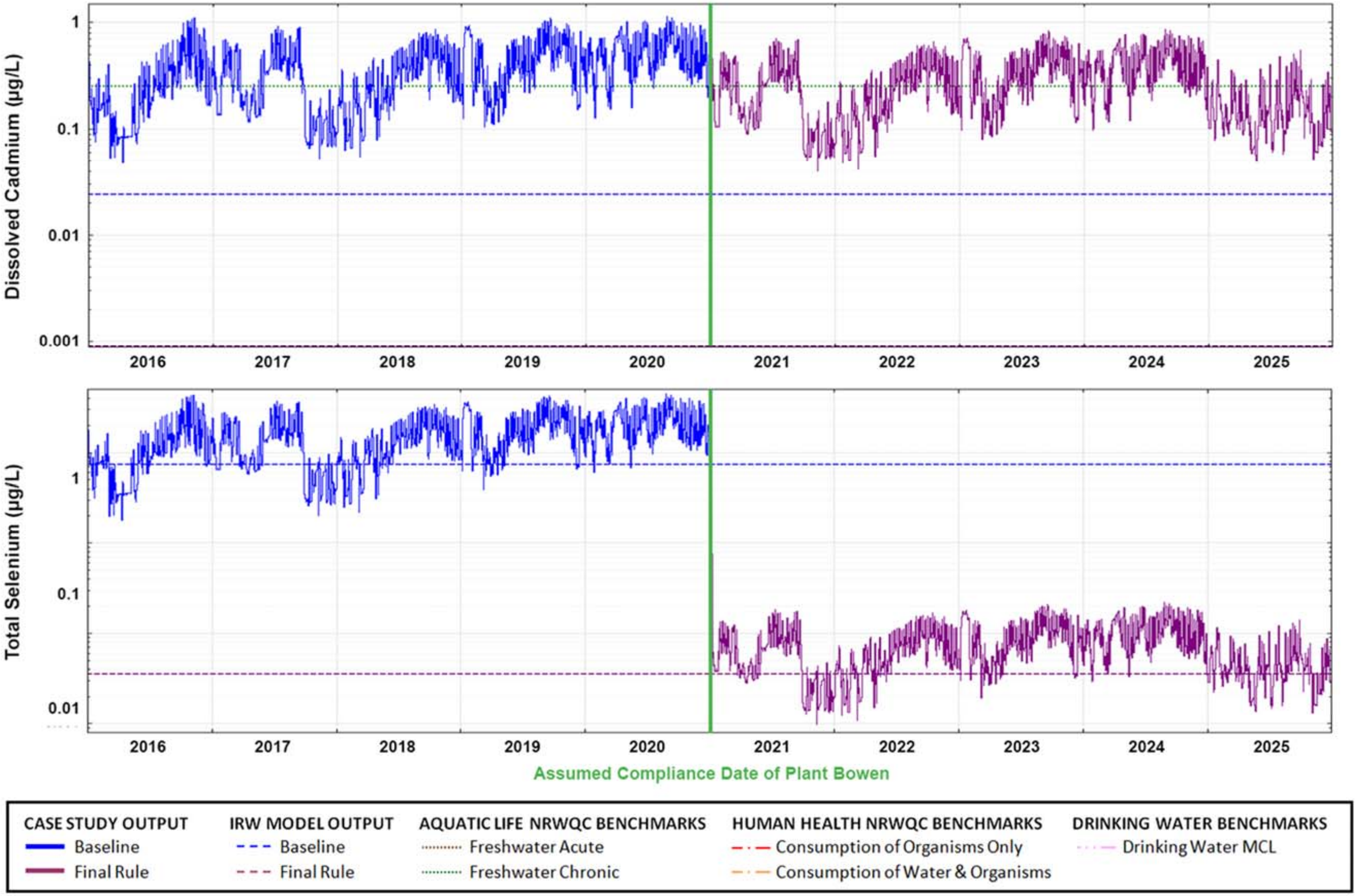


Figure G-7. Modeled Concentrations in Etowah River Water Column at Plant Bowen Immediate Receiving Water (Dissolved Cadmium, Total Selenium)

Table G-19. Average Water Column Concentrations Downstream of Plant Bowen at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
18	Etowah River / IRW	3.61	3.61	3.5521	0.5095	1.6421	0.6667	2.0928	1.4225	1.7789	3.7456
17	Etowah River	1.48	5.09	2.5373	0.3532	1.1484	0.5990	1.4836	1.0056	1.2664	2.5855
16	Etowah River	1.42	6.51	2.4625	0.3077	1.0395	0.4300	1.4091	0.9470	1.2178	2.2000
15	Etowah River	0.58	7.10	2.4351	0.2988	1.0163	0.4017	1.3887	0.9320	1.2025	2.1272
14	Etowah River	1.20	8.29	2.3959	0.2871	0.9850	0.3660	1.3601	0.9111	1.1809	2.0316
13	Etowah River	3.69	11.99	2.4026	0.3190	1.0550	0.4924	1.3918	0.9399	1.1944	2.3093
12	Etowah River	1.09	13.08	2.3771	0.3115	1.0354	0.4681	1.3739	0.9269	1.1805	2.2502
11	Etowah River	1.29	14.36	2.3582	0.2976	1.0034	0.4155	1.3538	0.9108	1.1678	2.1304
10	Etowah River	0.37	14.74	2.4742	0.3076	1.0550	0.4226	1.3632	0.8887	1.2246	2.2114
9	Etowah River	2.95	17.69	2.4181	0.3033	1.0363	0.4246	1.3339	0.8701	1.1972	2.1861
8	Etowah River	2.70	20.39	2.7308	0.5530	1.6659	1.3016	1.7191	1.1694	1.4387	4.2600
7	Etowah River	0.90	21.29	2.6890	0.5256	1.5999	1.1982	1.6785	1.1380	1.4116	4.0264
6	Etowah River	1.26	22.55	2.6458	0.4943	1.5239	1.0827	1.6334	1.1032	1.3821	3.7597
5	Etowah River	2.82	25.38	2.6189	0.4847	1.4972	1.0559	1.6113	1.0873	1.3658	3.6830
4	Etowah River	2.19	27.57	2.7324	0.6494	1.8852	1.7094	1.7807	1.2069	1.4685	5.0578
3	Etowah River	2.48	30.05	2.6886	0.6536	1.8873	1.7431	1.7639	1.1981	1.4495	5.1046
2	Etowah River	1.89	31.94	2.6892	0.6629	1.9009	1.7746	1.7696	1.2032	1.4526	5.1547
1	Etowah River / End	2.81	34.75	2.6554	0.6282	1.8203	1.6351	1.7279	1.1704	1.4270	4.8579

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-20. Average Water Column Concentrations Downstream of Plant Bowen Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
18	Etowah River/IRW	3.61	3.61	3.5450	0.3900	1.6162	0.6624	0.9963	0.0072	1.7515	2.2700
17	Etowah River	1.48	5.09	2.5322	0.2704	1.1302	0.5960	0.7063	0.0051	1.2469	1.5668
16	Etowah River	1.42	6.51	2.4576	0.2355	1.0231	0.4278	0.6709	0.0048	1.1990	1.3333
15	Etowah River	0.58	7.10	2.4302	0.2287	1.0003	0.3998	0.6611	0.0047	1.1840	1.2891
14	Etowah River	1.20	8.29	2.3911	0.2197	0.9695	0.3642	0.6475	0.0046	1.1626	1.2312
13	Etowah River	3.69	11.99	2.3978	0.2442	1.0384	0.4900	0.6627	0.0049	1.1760	1.4006
12	Etowah River	1.09	13.08	2.3723	0.2385	1.0191	0.4657	0.6542	0.0049	1.1624	1.3636
11	Etowah River	1.29	14.36	2.3534	0.2278	0.9876	0.4134	0.6446	0.0048	1.1499	1.2910
10	Etowah River	0.37	14.74	2.3036	0.2401	1.0396	0.4206	0.6706	0.0046	1.2071	1.4017
9	Etowah River	2.95	17.69	2.2517	0.2368	1.0212	0.4227	0.6560	0.0045	1.1801	1.3855
8	Etowah River	2.70	20.39	2.5377	0.4328	1.6418	1.2965	0.8479	0.0062	1.4182	2.7158
7	Etowah River	0.90	21.29	2.4979	0.4113	1.5768	1.1935	0.8280	0.0060	1.3915	2.5654
6	Etowah River	1.26	22.55	2.4579	0.3866	1.5019	1.0785	0.8056	0.0059	1.3624	2.3926
5	Etowah River	2.82	25.38	2.4331	0.3791	1.4753	1.0525	0.7947	0.0059	1.3462	2.3441
4	Etowah River	2.19	27.57	2.4324	0.5100	1.8580	1.7033	0.8992	0.0072	1.4481	3.2327
3	Etowah River	2.48	30.05	2.3930	0.5134	1.8602	1.7368	0.8908	0.0072	1.4295	3.2636
2	Etowah River	1.89	31.94	2.3926	0.5197	1.8754	1.7578	0.8939	0.0073	1.4325	3.2965
1	Etowah River/End	2.81	34.75	2.3624	0.4923	1.7955	1.6212	0.8728	0.0072	1.4072	3.1060

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-21. Total Miles of Etowah River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	**Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)**							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	34.75	34.75	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Cancer Adult Subsistence	3.61	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-22. Total Miles of Etowah River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	**Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)**							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Cancer Adult Subsistence	3.61	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – LICK CREEK & WHITE RIVER, IN

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Lick Creek and White River case study model.

Model Development & Input Variables

WASP Model Design. The Lick Creek and White River WASP model starts at the convergence of the West Fork White River (COMID 18471042) and the East Fork White River (COMID 18446060). The model extends approximately 52 miles downstream to just upstream of where the White River converges with the Wabash River (COMID 18471318). Petersburg Generating Station's immediate receiving water, Lick Creek (COMID 18471122) is approximately 3 miles downstream of the confluence of the East Fork and West Fork of the White River.

The Lick Creek and White River WASP model consists of 78 modeled segments. Segment IDs 1-19 represent the surface water of the White River with Segment ID 1 being the most downstream segment, Segment ID 19 being the West Fork White River, and Segment 18 being the East Fork White River. Lick Creek, the immediate receiving water, is represented as Segment 76 and intersects the White River between Segment 16 and Segment 17. The remaining model segments represent tributary surface waters (Segment IDs 20-25), the upper benthic layers (Segment IDs 26-50 & 77), and the lower benthic layers (Segment IDs 51-75 & 78). Figure G-8 illustrates the segmentation of the Etowah River WASP model.

The modeling period starts in 1986 (the year the last generating unit at Petersburg Generating Station began operating) and extends through 2034, covering a period of 49 years. Based on Petersburg Generating Station's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Lick Creek and White River WASP model. EPA scaled the White River stream gage data from Gage ID 033740000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area at the East Fork White River and West Fork White River modeling boundaries.

No USGS stream flow data were available on Lick Creek; therefore, EPA used stream flow data from one USGS stream gage on nearby Kessinger Ditch as a surrogate stream to represent inflow from Lick Creek. EPA scaled the Kessinger Ditch stream gage data from Gage ID 03360895 to produce a dataset with an average annual flow rate that closely approximates that of Lick Creek, as defined by NHDPlus Version 1.

Figure G-8 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-23 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-24 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

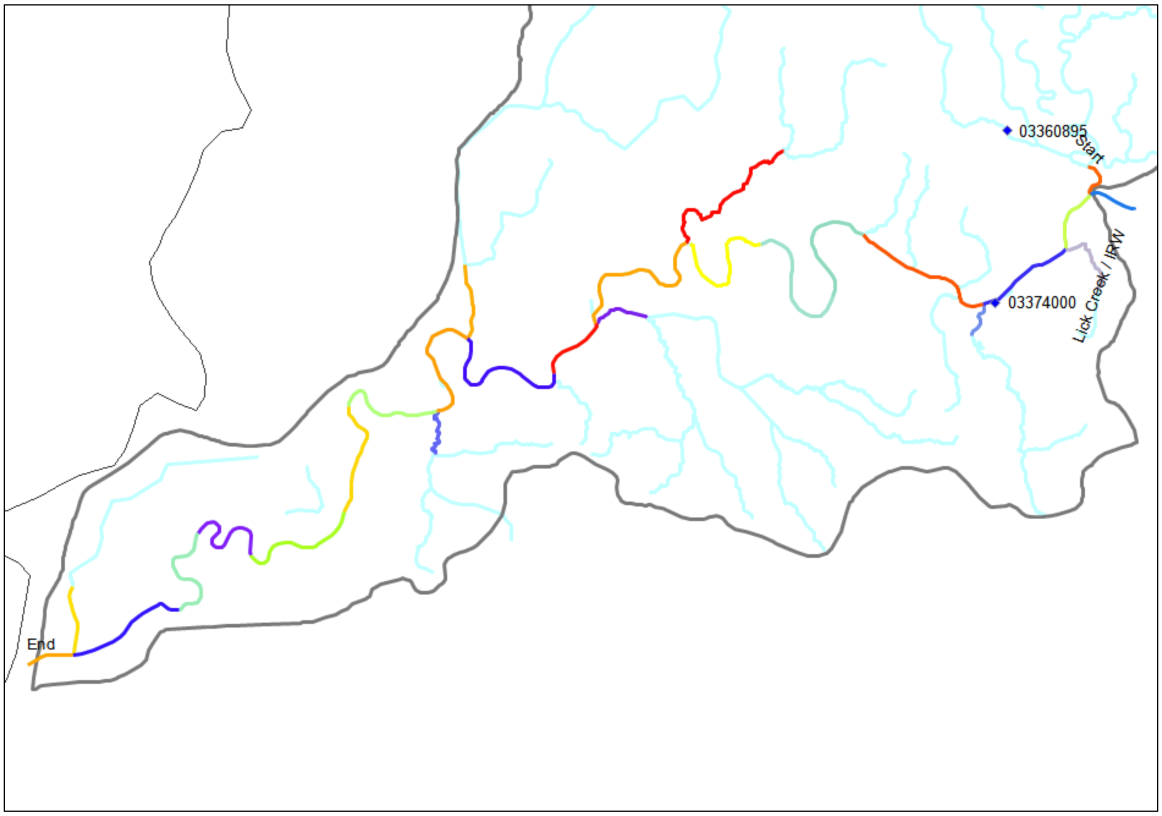


Figure G-8. Geographic Extent and Segmentation – Lick Creek & White River WASP Model

Model Input Variables. Table G-25 presents the pollutant loadings modeled from Petersburg Generating Station at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-26 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Lick Creek and White River case study model.

Table G-27 presents the pollutant contributions flowing into the Lick Creek and White River WASP model boundaries calculated using available STORET monitoring data.

Table G-28 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.99 mg/L, 4.70 mg/L, and 89.24 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-29 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 500 mg/L each.

Model Results

Case study modeling of Lick Creek and the White River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, copper, lead, selenium, and thallium. Figure G-9, Figure G-10, Figure G-11, and Figure G-12 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[9]

Case study modeling of Lick Creek and the White River revealed that average water column concentrations of four pollutants (arsenic, cadmium, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of wildlife and/or human health benchmarks. Table G-30 and Table G-31 illustrate the average modeled pollutant concentration in each water column segment downstream of Petersburg Generating Station (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-32 and Table G-33 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

---

[9] To improve clarity, Figure G-9, Figure G-10, Figure G-11, and Figure G-12 present the baseline water column concentrations leading up to the assumed compliance date of Petersburg Generating Station. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-23. USGS Stream Gages with Flow Data Used in Lick Creek and White River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
3374000	White River near Petersburg, IN	Full Record from 04/01/1928 - 12/11/2013	28,825	West Fork White River	13,923	0.483
3374000	White River near Petersburg, IN	Full Record from 04/01/1928 - 12/11/2013	28,825	East Fork White River	14,880	0.516
3360895	Kessinger Ditch near Monroe City, IN	Full Record from 10/01/1992 - 9/30/1998	64.27 [a]	Lick Creek	4.46 [b]	0.069 [c]

Acronyms: USGS (U.S. Geological Survey).

a – This value represents the mean annual flow (in cfs), as defined by NHDPlus Version 1, at gage ID 3360895.

b – This value represents the mean annual flow (in cfs), as defined by NHDPlus Version 1, of the Lick Creek immediate receiving water.

c – This value represents the scale factor determined by the dividend of the mean annual flow of at gage ID 3360895 and the Lick Creek immediate receiving water.

Table G-24. Stream Flow Data Periods – Lick Creek and White River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
White River (Gage ID 3374000)	
01/01/1986 - 12/11/2013	01/01/1986 - 12/11/2013
12/12/2013 – 12/31/2018	12/12/2005 – 12/31/2010
01/01/2002 - 12/11/2029	01/01/1986 - 12/11/2013
12/12/2029 – 12/31/2034	12/12/2005 – 12/31/2010
Kessinger Ditch (Gage ID 3360895)	
01/01/1986 - 9/30/1986	01/01/1998 - 09/30/1998
10/01/1986 - 9/30/1992	10/01/1992 - 09/30/1998
10/01/1992 - 9/30/1998	10/01/1992 - 09/30/1998
10/01/1998 - 9/30/2004	10/01/1992 - 09/30/1998
10/01/2004 - 9/30/2010	10/01/1992 - 09/30/1998
10/01/2010 - 9/30/2016	10/01/1992 - 09/30/1998
10/01/2016 - 12/31/2018	10/01/1992 - 12/31/1994
01/01/2002 - 9/30/2002	01/01/1998 - 09/30/1998
10/01/2002 - 9/30/2008	10/01/1992 - 09/30/1998
10/01/2008 - 9/30/2014	10/01/1992 - 09/30/1998
10/01/2014 - 9/30/2020	10/01/1992 - 09/30/1998
10/01/2020 - 9/30/2026	10/01/1992 - 09/30/1998
10/01/2026 - 9/30/2032	10/01/1992 - 09/30/1998
10/01/2032 - 12/31/2034	10/01/1992 - 12/31/1994

Table G-25. Pollutant Loadings – Petersburg Generating Station

Wastestream	Pollutant Loadings (g/day)							
	As	Cd	Cu	Ni	Pb	Se	Tl	Zn
Baseline [a]								
FGD Wastewater [c]	2.86	2.07	1.85	4.47	1.66	455.14	4.81	9.80
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	49.78	25.34	174.33	150.96	79.01	5.40	67.21	152.59
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**52.64**	**27.40**	**176.18**	**155.43**	**80.67**	**460.54**	**96.27**	**162.39**
Final Rule [b]								
FGD Wastewater	2.86	2.07	1.85	3.09	1.66	2.81	4.81	9.80
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**2.86**	**2.07**	**1.85**	**3.09**	**1.66**	**2.81**	**4.81**	**9.80**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1986 through 12/31/2034).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2034).

c – In estimating the historical pollutant loadings associated with Petersburg Generating Station's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 1977 and 1996. The pollutant loadings associated with FGD systems installed before the start of the modeling period (01/01/1986) are incorporated at the beginning or the model.

Table G-26. Pollutant Contributions from Non-Steam Electric Point Sources – Lick Creek and White River WASP Model

Facility Name	Model COMID	City	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Pride Mine S-321 [a]	18471050 (White River)	Monroe City	(38.54,-87.27)	Cu	9.23
				Ni	9.23
				Zn	9.23

a – EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

Table G-27. Pollutant Contributions from STORET Monitoring Data – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
West Fork White River	18471042	10947 (38.56,-87.24) 2719 (38.56,-87.24) WWL090-0028 (35.55,-87.24)	As	--	19,498.53
			Cu	--	74,468.84
			Ni	--	130,549.28
			Pb	--	37,390.75
			Zn	--	228,842.01
			TOC	5,104.00	--
			TSS	104,000.00	--
East Fork White River	18446060	2619 (38.54,-87.22)	As	--	17,881.15
			Cd	--	506.03
			Cu	--	35,794.47
			Ni	--	43,219.91
			Pb	--	20,429.79
			Zn	--	134,155.14
			TOC	3,475.43	--
			TSS	62,087.96	--

Table G-27. Pollutant Contributions from STORET Monitoring Data – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Conger Creek	18471078	2511 (38.52,-87.45) 2513 (38.51,-87.45) WWL100-0002 (38.51,-87.44)	Cu	--	1,045.39
			Pb	--	269.15
			Zn	--	2,736.70
			TOC	5,700.00	--
			TSS	95,200.00	--
Upper River Deshee	18471082	2512 (38.52,-87.53)	Pb	--	362.50
			Zn	--	1,100.85
			TOC	3,120.00	--
			TSS	18,600.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-28. Organic Solids, Sands, and Silts/Fines Inputs – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
West Fork White River	18471042	2.55	5.20	98.80
East Fork White River	18446060	1.74	3.10	58.98
Conger Creek	18471078	2.85	4.76	90.44
Upper River Deshee	18471082	1.56	0.93	17.67
All Other Inflows [d]	N/A	2.17	3.50	66.47

Acronyms: N/A (Not Applicable).

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-27.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-27.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-27.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-29. Sediment Transport Parameters – Lick Creek and White River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the 'TAUcritcoh' parameter.

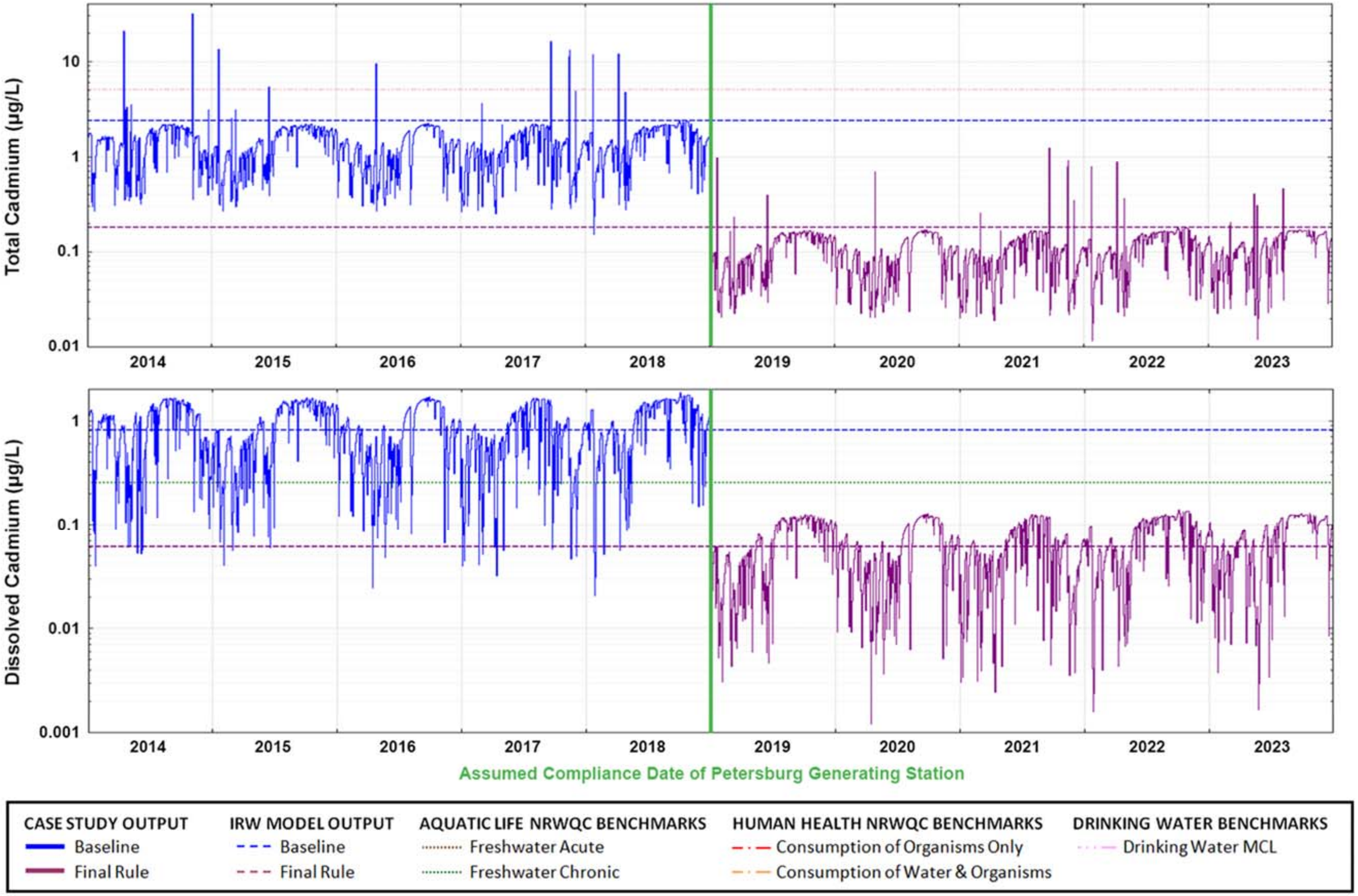


Figure G-9. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Cadmium, Dissolved Cadmium)

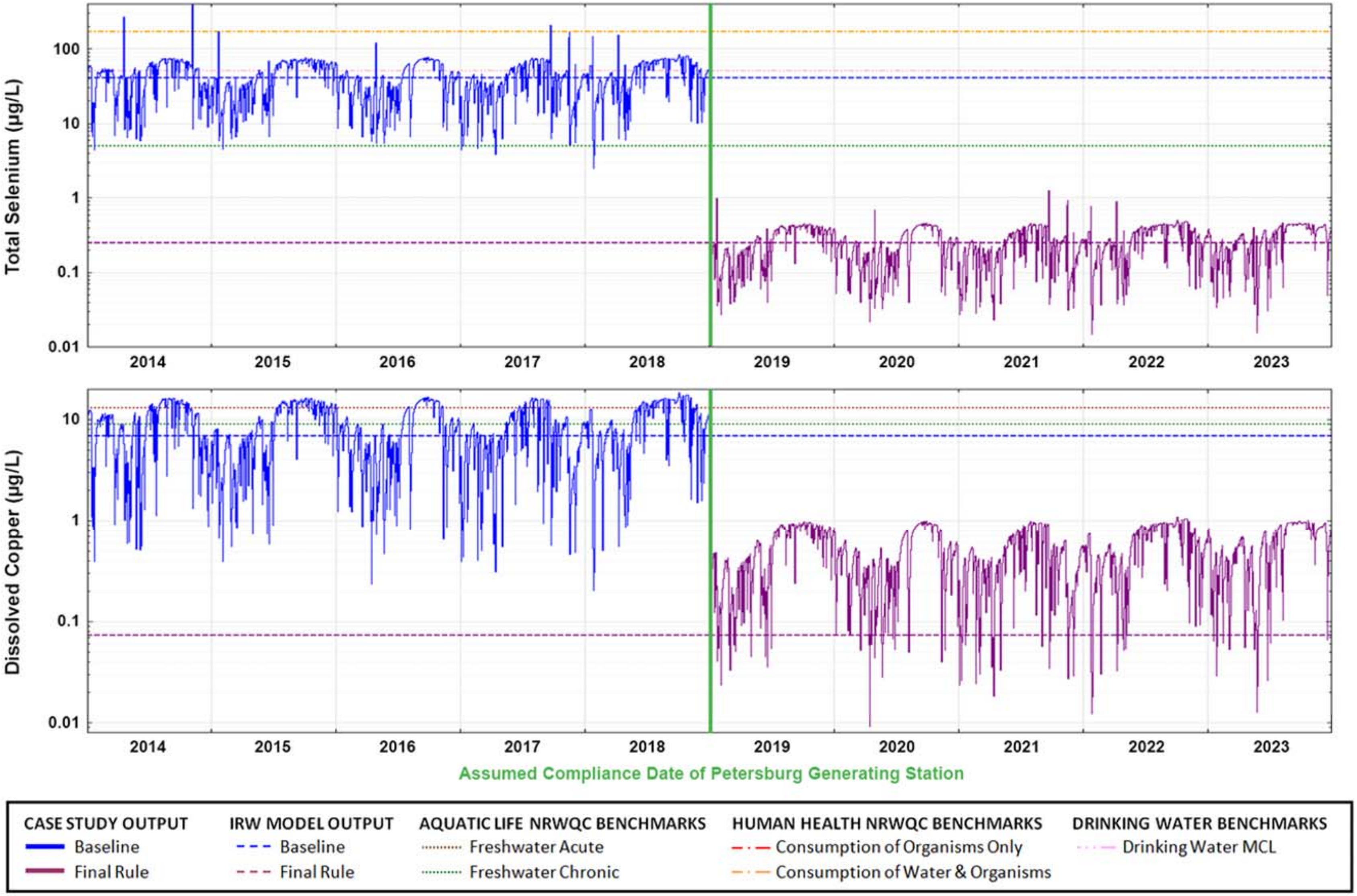


Figure G-10. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Selenium, Dissolved Copper)

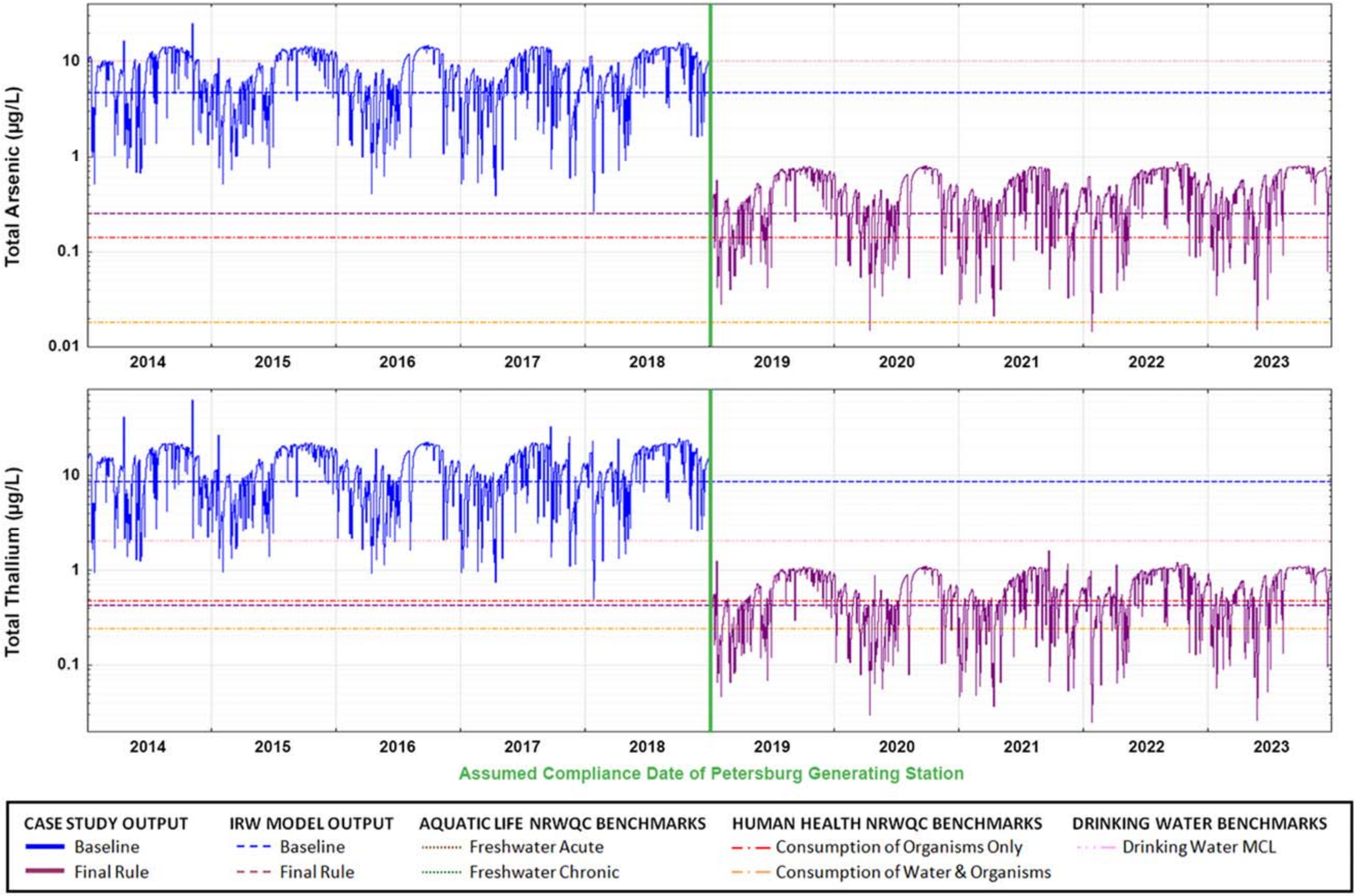


Figure G-11. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Arsenic, Total Thallium)

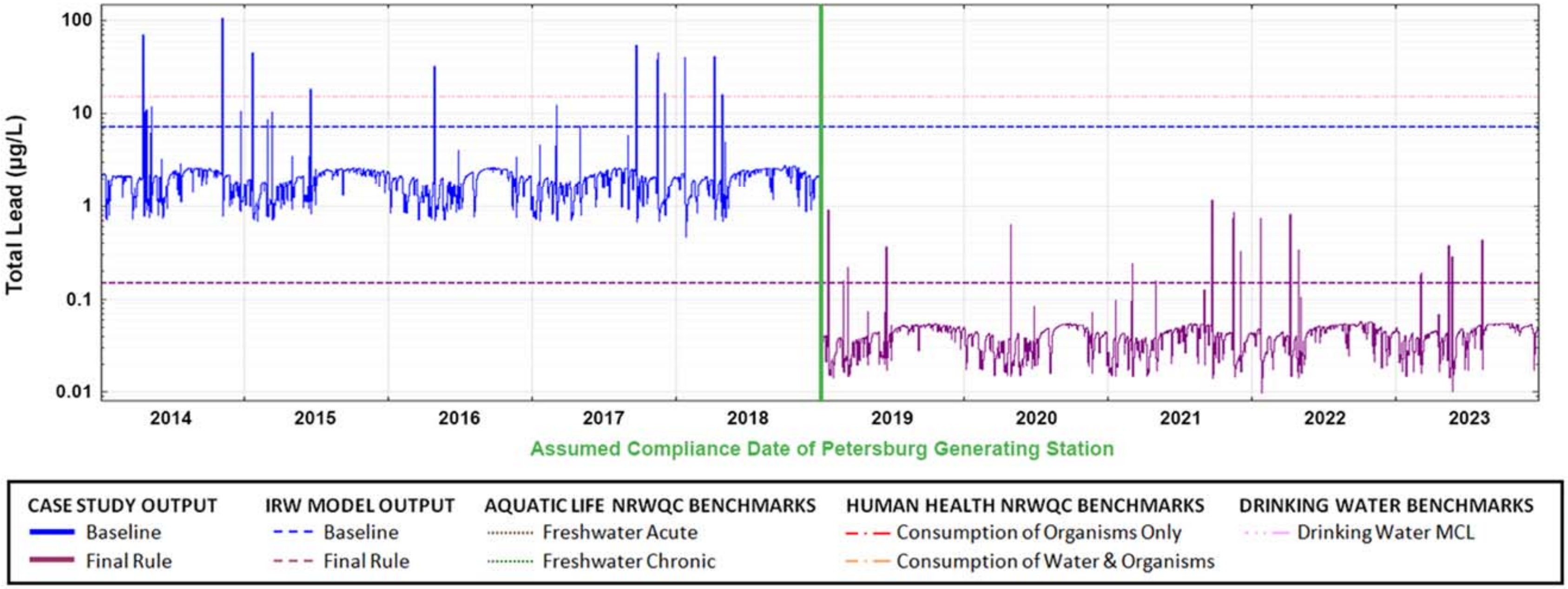


Figure G-12. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Lead)

Table G-30. Average Water Column Concentrations Downstream of Petersburg Generating Station at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
76	Lick Creek / IRW	1.82	1.82	7.8099	1.4260	12.1623	2.2256	17.0962	43.0318	12.0267	7.9902
16	White River	2.53	4.35	2.1741	0.0169	3.9202	1.4878	7.9745	0.0217	0.0053	11.0843
15	White River	3.64	7.99	1.9842	0.0130	3.1428	1.0360	6.8940	0.0176	0.0046	8.3919
14	White River	3.39	11.38	1.8988	0.0108	2.7187	0.7764	6.3429	0.0156	0.0042	6.8805
13	White River	3.39	14.77	1.8498	0.0096	2.4878	0.6399	6.0350	0.0147	0.0041	6.0692
12	White River	3.39	18.17	1.8294	0.0090	2.3642	0.5643	5.8819	0.0143	0.0040	5.6257
11	White River	4.43	22.59	1.9038	0.0165	3.4944	1.4571	6.9169	0.0290	0.0056	10.2181
10	White River	1.78	24.37	1.8990	0.0197	4.0254	1.8743	7.2995	0.0333	0.0060	12.3741
9	White River	3.88	28.26	1.9106	0.0187	3.8692	1.7404	7.2015	0.0325	0.0059	11.7421
8	White River	3.22	31.48	2.8165	0.0657	11.7204	7.8841	15.3397	0.0872	0.0119	44.4205
7	White River	2.97	34.45	2.9378	0.0572	10.4477	6.5913	14.7231	0.0813	0.0119	38.2040
6	White River	2.97	37.42	2.6471	0.0521	9.4987	6.0681	13.2868	0.0724	0.0105	34.9036
5	White River	2.97	40.39	2.5550	0.0494	9.0307	5.7329	12.7097	0.0687	0.0101	33.1043
4	White River	2.97	43.36	2.4986	0.0474	8.6786	5.4787	12.3055	0.0661	0.0098	31.7293
3	White River	2.97	46.33	2.4569	0.0457	8.3900	5.2645	11.9847	0.0640	0.0095	30.5571
2	White River	2.97	49.30	2.4265	0.0443	8.1520	5.0746	11.7264	0.0623	0.0093	29.5784
1	White River / End	1.17	50.47	2.4061	0.0455	8.3071	5.2341	11.7954	0.0646	0.0095	30.2942

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-31. Average Water Column Concentrations Downstream of Petersburg Generating Station Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
76	Lick Creek / IRW	1.82	1.82	0.4306	0.1093	0.7301	0.0469	1.2803	0.2617	0.5995	0.8859
16	White River	2.53	4.35	2.1711	0.0159	3.9132	1.4855	7.9669	0.0001	0.0003	11.0790
15	White River	3.64	7.99	1.9815	0.0123	3.1377	1.0346	6.8877	0.0001	0.0002	8.3882
14	White River	3.39	11.38	1.8962	0.0103	2.7144	0.7754	6.3372	0.0001	0.0002	6.8771
13	White River	3.39	14.77	1.8473	0.0092	2.4838	0.6392	6.0295	0.0001	0.0002	6.0663
12	White River	3.39	18.17	1.8269	0.0086	2.3604	0.5636	5.8767	0.0001	0.0002	5.6229
11	White River	4.43	22.59	1.9010	0.0156	3.4867	1.4556	6.9088	0.0054	0.0006	10.2123
10	White River	1.78	24.37	1.8961	0.0185	4.0157	1.8722	7.2905	0.0064	0.0007	12.3665
9	White River	3.88	28.26	1.9077	0.0176	3.8599	1.7386	7.1928	0.0063	0.0007	11.7352
8	White River	3.22	31.48	2.8120	0.0608	11.6855	7.8735	15.3177	0.0137	0.0013	44.3905
7	White River	2.97	34.45	2.9331	0.0530	10.4162	6.5828	14.7021	0.0129	0.0013	38.1791
6	White River	2.97	37.42	2.6430	0.0484	9.4716	6.0604	13.2683	0.0117	0.0011	34.8812
5	White River	2.97	40.39	2.5510	0.0459	9.0055	5.7261	12.6922	0.0110	0.0011	33.0831
4	White River	2.97	43.36	2.4948	0.0440	8.6545	5.4724	12.2886	0.0106	0.0011	31.7090
3	White River	2.97	46.33	2.4531	0.0425	8.3679	5.2585	11.9682	0.0102	0.0010	30.5324
2	White River	2.97	49.30	2.4228	0.0411	8.1243	5.0689	11.7104	0.0099	0.0010	29.5539
1	White River / End	1.17	50.47	2.4024	0.0421	8.2818	5.2278	11.7788	0.0100	0.0010	30.2683

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-32. Total Miles of Lick Creek and White River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	1.82	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	1.82	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	1.82	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Cancer Adult Subsistence	1.82	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-33. Total Miles of Lick Creek and White River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – OHIO RIVER, PA/WV/OH

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Ohio River case study model.

Model Development & Input Variables

WASP Model Design. The Ohio River WASP model starts approximately 12 miles upstream of the first steam electric power plant immediate receiving water at COMID 3821033. There are two coal-fired plants modeled in the Ohio River WASP simulation. The upstream plant, Bruce Mansfield plant, discharges to the Ohio River (COMID 3821113) from a large surface impoundment named Little Blue Run. Approximately 13 miles downstream of this immediate receiving water is the W.H. Sammis plant immediate receiving water (COMID 3821343). Ending just upstream of the Cardinal Plant immediate receiving water, the entire Ohio River WASP model is 49 miles long.

The Ohio River WASP model consists of 84 modeled segments. Segment IDs 1-17 represent the surface water of the Ohio River with Segment ID 1 being the most downstream segment and Segment ID 17 being the most upstream segment. The immediate receiving waters of the Bruce Mansfield plant and the W.H. Sammis plant are located at Segment ID 13 and 9, respectively. The remaining model segments represent tributary surface waters (Segment IDs 18-28), the upper benthic layers (Segment IDs 29-56), and the lower benthic layers (Segment IDs 57-84). Figure G-13 illustrates the segmentation of the Ohio River WASP model.

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that Bruce Mansfield and W.H. Sammis plants will achieve the limitations under the final rule by 2020 and 2021, respectively. EPA focused the assessment of the improvements under the final rule on the period after the 2021 assumed compliance date for W.H. Sammis Plant.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Ohio River WASP model. EPA scaled the Ohio River stream gage data from Gage ID 03086000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from three USGS stream gages to represent inflow from three tributaries to the Ohio River WASP modeling area, as described below:

- EPA scaled the Little Beaver Creek stream gage data from Gage ID 03109500 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.
- EPA scaled the Yellow Creek stream gage data from Gage ID 03110000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

- EPA scaled the Raccoon Creek stream gage data from Gage ID 03108000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-13 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-34 presents additional information about the four stream gages and the time period covered in the stream flow data record at each. Table G-35 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

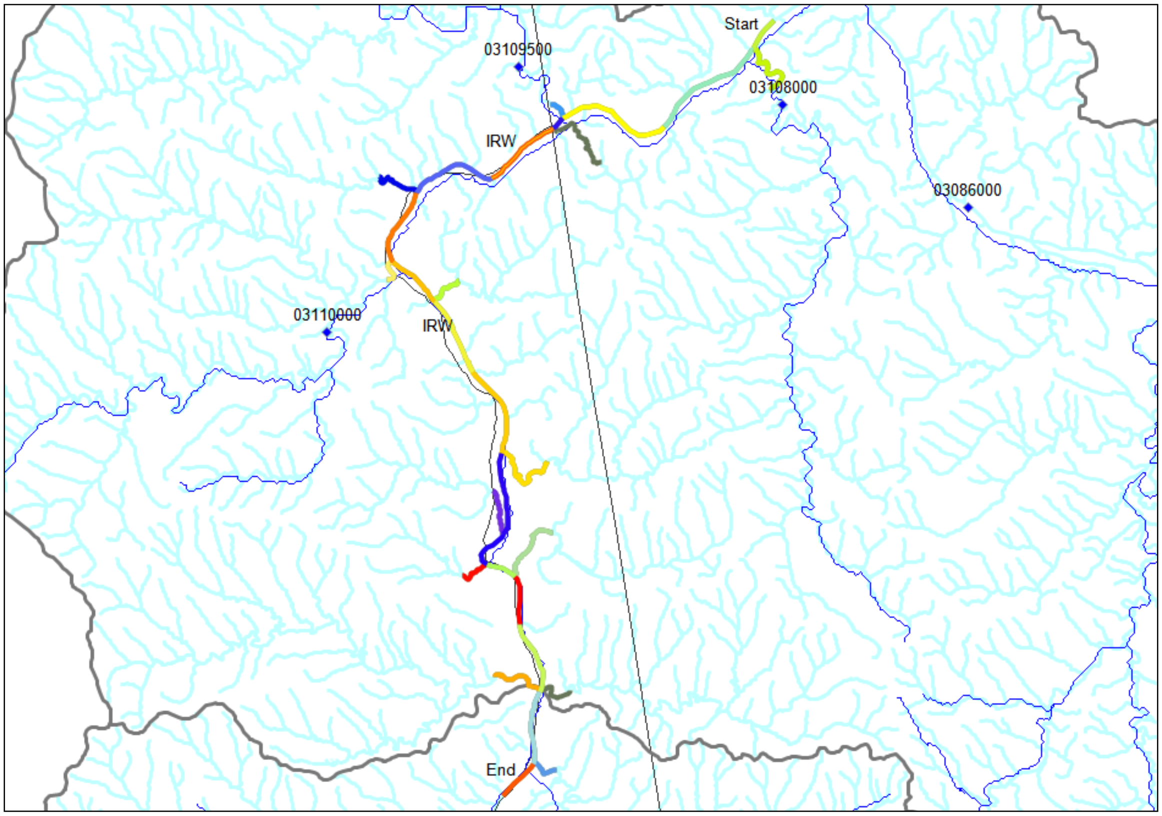


Figure G-13. Geographic Extent and Segmentation – Ohio River WASP Model

Model Input Variables. Table G-36 presents the pollutant loadings modeled from Bruce Mansfield plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. Table G-37 presents the pollutant loadings modeled from W.H. Sammis plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-38 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Ohio River case study model.

Table G-39 presents the pollutant contributions flowing into the Ohio River WASP model boundaries calculated using available STORET monitoring data.

Table G-40 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.36 mg/L, 0.57 mg/L, and 10.85 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-41 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 100 mg/L each.

Model Results

Case study modeling of the Ohio River revealed water quality benchmark exceedances in the W.H. Sammis plant immediate receiving water and/or in downstream segments for arsenic and lead. Figure G-14 illustrates the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[10]

Case study modeling of the Ohio River revealed that average water column concentrations of thallium in the W.H. Sammis plant immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Figure G-15 illustrates the water concentration outputs for thallium in the W.H. Sammis plant immediate receiving water before and after the assumed compliance date for the final rule. Table G-42 and Table G-43 illustrate the average modeled pollutant concentration in each water column segment downstream of Bruce Mansfield plant (including the Bruce Mansfield plant immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-44 and Table G-45 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

---

[10] To improve clarity, Figure G-14 and Figure G-15 present the baseline water column concentrations leading up to the assumed compliance date of Bruce Mansfield plant and W.H. Sammis plant. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-34. USGS Stream Gages with Flow Data Used in Ohio River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
3086000	Ohio River near Sewickley, PA	Full Record from 01/01/1982 - 09/30/2013	50,475	Ohio River	58,947	1.170
3109500	Little Beaver Creek	Full Record from 01/01/1982 - 09/30/2013	1,286	Little Beaver Creek	1,345	1.046
3110000	Yellow Creek	Full Record from 01/01/1982 - 09/30/2013	382	Yellow Creek	612	1.600
3108000	Raccoon Creek	Full Record from 01/01/1982 - 09/30/2013	464	Raccoon Creek	477	1.028

Acronyms: USGS (U.S. Geological Survey).

Table G-35. Stream Flow Data Periods – Ohio River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Ohio River (Gage ID 3086000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Little Beaver Creek (Gage ID 3109500)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Yellow Creek (Gage ID 3110000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Raccoon Creek (Gage ID 3108000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012

Table G-36. Pollutant Loadings – Bruce Mansfield Plant

Wastestream	**Pollutant Loadings (g/day)**							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	29.09	431.42	83.34	3,364.27	17.87	4,476.75	52.63	5,335.30
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	50.21	13.86	61.38	231.01	46.21	25.46	235.52	188.79
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**79.30**	**445.28**	**144.72**	**3,595.28**	**64.08**	**4,502.21**	**288.15**	**5,524.09**
Final Rule [b]								
FGD Wastewater	22.35	16.13	14.48	24.16	12.99	21.93	37.58	76.53
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**22.35**	**16.13**	**14.48**	**24.16**	**12.99**	**21.93**	**37.58**	**76.53**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2021 through 12/31/2036).

Table G-37. Pollutant Loadings – W.H. Sammis Plant

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	5.82	4.20	3.77	9.09	3.38	925.46	9.78	19.92
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	353.61	97.59	432.31	1,626.99	325.44	179.30	1,658.76	1,329.69
Combustion Residual Leachate	2.34	0.62	0.46	2.83	-	6.75	0.07	12.82
Total	**361.77**	**102.41**	**436.54**	**1,638.91**	**328.82**	**1,111.51**	**1,668.61**	**1,362.43**
Final Rule [b]								
FGD Wastewater	5.82	4.20	3.77	6.29	3.38	5.71	9.78	19.92
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	2.34	0.62	0.46	2.83	-	6.75	0.07	12.82
Total	**8.16**	**4.82**	**4.23**	**9.12**	**3.38**	**12.46**	**9.85**	**32.74**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled from 01/01/1982 through 12/31/2036.

b – The final rule pollutant loadings are modeled from 01/01/2021 through 12/31/2036.

c - In estimating the historical pollutant loadings associated with W.H. Sammis plant’s three FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between March and May 2010. EPA did not model any FGD wastewater pollutant loadings before the installation of W.H. Sammis plant’s first FGD system.

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
City of Chester [a]	3821165 (Ohio River)	Chester, WV	(40.61,-80.57)	Cu	32.63
				Pb	24.40
				Zn	87.47
East Liverpool WWTP [a]	3821167 (Ohio River)	East Liverpool, OH	(40.62,-80.58)	Cu	13.96
				Zn	375.00
Town of Newell [a]	3821149 (Ohio River)	Newell, WV	(40.62,-80.61)	Cu	3.92
				Pb	1.49
				Zn	6.80
Wellsville STP [a]	3821273 (Ohio River)	Wellsville, OH	(40.60,-80.66)	Cu	48.94
				Pb	2.64
				Zn	134.64
Hancock County PSD [a]	3821301 (Ohio River)	New Cumberland, WV	(40.58,-80.66)	Cu	4.69
				Pb	1.57
Hancock County PSD WWTP [a]	3821355 (Ohio River)	New Cumberland, WV	(40.51,-80.62)	Cu	6.05
				Pb	0.87
				Zn	45.16
City of New Cumberland [a]	3824147 (Ohio River)	New Cumberland, WV	(40.49,-80.60)	Cu	6.85
				Pb	0.48
				Zn	18.25
Toronto WWTP [a]	3824175 (Ohio River)	Toronto, OH	(40.50,-80.61)	Zn	150.75

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
City of Weirton [a]	3824185 (Ohio River)	Weirton, WV	(40.38,-80.61)	As	12.03
				Cd	15.49
				Cu	149.90
				Ni	101.78
				Pb	60.88
				Zn	1,040.57
City of Steubenville, Wastewater Treatment Plant [a]	3824195 (Ohio River)	Steubenville, OH	(40.36,-80.61)	Cu	116.49
				Zn	560.18
City of Follansbee [a]	3824211 (Ohio River)	Follansbee, WV	(40.32,-80.60)	As	1.47
				Cd	14.91
				Cu	183.20
				Ni	24.38
				Pb	14.08
				Zn	392.83
Mingo Junction WTP [a]	19453097 (Cross Creek)	Mingo Junction, OH	(40.31,-80.61)	Cu	35.80
City of Wellsburg [a]	19453103 (Ohio River)	Wellsburg, WV	(40.27,80.62)	As	436.14
				Cd	31.90
				Cu	1,159.12
				Ni	2.26
				Pb	0.24
				Zn	20.64
CBS Beaver Groundwater Remediation [b]	3821033 (Two Mile Run)	Beaver, PA	(40.69,-80.31)	Zn	1,772.26

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Horsehead Corp Monaca Smelter [b]	3821033 (Ohio River)	Monaca, PA	(40.67,-80.34)	As	16.34
				Cd	66.43
				Cu	190.61
				Pb	63.10
				Se	12.39
				Zn	1,259.91
BASF Monaca Plant [b]	3821039 (Ohio River)	Monaca, PA	(40.66,-80.35)	Zn	257.26
Lyondell Chem Beaver Valley [b]	3821057 (Ohio River)	Monaca, PA	(40.66,-80.36)	Cu	72.06
				Ni	64.22
				Pb	36.23
				Zn	83.68
Allegheny Technologies Midland Plant [b]	3821109 (Ohio River)	Midland, PA	(40.64,-80.47)	Ni	441.29
Heritage-WTI Inc. [b]	3821157 (Ohio River)	East Liverpool, OH	(40.63,-80.55)	As	0.84
				Cd	0.57
				Cu	5.42
				Ni	2.69
				Pb	5.00
				Zn	48.85
Homer Laughlin China Co [b]	3821149 (Ohio River)	Newell, WV	(40.62,-80.61)	Cd	1.13
				Ni	7.71
				Pb	0.99
				Se	1.45
				Zn	1,101.25

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Ergon West Virginia Inc [b]	3821189 (Ohio River)	Newell, WV	(40.61,-80.63)	As	304.33
				Cu	7.99
				Zn	13.55
Marsh Bellofram Corporation [b]	3821301 (Ohio River)	Newell, WV	(40.58,-80.65)	Cu	2.24
				Ni	0.30
				Pb	0.15
				Zn	1.03
Mountaineer Park Incorporated [b]	3821301 (Ohio River)	Chester, WV	(40.57,-80.65)	Cu	2,669.15
				Pb	2,358.45
				Zn	36,768.62
Titanium Metals Corp [b]	3824175 (Ohio River)	Toronto, OH	(40.45,-80.61)	Cu	0.09
				Zn	1.63
Mittal Steel USA Weirton Inc [b]	3824175 (Ohio River)	Weirton, WV	(40.43,-80.60)	Cu	385.18
				Ni	63.48
				Pb	182.75
				Se	252.54
				Zn	1,935.80
Severstal Wheeling Inc - Steubenville Plant [b]	3824211 (Ohio River)	Steubenville, OH	(40.35,-80.61)	Zn	1,042.47
Severstal Wheeling Inc - Follansbee [b]	3824211 (Ohio River)	Follansbee, WV	(40.35,-80.61)	As	250.85
				Cd	0.01
				Cu	201.14
				Ni	0.06
				Pb	0.33
				Se	3,364.80
				Zn	460.56

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
RG Steel Wheeling LLC Beech Bottom Plant [b]	3824211 (Ohio River)	Beech Bottom, WV	(40.35,-80.61)	As	2.22
				Cu	3.57
				Ni	68.46
				Pb	2.86
				Se	5.92
				Zn	229.79
Koppers Follansbee Tar Plant [b]	3824211 (Ohio River)	Follansbee, WV	(40.34,-80.61)	As	11.94
				Se	2.33
				Zn	15.42
Wheeling-Nisshin [b]	3824211 (Ohio River)	Follansbee, WV	(40.33,-80.60)	Pb	5.06
				Zn	55.43
Wheeling Pittsburgh Steel Steubenville South Mingo [b]	3824211 (Ohio River)	Mingo Junction, OH	(40.32,-80.60)	Cu	0.73
				Zn	9.33
NGC Industries LLC A Subsidiary [c]	3821097 (Ohio River)	Shippingport, PA	(40.63,-80.42)	Pb	0.62
Whemco-Steel Castings Inc [c]	3821109 (Ohio River)	Midland, PA	(40.63,-80.45)	Ni	0.76
Mittal Steel USA Weirton Inc [c]	3824175 (Ohio River)	Weirton, WV	(40.42,-80.60)	Cu	518.22
				Ni	134.22
				Pb	334.29
				Zn	1,923.75

a – EPA identified that this publicly operated treatment works (POTW) facility is a direct discharger with 2011 DMR loadings.

b - EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

c - EPA identified that this facility is a direct discharger with 2011 TRI loadings.

Table G-39. Pollutant Contributions from STORET Monitoring Data – Ohio River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Ohio River	3821033	WQN0902 (40.53,-80.19)	Cu	--	175,758.13
			Ni	--	126,664.12
			Pb	--	79,371.40
			Zn	--	1,247,520.00
			TOC	2,426.67	--
			TSS	21,434.78	--
Raccoon Creek	3821043	WQN0903 (40.63,-80.34)	Cu	--	376.43
			Ni	--	1,663.34
			Pb	--	525.00
			Zn	--	13,504.33
			TOC	2,232.63	--
			TSS	16,893.62	--
Buffalo Creek	19453099	O-092-0004 (40.26,-80.55) O-092-0003 (40.25,-80.59) O-092-0001 (40.24,-80.59) O-092-0012 (40.23,-80.52) O-092-0006 (40.20,-80.60) O-092-0002 (40.20,-80.56) O-092-0007 (40.19,-80.55) O-092-0008 (40.16,-80.53)	TSS	10,333.33	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-40. Organic Solids, Sands, and Silts/Fines Inputs – Ohio River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Ohio River	3821033	1.21	1.07	20.36
Raccoon Creek	3821043	1.12	0.84	16.05
Buffalo Creek	3821043	*	0.52 [e]	9.82 [e]
All Other Inflows [d]	N/A	1.16	0.81	15.41

Acronyms: N/A (Not Applicable).

* – No TOC results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-39.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-39.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-39.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

e – These concentrations were calculated using the ‘All Other Inflows’ concentration.

Table G-41. Sediment Transport Parameters – Ohio River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

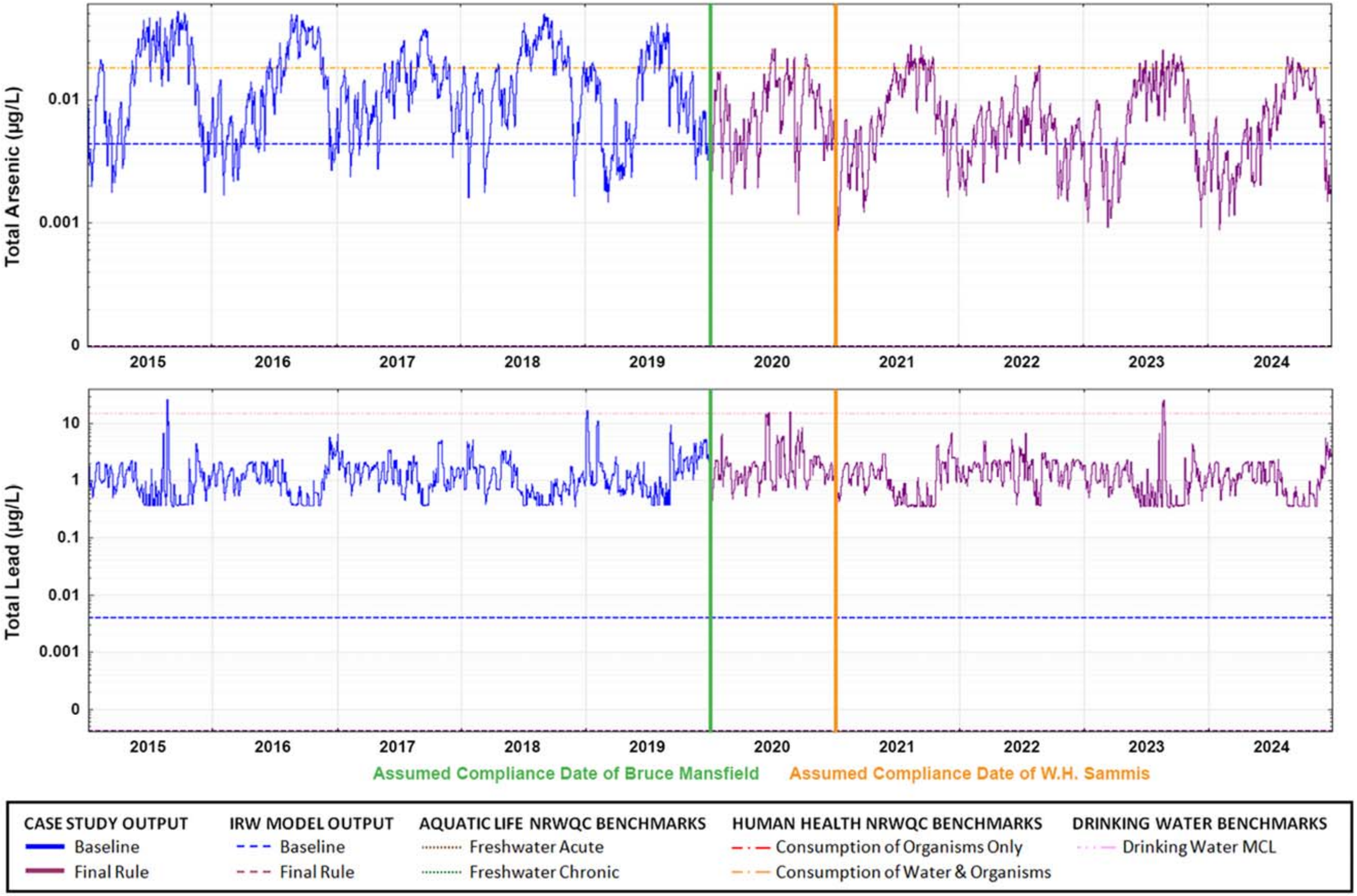


Figure G-14. Modeled Concentrations in Ohio River Water Column at W.H. Sammis Plant Immediate Receiving Water (Total Arsenic, Total Lead)

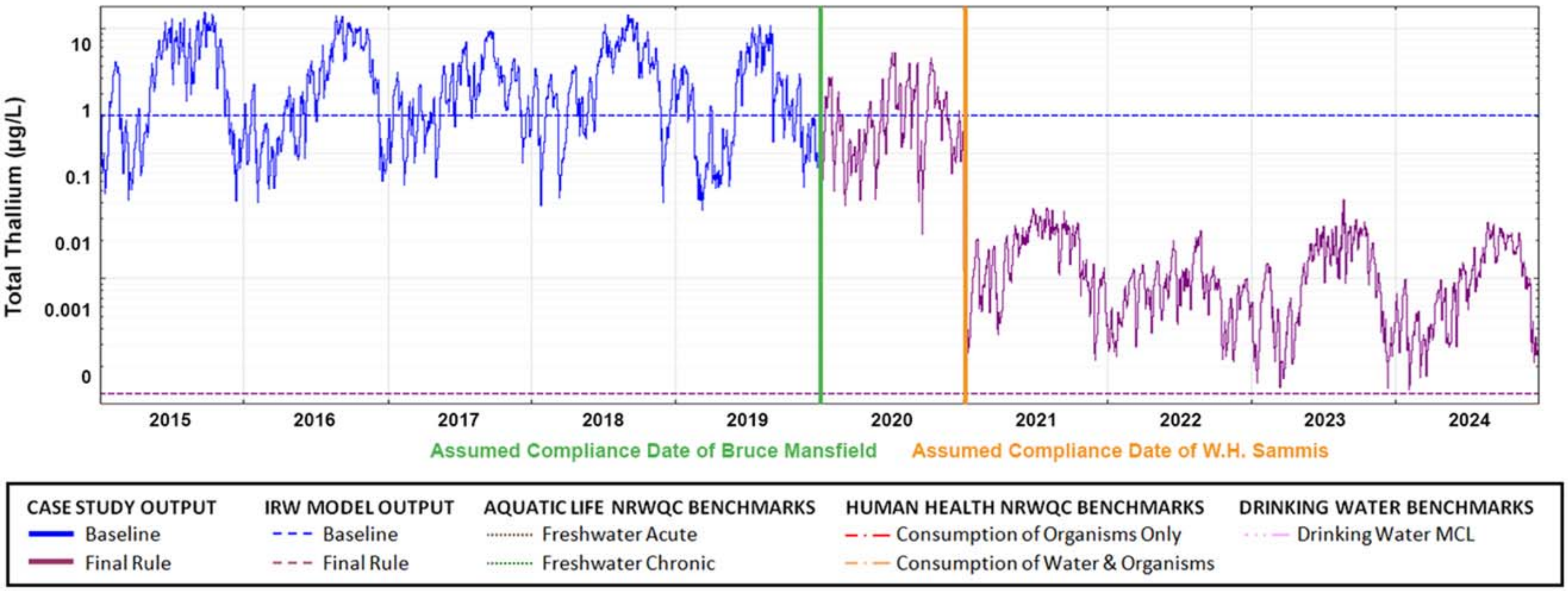


Figure G-15. Modeled Concentrations in Ohio River Water Column at W.H. Sammis Plant Immediate Receiving Water (Total Thallium)

Table G-42. Average Water Column Concentrations Downstream of Bruce Mansfield Plant at Baseline

Segment Data				**Average Total Water Column Concentration over Modeling Period (µg/L)[a]**							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
13	Ohio River / Mansfield IRW	3.31	3.31	0.0020	0.0082	2.6416	0.6965	2.4564	0.0867	0.0058	15.5174
12	Ohio River	3.71	7.02	0.0083	0.0094	2.8186	0.8586	2.4577	0.0883	0.0057	17.6384
11	Ohio River	3.26	10.29	0.0083	0.0111	3.1227	0.9913	2.5719	0.0939	0.0059	20.0130
10	Ohio River	2.40	12.69	0.0093	0.0145	3.9276	1.4032	3.0175	0.1118	0.0067	26.6303
9	Ohio River / Sammis IRW	3.43	16.12	0.0158	0.0165	3.8615	1.4652	2.8946	0.1285	0.0394	26.8808
8	Ohio River	3.88	20.00	0.0165	0.0147	3.6063	1.1281	2.9481	0.1275	0.0401	23.2738
7	Ohio River	3.45	23.45	0.0157	0.0127	3.2123	0.9050	2.7435	0.1225	0.0380	19.8669
6	Ohio River	1.76	25.21	0.0155	0.0121	3.0856	0.8119	2.6984	0.1200	0.0375	18.6383
5	Ohio River	1.33	26.54	0.0157	0.0120	3.0046	0.7527	2.6689	0.1183	0.0372	17.8563
4	Ohio River	2.02	28.56	0.0156	0.0117	2.9513	0.7228	2.6419	0.1171	0.0369	17.3905
3	Ohio River	3.08	31.64	0.0209	0.0182	3.1309	0.8725	2.7427	0.1877	0.0371	19.0188
2	Ohio River	3.06	34.70	0.0202	0.0183	3.0956	0.9017	2.6655	0.1836	0.0360	19.1172
1	Ohio River / End	1.85	36.55	0.0285	0.0195	3.1928	0.9529	2.6998	0.1859	0.0362	19.7848

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-43. Average Water Column Concentrations Downstream of Bruce Mansfield Plant Under Final Rule

Segment Data				**Average Total Water Column Concentration over Modeling Period (μg/L)[a]**							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
13	Ohio River / Mansfield IRW	3.31	3.31	0.0008	0.0011	2.6393	0.6959	2.3863	0.0006	0.0008	15.4307
12	Ohio River	3.71	7.02	0.0072	0.0013	2.8161	0.8577	2.3875	0.0007	0.0007	17.5355
11	Ohio River	3.26	10.29	0.0071	0.0016	3.1199	0.9900	2.4986	0.0012	0.0008	19.8906
10	Ohio River	2.40	12.69	0.0080	0.0020	3.9241	1.4013	2.9313	0.0014	0.0009	26.4824
9	Ohio River / Sammis IRW	3.43	16.12	0.0076	0.0021	3.8493	1.4561	2.7809	0.0016	0.0010	26.7054
8	Ohio River	3.88	20.00	0.0080	0.0019	3.5949	1.1213	2.8337	0.0016	0.0011	23.1208
7	Ohio River	3.45	23.45	0.0076	0.0016	3.2019	0.8995	2.6370	0.0063	0.0010	19.7342
6	Ohio River	1.76	25.21	0.0075	0.0016	3.0756	0.8069	2.5936	0.0062	0.0010	18.5127
5	Ohio River	1.33	26.54	0.0077	0.0018	2.9948	0.7481	2.5653	0.0061	0.0010	17.7351
4	Ohio River	2.02	28.56	0.0077	0.0018	2.9417	0.7183	2.5393	0.0061	0.0010	17.2733
3	Ohio River	3.08	31.64	0.0130	0.0075	3.1209	0.8674	2.6388	0.0746	0.0010	18.8868
2	Ohio River	3.06	34.70	0.0125	0.0076	3.0855	0.8961	2.5642	0.0731	0.0010	18.9822
1	Ohio River / End	1.85	36.55	0.0208	0.0084	3.1826	0.9468	2.5974	0.0738	0.0010	19.6433

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-44. Total Miles of Ohio River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	**Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)**							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	23.86	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-45. Total Miles of Ohio River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – MISSISSIPPI RIVER, MO/IL

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Mississippi River case study model.

Model Development & Input Variables

WASP Model Design. The Mississippi River WASP model encompasses a 46-mile-long reach of the Mississippi River, 23 miles of which is downstream of the Rush Island plant immediate receiving water (COMID 3629181). The model has two start boundaries that are on the Meramec River (COMID 5052703) and Mississippi River (COMID 3629071) shortly upstream of their confluence. This model ends at the confluence of the Mississippi River and Kaskaskia River (COMID 5089872).

The Mississippi River WASP model consists of 90 modeled segments. Segment IDs 1-16 represent the surface water of the Ohio River with Segment ID 1 being the most downstream segment and Segment ID 16 being the most upstream segment. The Meramec River start boundary, which is also the Meramec plant's immediate receiving water (COMID 5052703), is represented by Segment ID 17. The immediate receiving water of the Rush Island is located at Segment ID 9. The remaining model segments represent tributary surface waters (Segment IDs 18-30), the upper benthic layers (Segment IDs 31-60), and the lower benthic layers (Segment IDs 61-90). Figure G-16 illustrates the segmentation of the Mississippi River WASP model.

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Meramec and Rush Island plants will achieve the limitations under the final rule by 2019 and 2023, respectively. For the Rush Island plant's immediate receiving water and downstream reaches, EPA focused the assessment of the baseline impacts and improvements under the final rule on the period after the 2023 assumed compliance date for the Rush Island plant.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Mississippi River WASP model. EPA scaled the Mississippi River stream gage data from Gage ID 07010000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one other USGS stream gages to represent inflow from the Meramec River, a tributary to the Mississippi River WASP modeling area. EPA scaled the Meramec River stream gage data from Gage ID 07019000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-16 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-46 presents additional information about the four stream gages and the time period covered in the stream flow data record at each. Table G-47 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

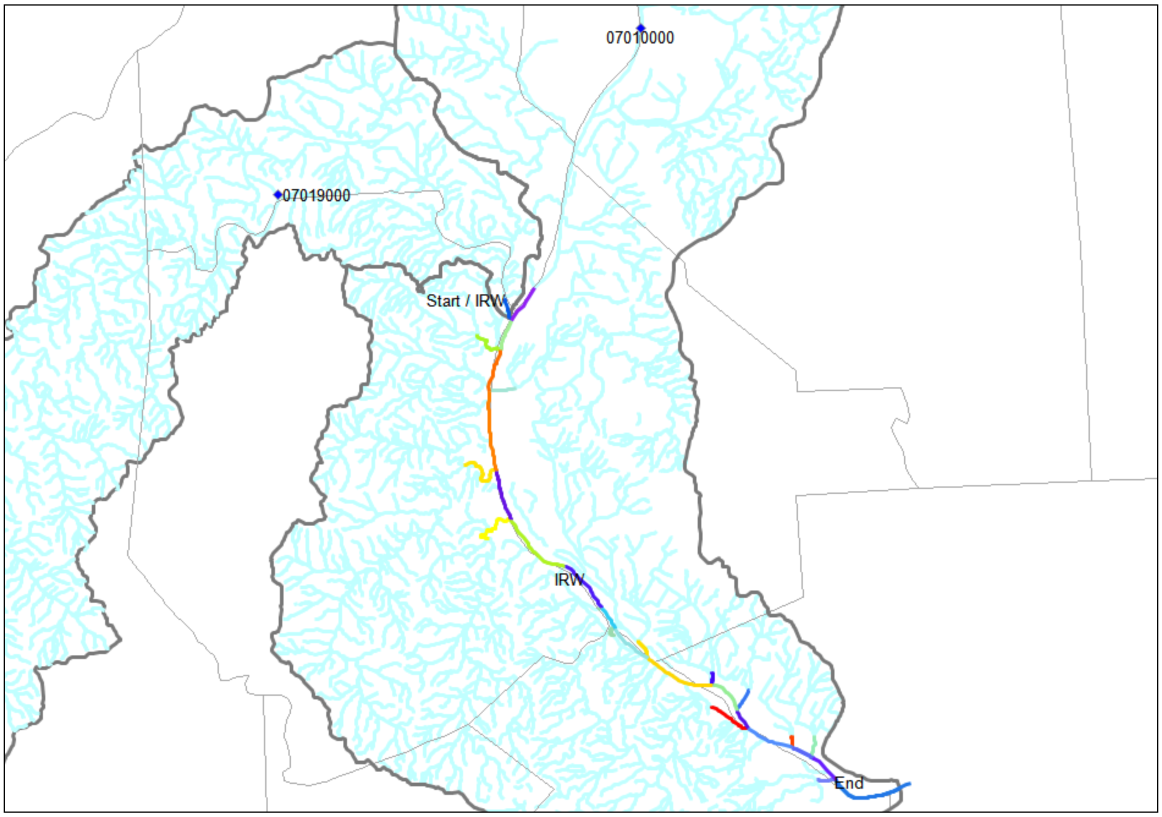


Figure G-16. Geographic Extent and Segmentation – Mississippi River WASP Model

Model Input Variables. Table G-48 presents the pollutant loadings modeled from Bruce Meramec plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. Table G-49 presents the pollutant loadings modeled from Rush Island plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-50 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Mississippi River case study model.

Table G-51 presents the pollutant contributions flowing into the Mississippi River WASP model boundaries calculated using available STORET monitoring data.

Table G-52 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 2.74 mg/L, 2.73 mg/L, and 51.94 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-53 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 100 mg/L each.

Model Results

Case study modeling of the Mississippi River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic. Figure G-17 illustrates the water concentration outputs for arsenic in the Rush Island plant immediate receiving water before and after the assumed compliance date for the final rule.[11]

Case study modeling of the Mississippi River revealed that average water column concentrations of arsenic in the Rush Island plant's immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Table G-54 and Table G-55 illustrate the average modeled pollutant concentration in each water column segment downstream of the Rush Island plant (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-56 and Table G-57 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

---

[11] To improve clarity, Figure G-17 presents the baseline water column concentrations leading up to the assumed compliance date of Rush Island plant. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-46. USGS Stream Gages with Flow Data Used in Mississippi River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
7010000	Mississippi River near St. Louis, MO	Full Record from 01/01/1880 - 11/19/2014	1,668,452	Mississippi River	1,667,867	1.000
7019000	Meramec River near Eureka, MO	Full Record from 10/01/1903 - 02/04/2015	9,811	Meramec River	10,264	1.046

Acronyms: USGS (U.S. Geological Survey).

Table G-47. Stream Flow Data Periods – Mississippi River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Mississippi River (Gage ID 7010000)	
01/01/1982 - 09/30/2014	01/01/1982 - 09/30/2014
10/01/2014 – 12/31/2020	10/01/2002 – 12/31/2008
01/01/1998 - 09/30/2030	01/01/1982 - 09/30/2014
10/01/2030 – 12/31/2036	10/01/2002 – 12/31/2008
Meramec River (Gage ID 7019000)	
01/01/1982 - 09/30/2014	01/01/1982 - 09/30/2014
10/01/2014 – 12/31/2020	10/01/2002 – 12/31/2008
01/01/1998 - 09/30/2030	01/01/1982 - 09/30/2014
10/01/2030 – 12/31/2036	10/01/2002 – 12/31/2008

Table G-48. Pollutant Loadings – Meramec Plant

Wastestream	**Pollutant Loadings (g/day)**							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	425.25	117.36	519.89	1,956.61	391.37	215.63	1,994.81	1,599.08
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**425.25**	**117.36**	**519.89**	**1,956.61**	**391.37**	**215.63**	**1,994.81**	**1,599.08**
Final Rule [b]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	--	--			--			--

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2036).

-- -- -- --

Table G-49. Pollutant Loadings – Rush Island Plant

Wastestream	**Pollutant Loadings (g/day)**							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	2,617.69	338.24	1,490.40	1,152.47	1,054.61	1,171.40	1,220.86	3,112.40
Bottom Ash Transport Water	109.07	55.52	381.96	330.76	173.11	11.83	200.40	334.33
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**2,726.76**	**393.76**	**1,872.36**	**1,483.22**	**1,227.72**	**1,183.23**	**1,421.26**	**3,446.73**
Final Rule [b]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	--	--			--			--

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled from 01/01/1982 through 12/31/2022.

b – The final rule pollutant loadings are modeled from 01/01/2023 through 12/31/2036.

-- -- -- --

Table G-50. Pollutant Contributions from Non-Steam Electric Point Sources – Mississippi River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
MSD Meramec Treatment Plant [a]	3629071 (Mississippi River)	St. Louis, MO	(38.39,-90.34)	As	139.02
				Cd	3.50
				Cu	52.2
				Ni	52.5
				Pb	156.5
				Zn	999.6
Doe Run Co Herculaneum Smelter [b]	3629127 (Mississippi River)	Herculaneum, MO	(38.26,-90.38)	Cd	156.87
				Cu	11.56
				Pb	49.42
				Zn	66.51
Doe Run Co Herculaneum Smelter [c]	3634867 [d] (Joachim Creek)	Herculaneum, MO	(38.26,-90.38)	As	6.09
				Cd	6.09
				Cu	8.35
				Ni	0.61
				Pb	280.97
				Zn	36.80

a – EPA identified that this publicly operated treatment works (POTW) facility is a direct discharger with 2011 DMR loadings.

b - EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

c - EPA identified that this facility is also an indirect discharger with 2011 TRI loadings.

d – These pollutant loadings for Doe Run Co Herculaneum are indirectly discharged to Joachim Creek via the Herculaneum Sewer District POTW.

Table G-51. Pollutant Contributions from STORET Monitoring Data – Mississippi River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Mississippi River	3629071	1707.02/3.7 (38.43,-90.29) GRW04449-331 (38.41,-90.32) J-36 (38.40,-90.32) 1707.03/41.0 (38.36,-90.36)	As	--	1,533,384.42
			Cd	--	63,000.95
			Cu	--	1,772,153.59
			Ni	--	4,216,002.40
			Pb	--	1,764,990.67
			Zn	--	6,485,964.73
			TSS	220,098.26	--
			TOC	5,298.95	--
Maeystown Creek	3629179	JD-02 (38.21,-90.26)	As	--	49.83
			Cd	--	1.21
			Cu	--	38.90
			Ni	--	11.55
			Pb	--	29.09
			Zn	--	152.55
			TOC	3,928.00	--
			TSS	43,000.00	--
South Gabouri Creek	3630453	1707.02/121/0.9/1.5 (37.97,-90.06)	TSS	5,000.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-52. Organic Solids, Sands, and Silts/Fines Inputs – Mississippi River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Mississippi River	3629071	2.65	11.00	209.09
Maeystown Creek	3629179	1.96	2.15	40.85
South Gabouri Creek	3630453	*	0.25 [e]	4.75 [e]
All Other Inflows [d]	N/A	2.31	4.47	84.90

Acronyms: N/A (Not Applicable).

* – No TOC results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-51.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-51.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-51.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

e – These concentrations were calculated using the ‘All Other Inflows’ concentration.

Table G-53. Sediment Transport Parameters – Mississippi River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	5.0	N/m^2
TAU_cD1_si[a]	5.0	N/m^2
TAU_cD2_si[a]	10.0	N/m^2
TAU_cD1_PO[a]	5.0	N/m^2
TAU_cD2_PO[a]	10.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

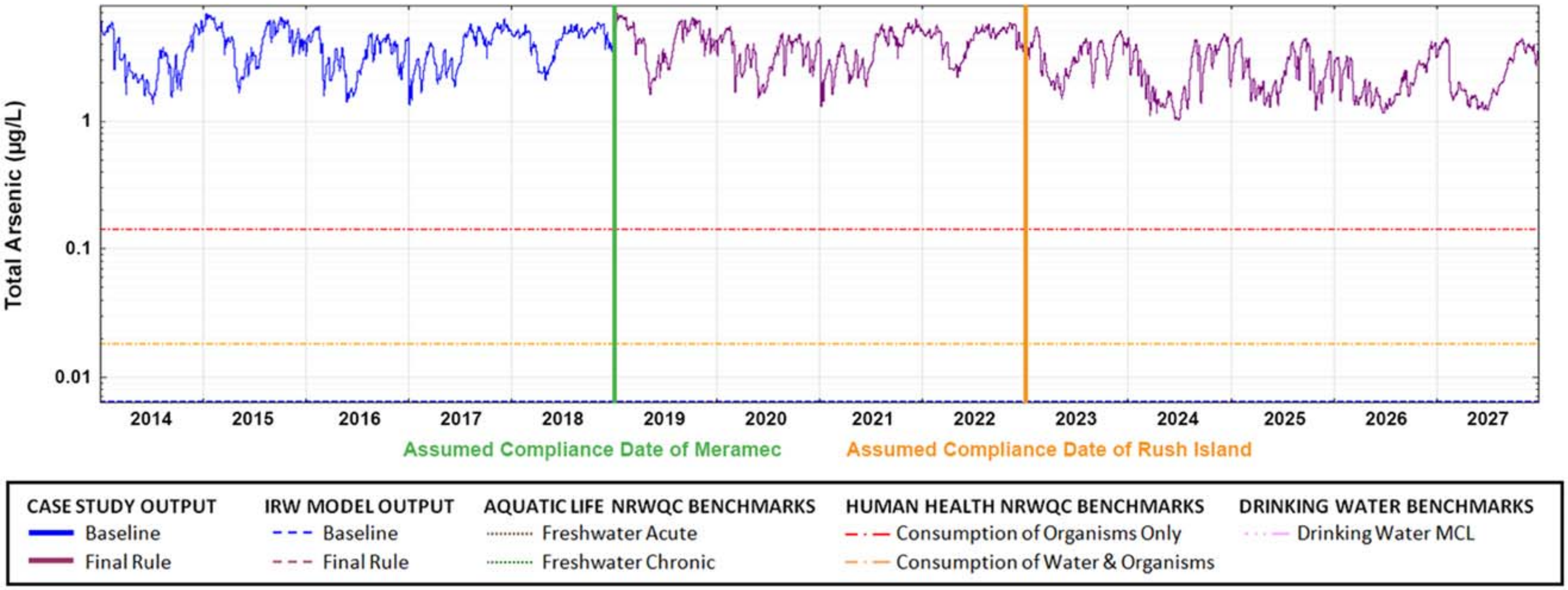


Figure G-17. Modeled Concentrations in Mississippi River Water Column at Rush Island Plant Immediate Receiving Water (Total Arsenic)

Table G-54. Average Water Column Concentrations Downstream of Rush Island Plant at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
9	Mississippi River / Rush Island IRW	1.48	1.48	3.2912	0.1287	3.5878	3.5149	8.7116	0.0044	0.0086	13.0108
8	Mississippi River	2.69	4.17	4.0944	0.1237	3.5546	3.2102	9.5052	0.0046	0.0099	12.3554
7	Mississippi River	4.33	8.49	3.0972	0.1171	3.2754	3.1789	8.0477	0.0040	0.0080	11.8195
6	Mississippi River	2.21	10.70	3.1050	0.1174	3.2833	3.1859	8.0684	0.0040	0.0080	11.8468
5	Mississippi River	1.25	11.95	3.1057	0.1174	3.2834	3.1858	8.0693	0.0040	0.0080	11.8467
4	Mississippi River	2.93	14.88	3.1055	0.1173	3.2816	3.1835	8.0667	0.0040	0.0080	11.8392
3	Mississippi River	1.40	16.27	3.1065	0.1173	3.2819	3.1834	8.0682	0.0040	0.0080	11.8395
2	Mississippi River	1.92	18.19	3.1078	0.1173	3.2820	3.1831	8.0699	0.0040	0.0080	11.8393
1	Mississippi River / End	5.06	23.25	3.1123	0.1173	3.2832	3.1830	8.0766	0.0040	0.0080	11.8412

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-55. Average Water Column Concentrations Downstream of Rush Island Plant Under Final Rule

Segment Data				**Average Total Water Column Concentration over Modeling Period (µg/L)[a]**							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
9	Mississippi River / Rush Island IRW	1.48	1.48	3.2833	0.1275	3.5819	3.5109	8.7034	0.0008	0.0006	12.9984
8	Mississippi River	2.69	4.17	4.0847	0.1225	3.5488	3.2066	9.4964	0.0009	0.0006	12.3438
7	Mississippi River	4.33	8.49	3.0898	0.1159	3.2700	3.1753	8.0402	0.0008	0.0005	11.8083
6	Mississippi River	2.21	10.70	3.0976	0.1162	3.2779	3.1823	8.0609	0.0008	0.0005	11.8357
5	Mississippi River	1.25	11.95	3.0984	0.1162	3.2780	3.1822	8.0618	0.0008	0.0005	11.8356
4	Mississippi River	2.93	14.88	3.0982	0.1161	3.2763	3.1799	8.0592	0.0008	0.0005	11.8281
3	Mississippi River	1.40	16.27	3.0992	0.1162	3.2765	3.1798	8.0607	0.0008	0.0005	11.8284
2	Mississippi River	1.92	18.19	3.1004	0.1162	3.2767	3.1795	8.0624	0.0008	0.0005	11.8282
1	Mississippi River / End	5.06	23.25	3.1049	0.1162	3.2779	3.1795	8.0691	0.0008	0.0005	11.8300

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-56. Total Miles of Mississippi River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	**Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)**							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	23.25	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-57. Total Miles of Mississippi River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	23.25	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – LAKE SINCLAIR, GA

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, EFDC model flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Lake Sinclair case study model.

Model Development & Input Variables

WASP Model Design. As discussed in Section 8.1.1 of the EA Report, EPA relied on the availability of an existing water quality model to perform case study modeling of Lake Sinclair. In contrast to the lotic case study models, the Lake Sinclair WASP model relies on Environmental Fluid Dynamics Code (EFDC) hydrodynamics to simulate the aquatic system in three dimensions.[12] The scope of the Lake Sinclair WASP model is limited by the boundaries of the pre-existing EFDC hydrodynamics. The modeling area encompasses the main body of Lake Sinclair, from Wallace Dam to Sinclair Dam, and the major tributaries feeding into the Lake.

The three-dimensional EFDC model, which provides the hydrodynamic foundation for the WASP model, divides the waterbody into 1,235 segments. Each segment represents a unique location and stratum within Lake Sinclair. The EFDC model uses stretch or sigma vertical coordinates and Cartesian coordinates to represent the physical characteristics of Lake Sinclair. Plant Harllee Branch's immediate receiving water is identified by the coordinate code I=30 J=32 K=5, where each coordinate represents the position on x, y, and z axes, respectively. The Lake Sinclair model does not have any segments representing benthic sediment. The model accounts for a total volume of approximately 340 million cubic meters.

As discussed earlier in this section, EPA adopted the preexisting Lake Sinclair EFDC model. The pre-existing model was designed with seven years of hydrodynamic and flow input, limiting the length of the period EPA could model. Based on Plant Harllee Branch's NPDES permitting cycle, EPA assumed that the plant would have achieved the limitations under the final rule by 2019, if it continued to operate. The modeling period begins in February 2012 (approximately seven years before the assumed compliance date) and extends through November 2025 (approximately seven years after the assumed compliance date).

Incorporation of Flow Data. EPA did not incorporate any USGS flow data into the Lake Sinclair WASP model. Instead, EPA used the seven years of hydrodynamic and flow input integrated into the EFDC model. Table G-58 presents how the EFDC hydrodynamic data were incorporated into the model to complete a full record of flow data for the entire modeling period.

Model Input Variables. As discussed in Section 8.2.6 of the EA Report, Plant Harllee Branch retired all of coal-fired generating units in April 2015. Despite the retirement of this plant, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric discharges on lentic waterbodies. Table G-59 presents the pollutant loadings modeled from Plant Harllee Branch at the evaluated wastestream level, both at baseline and after

---

[12] The Black Creek, Etowah River, Lick Creek and White River, Ohio River, and Mississippi River case study models relied on NHDPlus Version 1 hydrodynamics for simulating lotic aquatic systems.

the plant achieves the limitations under the final rule.[13] EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Lake Sinclair case study model.

Table G-60 presents the pollutant contributions flowing into the Lake Sinclair WASP model boundaries calculated using available STORET monitoring data.

Table G-61 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.91 mg/L, 0.20 mg/L, and 3.85 mg/L, respectively.

Model Results

Case study modeling of Lake Sinclair revealed water quality benchmark exceedances in the immediate receiving water and neighboring segments for arsenic and thallium. Figure G-18 illustrates the water concentration outputs averaged for all model segments before and after the assumed compliance date for the final rule.[14] Case study modeling also revealed frequent (more than 50 percent of the modeling period) water quality benchmark exceedances of three pollutants (arsenic, cadmium, and thallium) in some segments of Lake Sinclair.

Case study modeling of the Lake Sinclair revealed that the average water column concentrations of thallium of all segments in the WASP model would trigger exceedances of human health benchmarks.

---

[13] EPA calculated pollutant loadings at the wastestream level for Plant Harllee Branch using the same loadings methodology that EPA used for other plants in the loadings analyses. EPA did not include Plant Harllee Branch or Lake Sinclair in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

[14] To improve clarity, Figure G-18 presents the baseline water column concentrations leading up to the assumed compliance date of Plant Harllee Branch. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-58. Stream Flow Data Periods – Lake Sinclair WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Lake Sinclair (EFDC Hydrodynamic Model)	
02/01/2012 – 12/31/2018	2/1/2001 – 12/31/2007
01/01/2019 – 11/30/2025	2/1/2001 – 12/31/2007

Table G-59. Pollutant Loadings – Plant Harllee Branch

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	35.18	521.69	100.78	4,068.20	21.61	5,413.46	63.65	6,451.65
Fly Ash Transport Water	44.28	12.01	97.91	55.28	39.77	14.80	13.57	360.25
Bottom Ash Transport Water	22.29	6.15	27.25	102.56	20.52	11.30	104.56	83.82
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**101.75**	**539.85**	**225.94**	**4,226.04**	**81.90**	**5,439.56**	**181.78**	**6,895.72**
Final Rule [b]								
FGD Wastewater	27.03	19.50	17.50	29.21	15.71	26.51	45.44	92.54
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**27.03**	**19.50**	**17.50**	**29.21**	**15.71**	**26.51**	**45.44**	**92.54**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

Note: Plant Harllee Branch has retired all coal-fired generating units. EPA calculated pollutant loadings at the wastestream level for Plant Harllee Branch using the same loadings methodology that EPA used for other plants in the loadings analyses. EPA did not include Plant Harllee Branch in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 02/01/2012 through 11/30/2025).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 11/30/2025).

c - In estimating the historical pollutant loadings associated with Plant Harllee Branch’s FGD systems, EPA incorporated the pollutant loadings from FGD wastewater when the system was installed in 2013. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Harllee Branch’s FGD system.

Table G-60. Pollutant Contributions from STORET Monitoring Data – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Oconee River	1057503	0301100602 (33.35,-83.16) 3038901 (33.35,-83.16) 0301100603 (33.33,-83.14)	TOC	3,818.44	--
			TSS	6,941.46	--
Crooked Creek	1056407	0301180202 (33.32,-83.28)	TOC	7,124.62	--
			TSS	18,992.31	--
Rooty Creek	1057629	0301180301 (33.32,-83.27) 3040101 (33.32,-83.37) 0301180302 (33.29,-83.35) 3040501 (33.29,-83.25)	As	--	58.89
			Cd	--	14.99
			Cu	--	45.10
			Ni	--	33.07
			Pb	--	29.59
			Tl	--	58.95
			Zn	--	452.25
			TOC	5,347.26	--
			TSS	11,635.71	--
Little River	1057681	3042001 (33.30,-83.42) 0301150301 (33.29,-83.43) 0301150302 (33.29,-83.43) 3041701 (33.31,-83.44) 0301150102 (33.31,-83.44)	As	--	960.78
			Cd	--	243.11
			Cu	--	1,037.67
			Ni	--	644.08
			Pb	--	482.01
			Tl	--	961.37
			Zn	--	6,098.66
			TOC	4,960.21	--
			TSS	15,576.92	--

Table G-60. Pollutant Contributions from STORET Monitoring Data – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Murder Creek	1057679	0301160703 (33.27,-83.48) 3043401 (33.25,-83.48) 0301160701 (33.25,-83.48)	As	--	642.79
			Cd	--	162.65
			Cu	--	328.26
			Ni	--	347.78
			Pb	--	322.48
			Tl	--	643.18
			Zn	--	1,654.57
			TOC	2,773.47	--
			TSS	21,383.33	--
Big Cedar Creek	1056893	3043801 (33.19,-83.44) 0301170401 (33.19,-83.44)	As	--	450.16
			Cd	--	113.90
			Cu	--	229.89
			Ni	--	243.56
			Pb	--	225.84
			Tl	--	450.44
			Zn	--	345.37
			TOC	3,407.30	--
			TSS	20,223.08	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-61. Organic Solids, Sands, and Silts/Fines Inputs – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Oconee River	1057503	1.91	0.35	6.59
Crooked Creek	1056407	3.56	0.95	18.04
Rooty Creek	1057629	2.67	0.58	11.05
Little River	1057681	2.48	0.78	14.80
Murder Creek	1057679	1.39	1.07	20.31
Big Cedar Creek	1056893	1.70	1.01	19.21
All Other Inflows [d]	N/A	2.29	0.79	15.00

Acronyms: N/A (Not Applicable).

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-60.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-60.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-60.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-62. Sediment Transport Parameters – Lake Sinclair WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

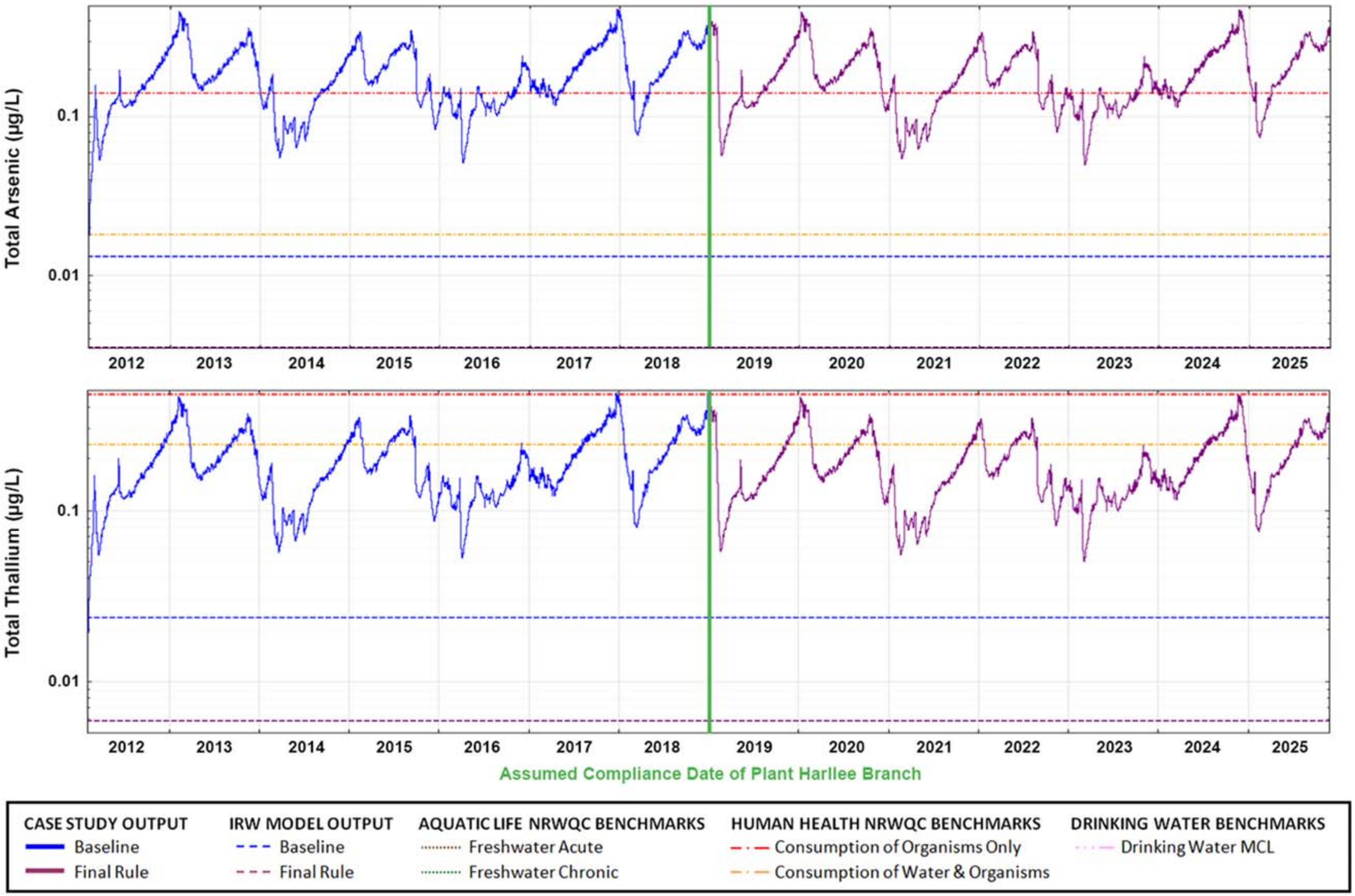


Figure G-18. Average Modeled Concentrations in All Segments in Lake Sinclair WASP Model (Total Arsenic, Total Thallium)

APPENDIX H
ADDITIONAL MODEL RESULTS

Table H-1. Number and Percentage of Immediate Receiving Waters that Exceeded a Criterion by Pollutant and Criteria Type at Baseline Pollutant Loadings

	Number of Immediate Receiving Waters that Exceeded a Criterion [a]						
						Total Receiving Waters [b]	
Pollutant	**Freshwater Acute NRWQC**	**Freshwater Chronic NRWQC**	**Human Health Water and Organism NRWQC**	**Human Health Organism Only NRWQC**	**Drinking Water MCL**	**Number Exceeding**	**Percentage Exceeding**
Arsenic	3 (c)	4 (c)	94 (d)	65 (d)	12	94	45%
Cadmium	9 (c)	29 (c)	No criterion	No criterion	11	29	14%
Chromium VI	0 (c)	0 (c)	No criterion	No criterion	0 (e)	0	0%
Copper	6 (c)	7 (c)	0	No criterion	0 (f); 1 (g)	7	3%
Lead	0 (c)	5 (c)	No criterion	No criterion	7 (f)	7	3%
Mercury	1 (c)	1 (c)	No criterion	No criterion	5 (d)	5	2%
Nickel	2 (c)	8 (c)	4	0	No criterion	8	4%
Selenium	No criterion	33	8	1	12	33	16%
Thallium	No criterion	No criterion	49	45	34	49	23%
Zinc	4 (c)	4 (c)	1	0	1 (g)	4	2%

Source: ERG, 2015d; ERG, 2015h.

Acronyms: MCL (Maximum Contaminant Level); NRWQC (National Recommended Water Quality Criteria).

a – A total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) were included in the water quality model. Table C-7 presents the criteria used for the analysis.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – NRWQC is expressed in terms of the dissolved pollutant in the water column.

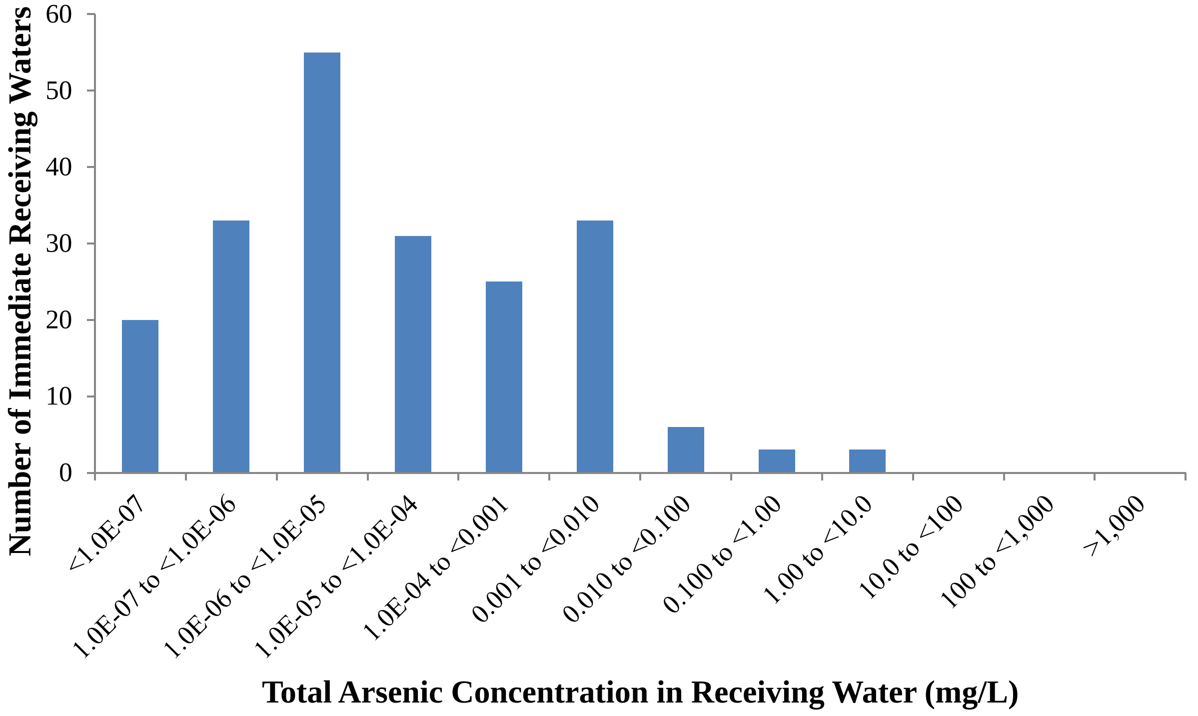
d – NRWQC or MCL is for inorganic form of metal. For the benchmark comparison, EPA used the total pollutant concentration in the water column. This might overestimate the number of exceedances.

e – MCL is for total chromium.

f - MCL used for comparison is the drinking water action level.

g – MCL used for comparison is a secondary (nonenforceable) drinking water standard.

Figure H-1. Baseline Total Arsenic Concentration in the Immediate Receiving Water



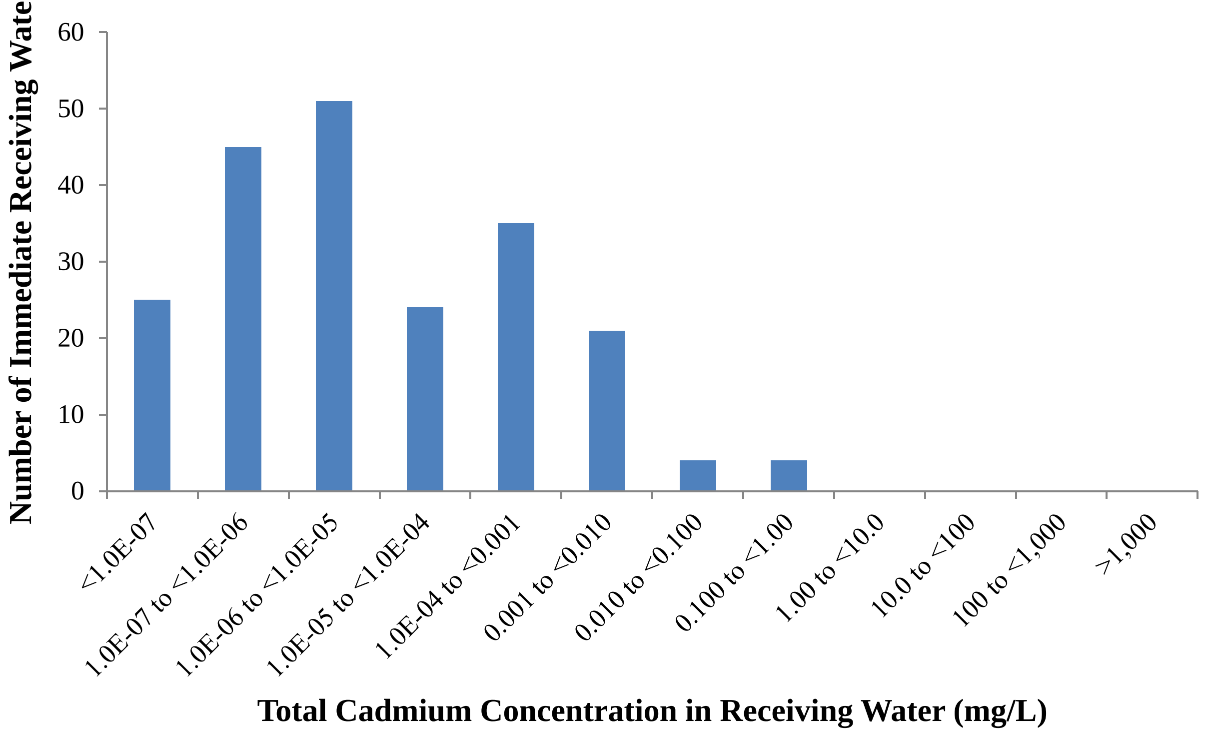
Source: ERG, 2015d; ERG, 2015h.

Table H-2. Total Arsenic Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	3.45E-08	2.07E-08	2.07E-08	0	0	0
25th	9.61E-07	6.28E-07	6.28E-07	1.21E-07	0	0
50th	7.88E-06	5.49E-06	5.49E-06	2.82E-06	3.62E-07	1.93E-07
75th	0.001	4.40E-04	4.40E-04	9.23E-05	1.62E-05	9.68E-06
95th	0.016	0.008	0.008	0.006	0.003	9.76E-04
Max	1.86	1.86	1.86	1.86	1.86	1.13

Source: ERG, 2015d; ERG, 2015h.

Figure H-2. Baseline Total Cadmium Concentration in the Immediate Receiving Water



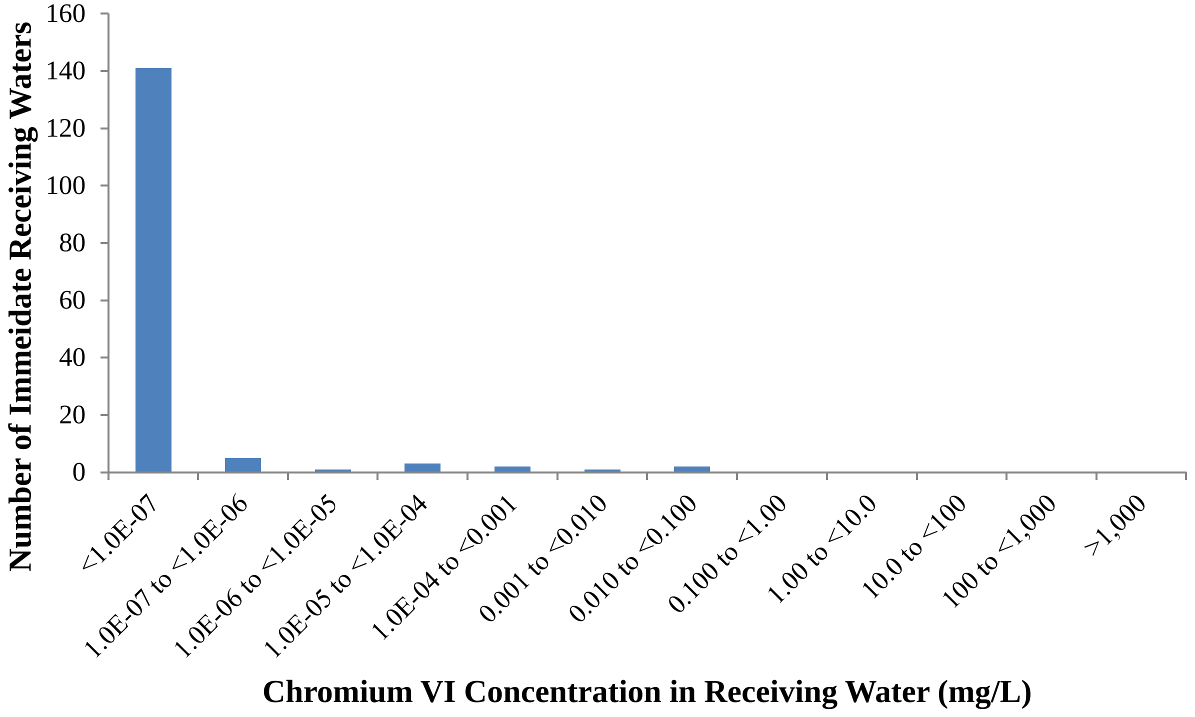
Source: ERG, 2015d; ERG, 2015h.

Table H-3. Total Cadmium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.43E-08	1.04E-08	1.04E-08	0	0	0
25th	5.10E-07	2.25E-07	2.25E-07	5.15E-08	0	0
50th	5.15E-06	2.10E-06	2.10E-06	9.87E-07	1.54E-07	1.36E-07
75th	1.75E-04	1.22E-04	1.22E-04	3.66E-05	8.42E-06	6.99E-06
95th	0.005	0.003	0.003	0.002	0.001	7.04E-04
Max	0.490	0.490	0.490	0.490	0.490	0.204

Source: ERG, 2015d; ERG, 2015h.

Figure H-3. Chromium VI Concentration in the Immediate Receiving Water



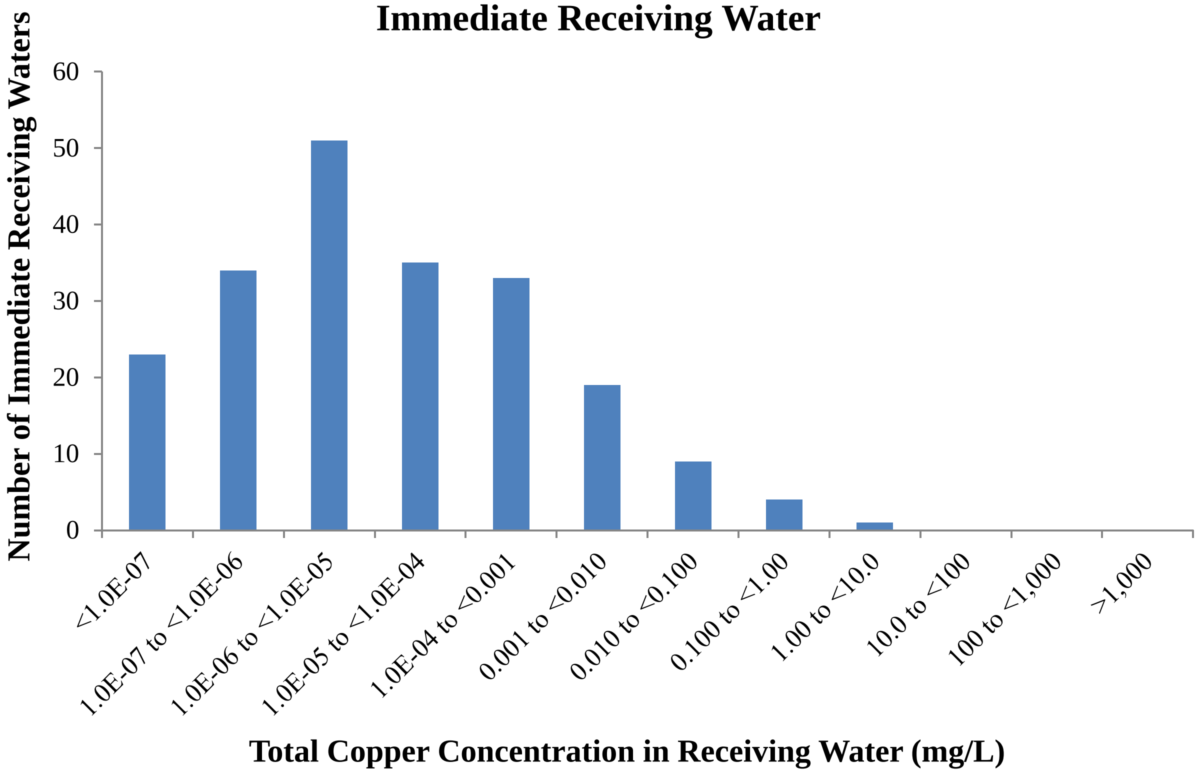
Source: ERG, 2015d; ERG, 2015h.

Table H-4. Chromium VI Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	0	0	0	0	0	0
25th	0	0	0	0	0	0
50th	0	0	0	0	0	0
75th	0	0	0	0	0	0
95th	5.38E-06	1.33E-06	1.33E-06	7.87E-08	0	0
Max	0.019	0.013	0.013	0.013	0.013	0.013

Source: ERG, 2015d; ERG, 2015h.

Figure H-4. Baseline Total Copper Concentration in the Immediate Receiving Water



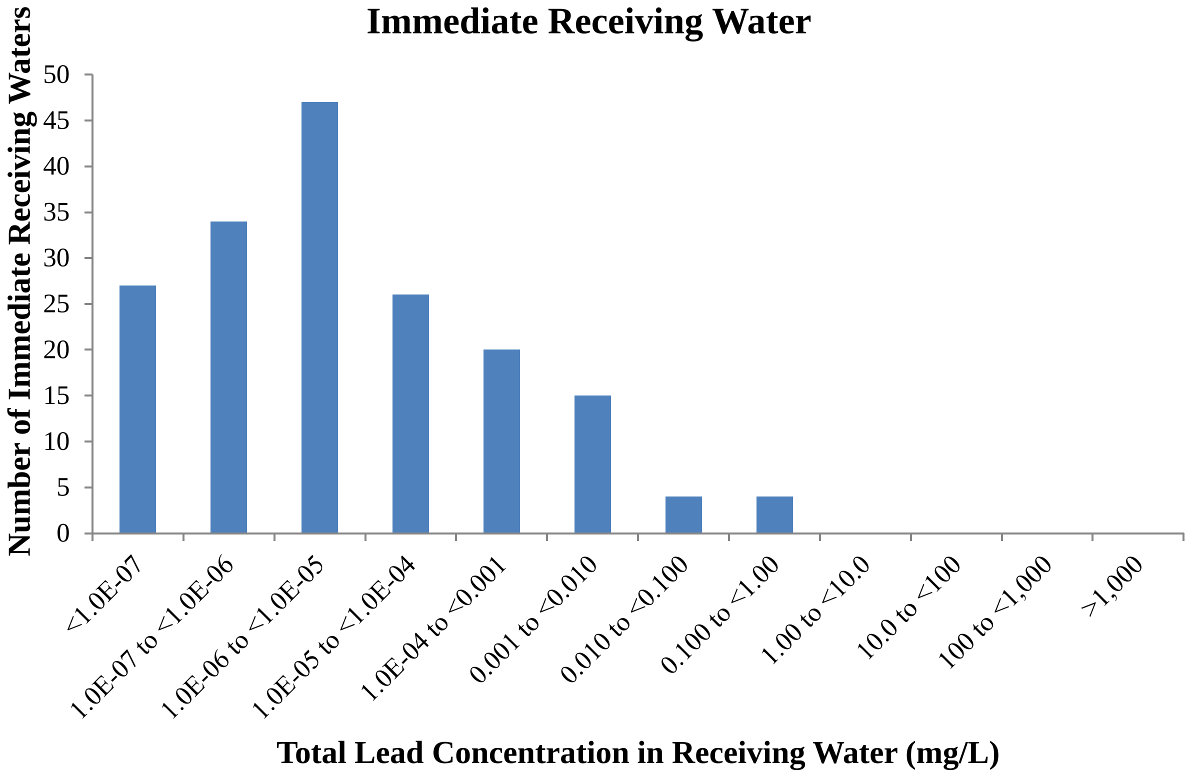
Source: ERG, 2015d; ERG, 2015h.

Table H-5. Total Copper Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.64E-08	1.01E-08	1.01E-08	0	0	0
25th	8.86E-07	5.37E-07	5.37E-07	7.86E-08	0	0
50th	8.30E-06	6.27E-06	6.27E-06	1.57E-06	1.33E-07	1.21E-07
75th	2.81E-04	2.33E-04	2.33E-04	4.21E-05	7.10E-06	6.27E-06
95th	0.015	0.009	0.009	0.002	0.001	6.32E-04
Max	1.15	0.778	0.778	0.778	0.778	0.778

Source: ERG, 2015d; ERG, 2015h.

Figure H-5. Baseline Total Lead Concentration in the Immediate Receiving Water



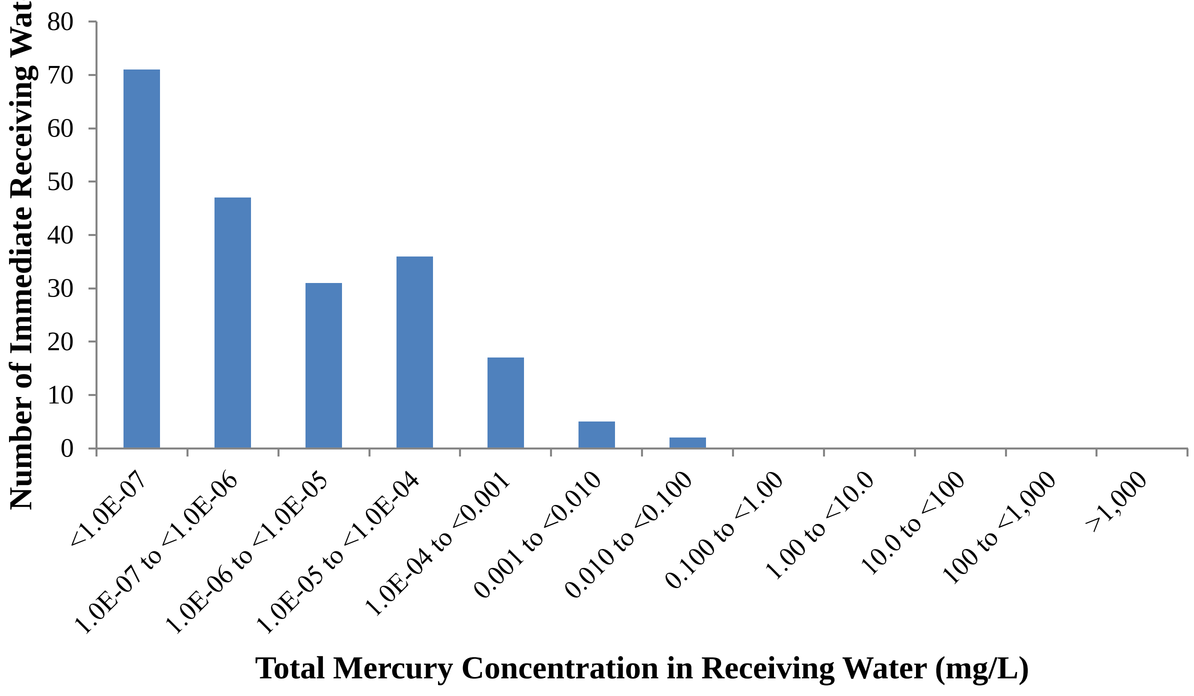
Source: ERG, 2015d; ERG, 2015h.

Table H-6. Total Lead Concentration (mg/L) in the Immediate Receiving Water by Percentile

	Scenario					
Percentile	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.41E-09	0	0	0	0	0
25th	4.47E-07	2.22E-07	2.22E-07	1.36E-09	0	0
50th	3.61E-06	2.91E-06	2.91E-06	3.65E-07	2.65E-09	2.65E-09
75th	7.65E-05	6.98E-05	6.98E-05	5.99E-06	4.47E-07	4.47E-07
95th	0.009	0.007	0.007	0.001	7.22E-05	7.22E-05
Max	0.757	0.510	0.510	0.510	0.510	0.510

Source: ERG, 2015d; ERG, 2015h.

Figure H-6. Baseline Total Mercury Concentration in the Immediate Receiving Water



Source: ERG, 2015d; ERG, 2015h.

Table H-7. Total Mercury Concentration (mg/L) in the Immediate Receiving Water by Percentile

	Scenario					
Percentile	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.70E-09	5.32E-10	3.94E-10	0	0	0
25th	4.50E-08	2.29E-08	1.86E-08	1.86E-09	0	0
50th	3.56E-07	1.79E-07	1.77E-07	6.24E-08	4.20E-09	2.32E-09
75th	1.68E-05	1.34E-05	1.28E-05	2.31E-06	2.14E-07	1.05E-07
95th	0.001	2.62E-04	2.58E-04	1.15E-04	4.17E-05	8.96E-06
Max	0.056	0.020	0.020	0.020	0.020	0.020

Source: ERG, 2015d; ERG, 2015h.

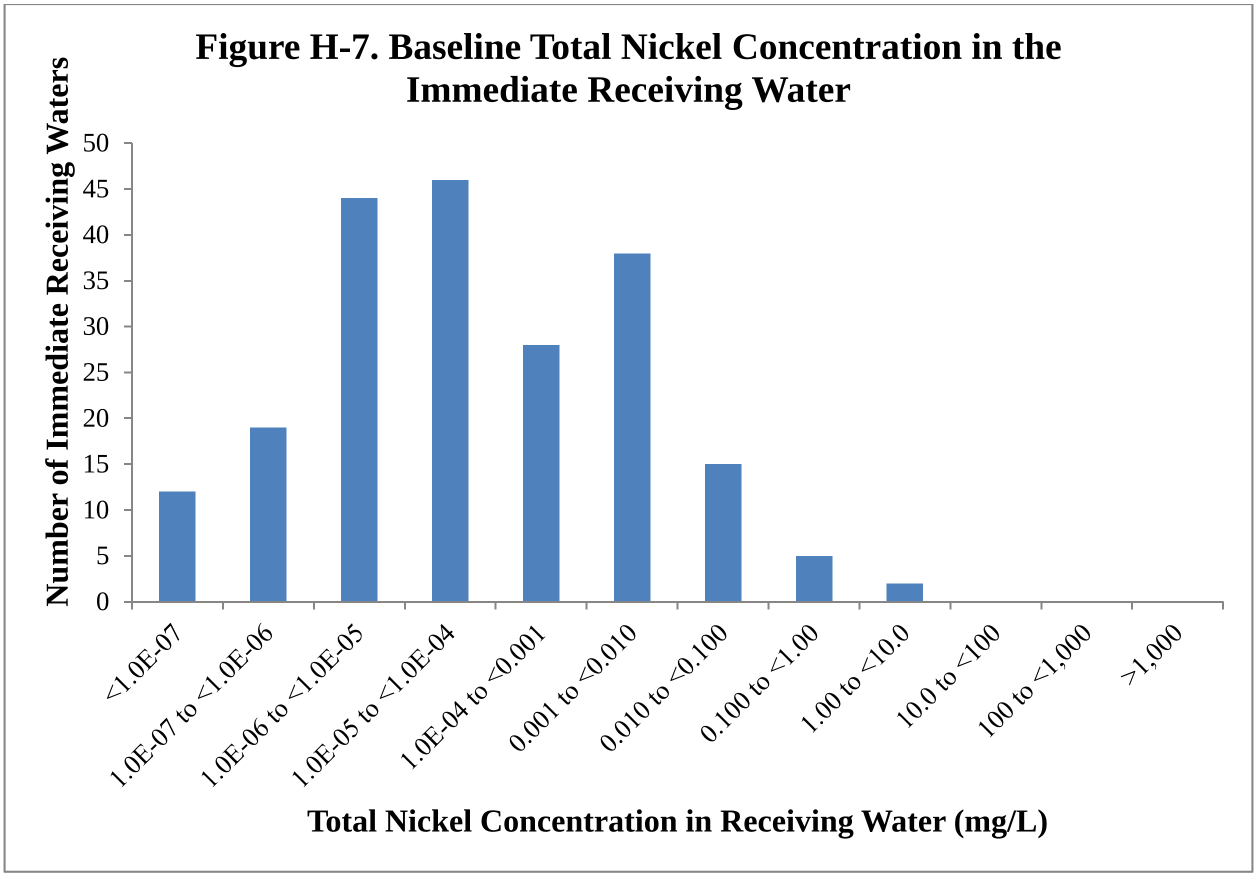


Figure H-7. Baseline Total Nickel Concentration in the Immediate Receiving Water

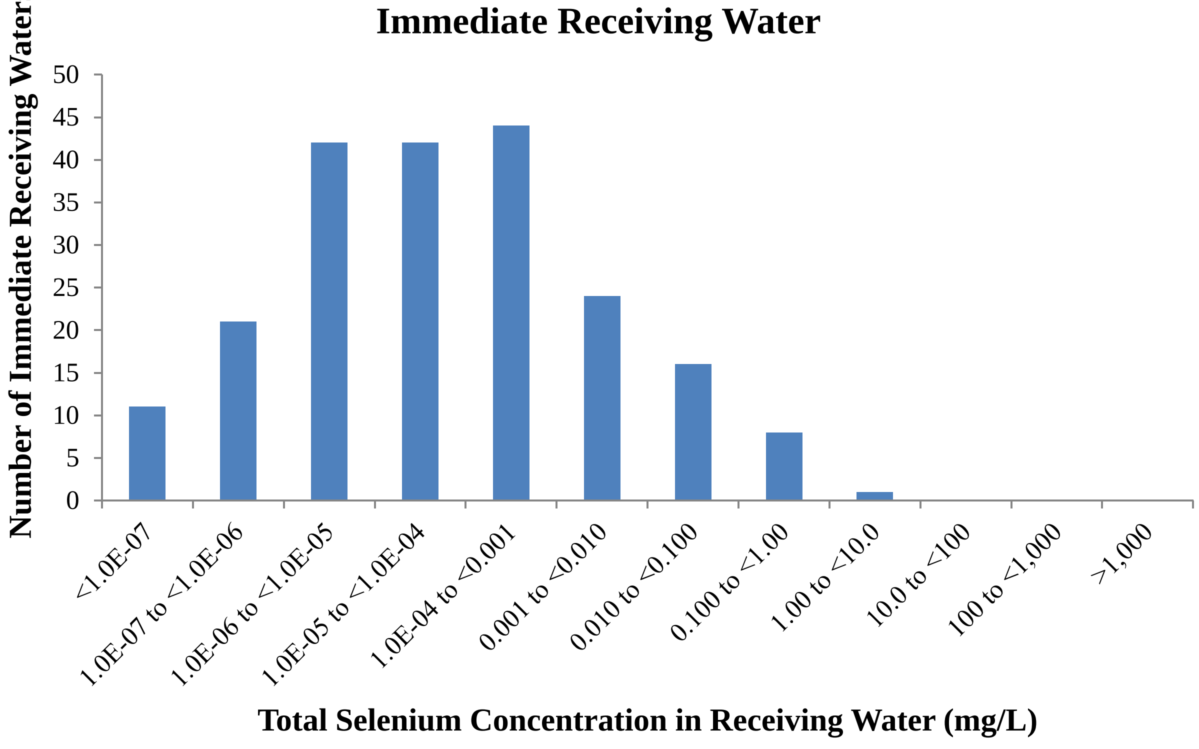
Source: ERG, 2015d; ERG, 2015h.

Table H-8. Total Nickel Concentration (mg/L) in the Immediate Receiving Water by Percentile

	Scenario					
Percentile	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	7.14E-08	4.16E-08	3.00E-08	0	0	0
25th	3.31E-06	1.31E-06	1.11E-06	1.86E-07	0	0
50th	3.34E-05	1.81E-05	1.81E-05	4.58E-06	4.17E-07	2.47E-07
75th	0.001	0.001	0.001	1.37E-04	1.62E-05	1.05E-05
95th	0.049	0.034	0.033	0.008	0.004	0.002
Max	2.25	2.25	2.25	2.25	2.25	0.616

Source: ERG, 2015d; ERG, 2015h.

Figure H-8. Baseline Total Selenium Concentration in the Immediate Receiving Water



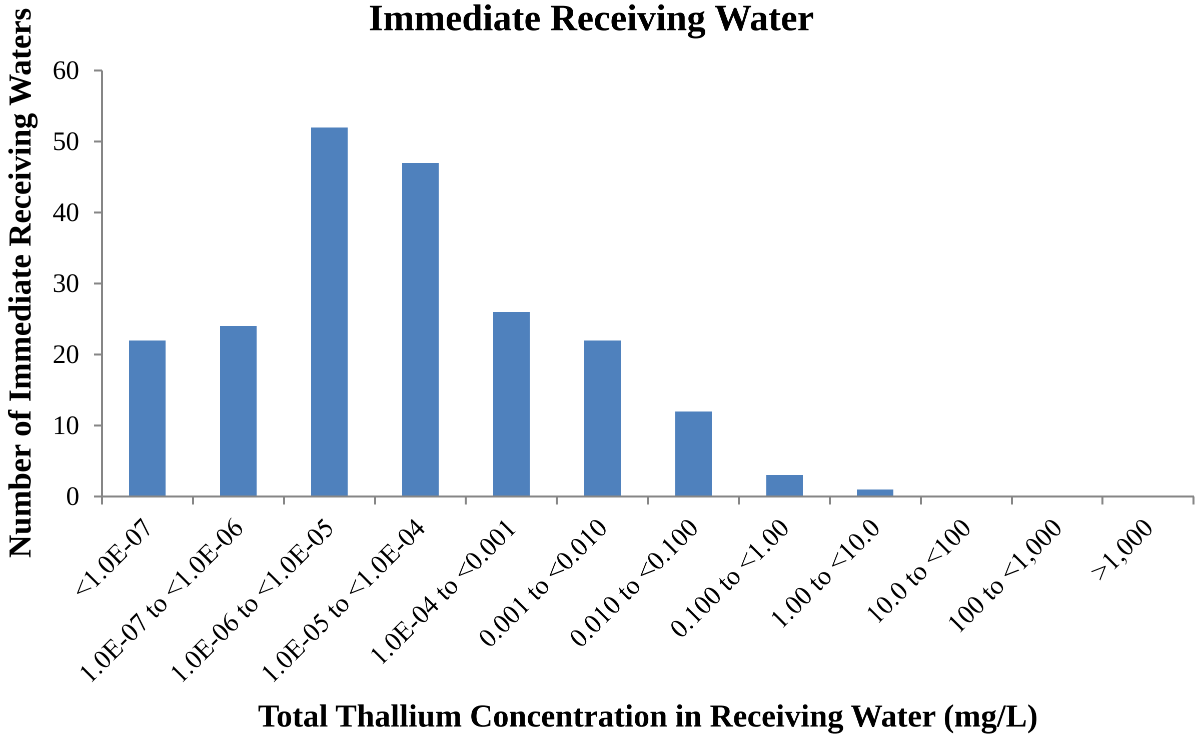
Source: ERG, 2015d; ERG, 2015h.

Table H-9. Total Selenium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	9.12E-08	3.84E-08	2.05E-08	0	0	0
25th	2.74E-06	2.46E-06	5.01E-07	1.19E-07	0	0
50th	5.46E-05	3.67E-05	5.30E-06	2.35E-06	3.82E-07	3.82E-07
75th	0.001	0.001	3.08E-04	9.68E-05	2.61E-05	2.61E-05
95th	0.064	0.040	0.017	0.013	0.010	0.010
Max	5.38	5.38	5.38	5.38	5.38	5.38

Source: ERG, 2015d; ERG, 2015h.

Figure H-9. Baseline Total Thallium Concentration in the Immediate Receiving Water



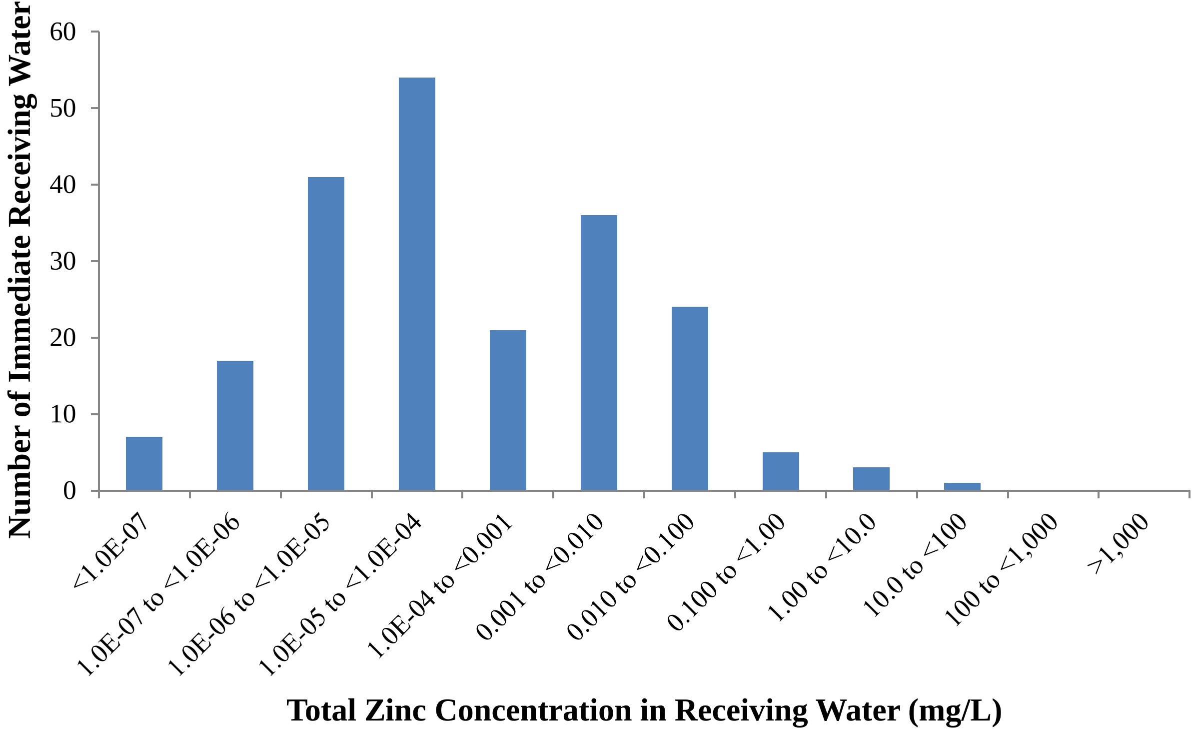
Source: ERG, 2015d; ERG, 2015h.

Table H-10. Total Thallium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.09E-08	5.95E-09	5.95E-09	0	0	0
25th	1.31E-06	7.82E-07	7.82E-07	6.08E-08	0	0
50th	1.49E-05	1.20E-05	1.20E-05	2.33E-06	1.89E-07	1.89E-07
75th	1.91E-04	1.54E-04	1.54E-04	3.71E-05	5.87E-06	5.87E-06
95th	0.035	0.033	0.033	0.004	3.42E-04	3.42E-04
Max	1.75	1.75	1.75	1.75	0.591	0.591

Source: ERG, 2015d; ERG, 2015h.

Figure H-10. Baseline Total Zinc Concentration in the Immediate Receiving Water



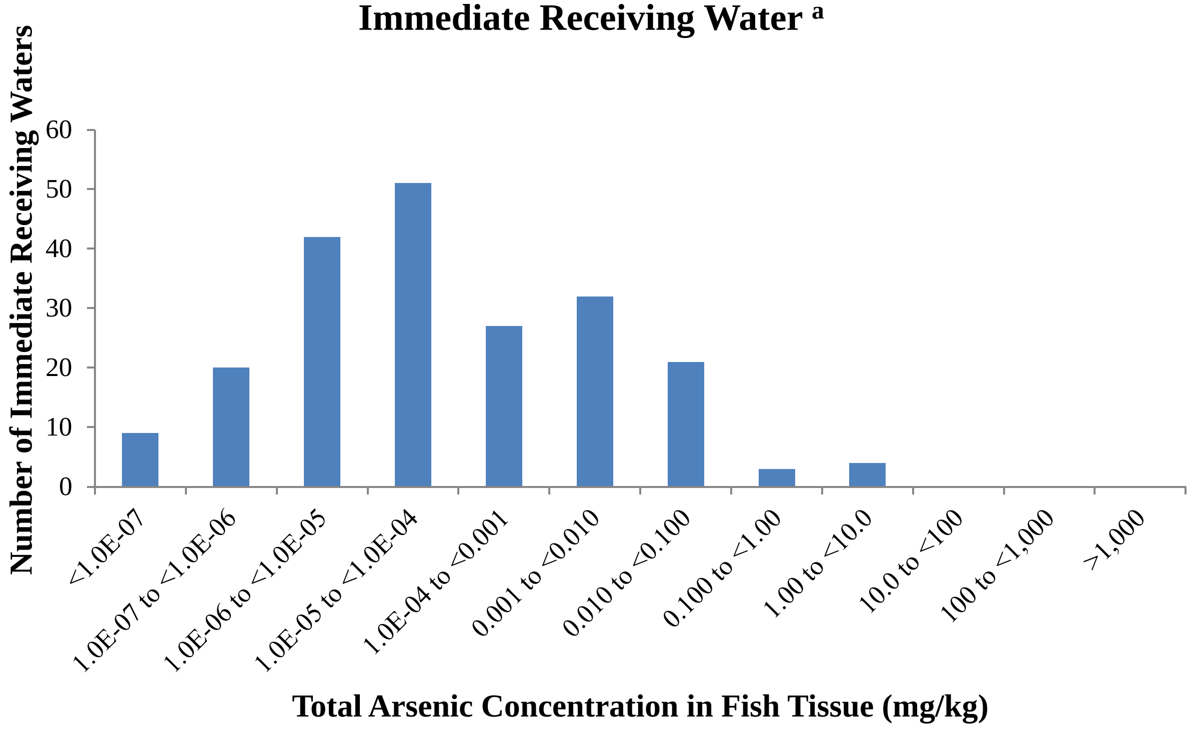
Source: ERG, 2015d; ERG, 2015h.

Table H-11. Total Zinc Concentration (mg/L) in the Immediate Receiving Water by Percentile

	Scenario					
Percentile	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	2.07E-07	9.14E-08	9.14E-08	0	0	0
25th	5.40E-06	2.43E-06	2.43E-06	4.67E-07	0	0
50th	6.37E-05	2.12E-05	2.12E-05	1.10E-05	1.44E-06	7.84E-07
75th	0.002	0.002	0.002	4.11E-04	7.72E-05	3.54E-05
95th	0.081	0.039	0.039	0.032	0.019	0.003
Max	10.2	10.2	10.2	10.2	10.2	1.43

Source: ERG, 2015d; ERG, 2015h.

Figure H-11. Baseline Total Arsenic Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total arsenic bioconcentration factors (BCFs) for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

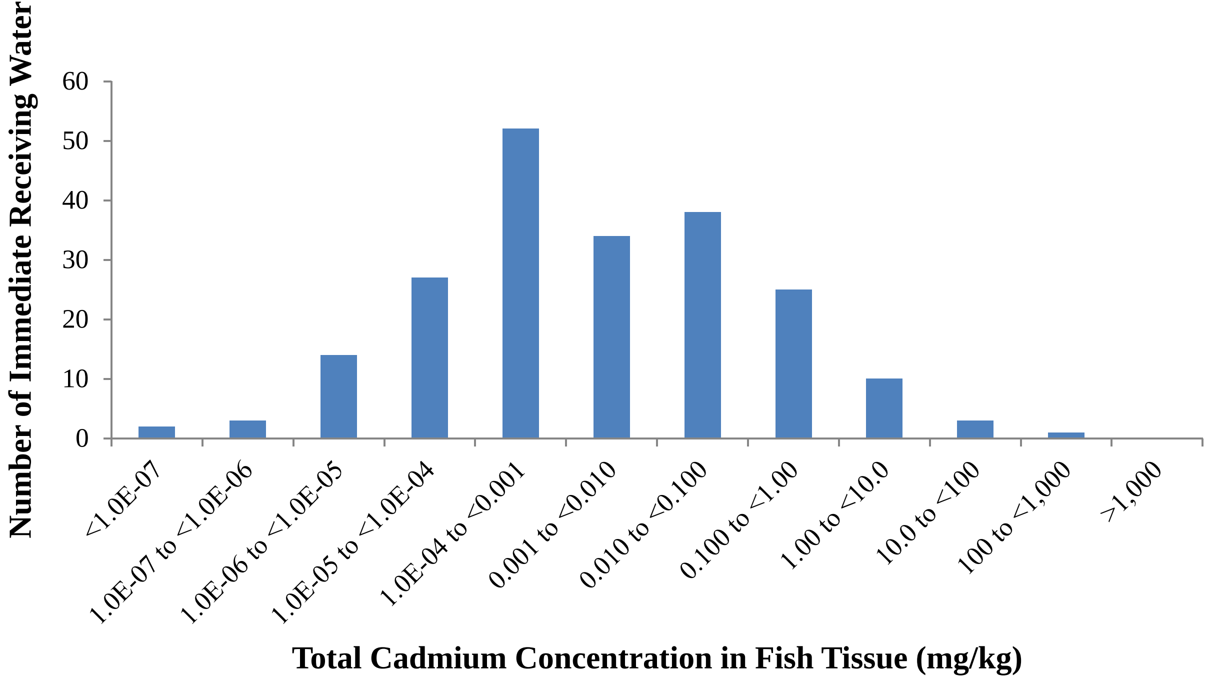
Table H-12. Total Arsenic Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.38E-07	8.28E-08	8.28E-08	0	0	0
25th	3.85E-06	2.51E-06	2.51E-06	4.86E-07	0	0
50th	3.15E-05	2.20E-05	2.20E-05	1.13E-05	1.45E-06	7.71E-07
75th	0.002	0.002	0.002	3.69E-04	6.49E-05	3.87E-05
95th	0.062	0.032	0.032	0.024	0.014	0.004
Max	7.45	7.45	7.45	7.45	7.45	4.53

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-12. Baseline Total Cadmium Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total cadmium BCFs for both T3 and T4 fish (see Appendix D**Error! Reference source not found.**). Therefore, the estimated concentrations presented here are identical for both trophic levels.

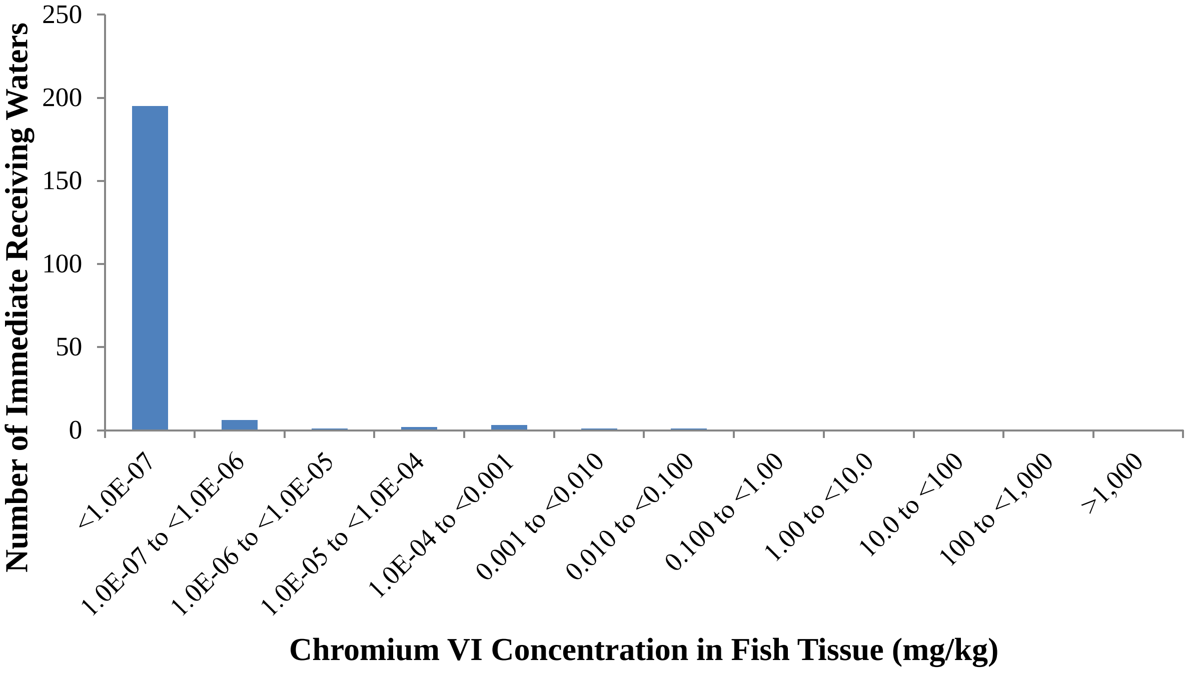
Table H-13. Total Cadmium Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	3.85E-06	2.81E-06	2.81E-06	0	0	0
25th	1.38E-04	6.08E-05	6.08E-05	1.39E-05	0	0
50th	0.001	5.67E-04	5.67E-04	2.66E-04	4.17E-05	3.67E-05
75th	0.047	0.033	0.033	0.010	0.002	0.002
95th	1.40	0.738	0.738	0.505	0.332	0.190
Max	132	132	132	132	132	55.1

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total cadmium BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-13. Baseline Chromium VI Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – BCFs for chromium VI are not available; EPA used the total chromium BCF values. The wildlife module applies the same total chromium BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

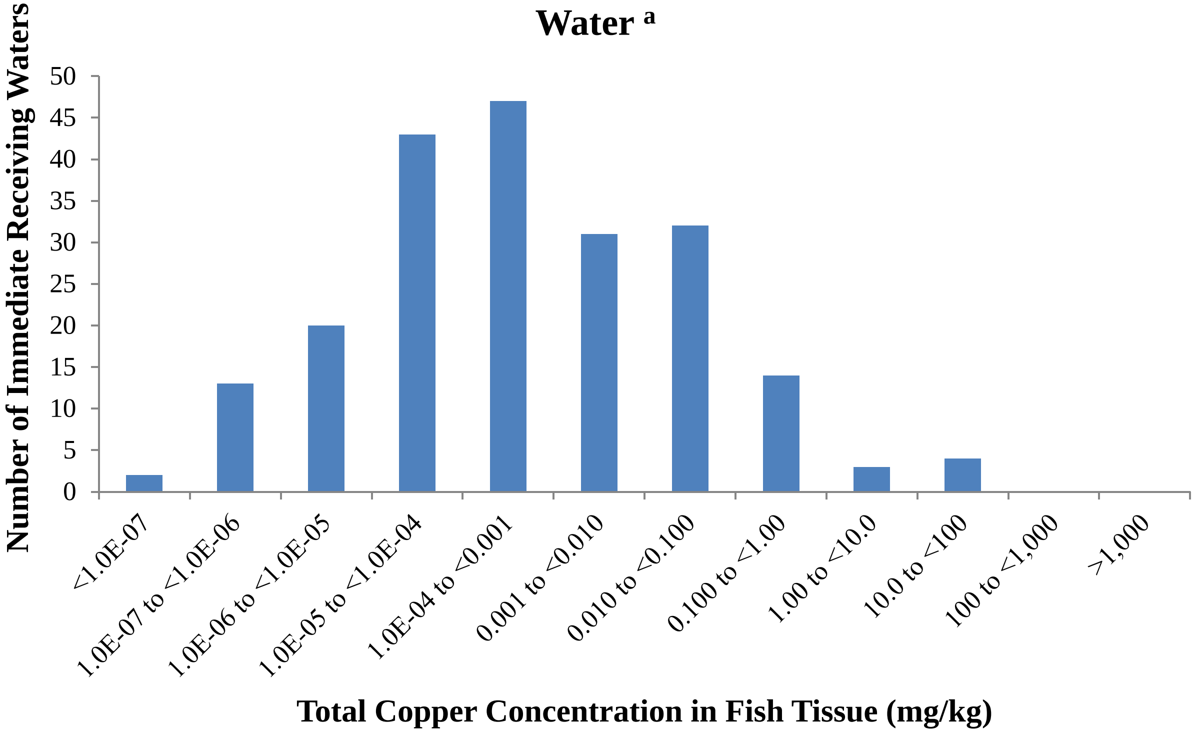
Table H-14. Chromium VI Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	0	0	0	0	0	0
25th	0	0	0	0	0	0
50th	0	0	0	0	0	0
75th	0	0	0	0	0	0
95th	3.67E-07	5.18E-08	5.18E-08	3.91E-09	0	0
Max	0.011	0.008	0.008	0.008	0.008	0.008

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total chromium BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-14. Total Copper Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total copper BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

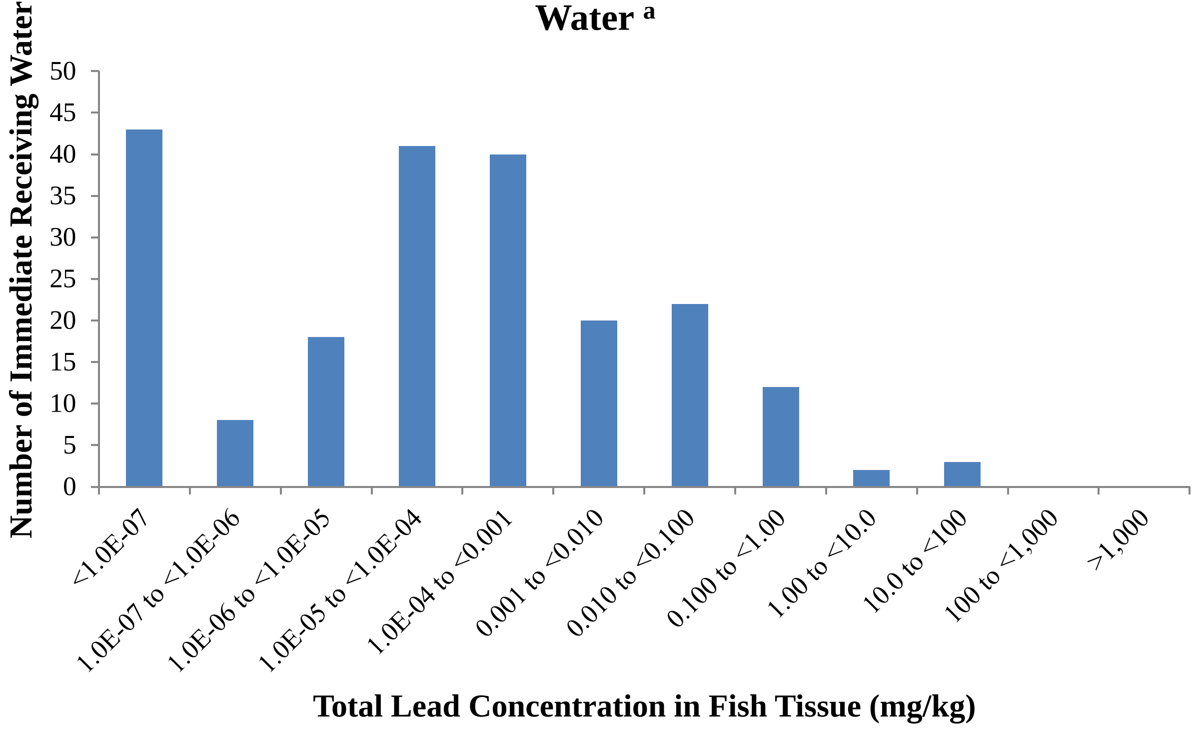
Table H-15. Total Copper Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	5.89E-07	3.65E-07	3.65E-07	0	0	0
25th	3.19E-05	1.93E-05	1.93E-05	2.83E-06	0	0
50th	2.99E-04	2.26E-04	2.26E-04	5.66E-05	4.78E-06	4.36E-06
75th	0.010	0.008	0.008	0.002	2.56E-04	2.26E-04
95th	0.540	0.340	0.340	0.072	0.036	0.023
Max	41.5	28.0	28.0	28.0	28.0	28.0

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total copper BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-15. Total Lead Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total lead BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-16. Total Lead Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	0	0	0	0	0	0
25th	2.12E-06	7.94E-07	7.94E-07	0	0	0
50th	7.01E-05	4.95E-05	4.95E-05	5.57E-06	0	0
75th	0.001	0.001	0.001	1.83E-04	1.03E-05	1.03E-05
95th	0.343	0.319	0.319	0.047	0.002	0.002
Max	34.8	23.5	23.5	23.5	23.5	23.5

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total lead BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

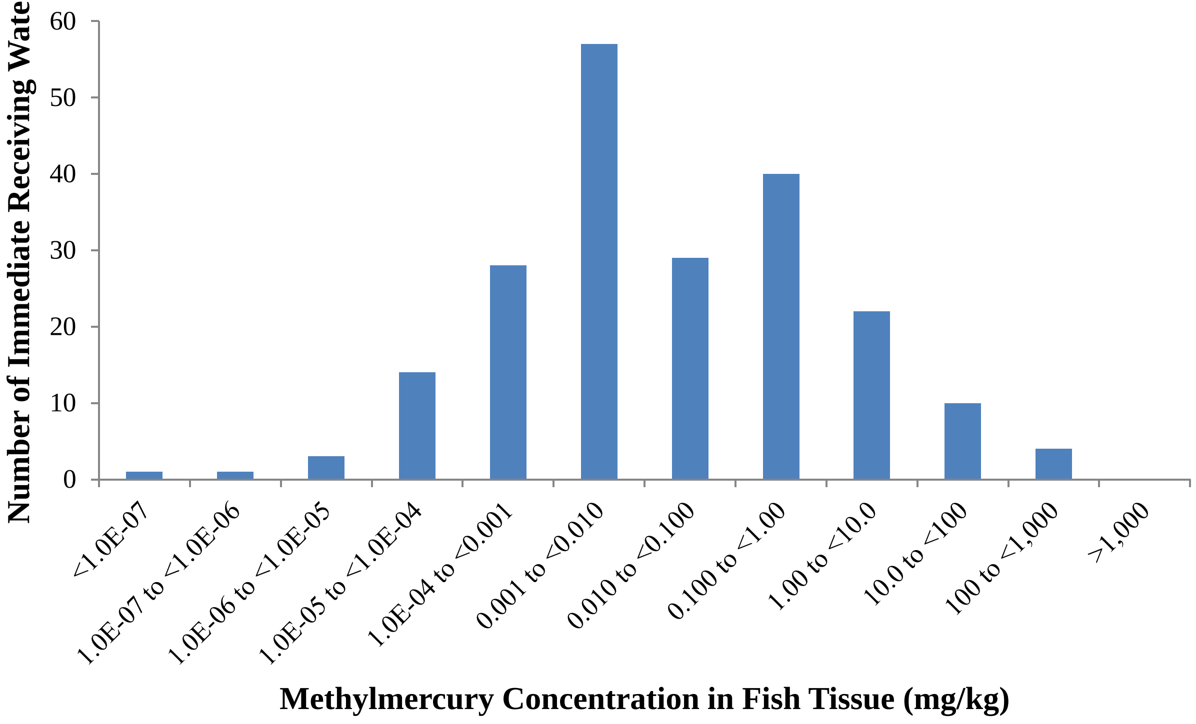


Figure H-16. Methylmercury Concentration in Trophic Level 3 Fish Tissue in the Immediate Receiving Water

Source: ERG, 2015d; ERG, 2015i.

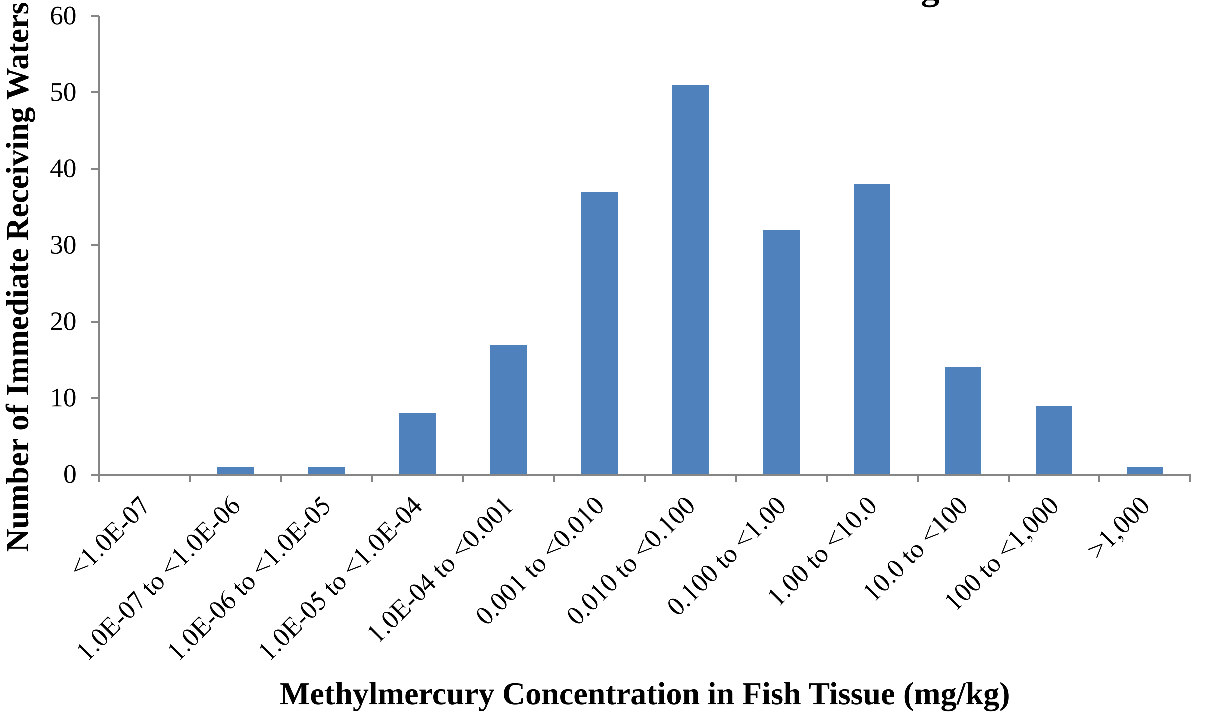
Table H-17. Methylmercury Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	2.86E-05	1.63E-05	9.58E-06	0	0	0
25th	0.001	8.10E-04	4.69E-04	5.71E-05	0	0
50th	0.010	0.005	0.005	0.001	1.76E-04	9.28E-05
75th	0.455	0.314	0.279	0.045	0.006	0.004
95th	16.826	9.42	9.42	2.66	1.43	0.230
Max	414.6	183	183	183	183	183

Source: ERG, 2015d; ERG, 2015i.

a – EPA calculated methylmercury fish tissue concentrations using bioaccumulation factors which do not fully account for the complexity of biogeochemical reactions that can occur within an aquatic environment and result in lower bioaccumulation rates of mercury in fish. For example, fish are known to bioaccumulate mercury at lower rates when exposed to surface waters with high selenium concentrations. In addition, bioaccumulation factors do not account for a maximum limit a fish could accumulate before a lethal concentration is reached. To address the outliers in mercury fish tissue concentrations, EPA compared fish tissue concentrations to site-specific data available in the national fish advisory database and established calibration factors to lower the outlier values. Fish tissue concentrations presented in the figure and table above represent the uncalibrated values calculated by the wildlife model. For further details on the methodology for selecting calibration factors see ERG memorandum "EA Model Validation and Calibration" (DCN SE04454).

Figure H-17. Methylmercury Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



Source: ERG, 2015d; ERG, 2015i.

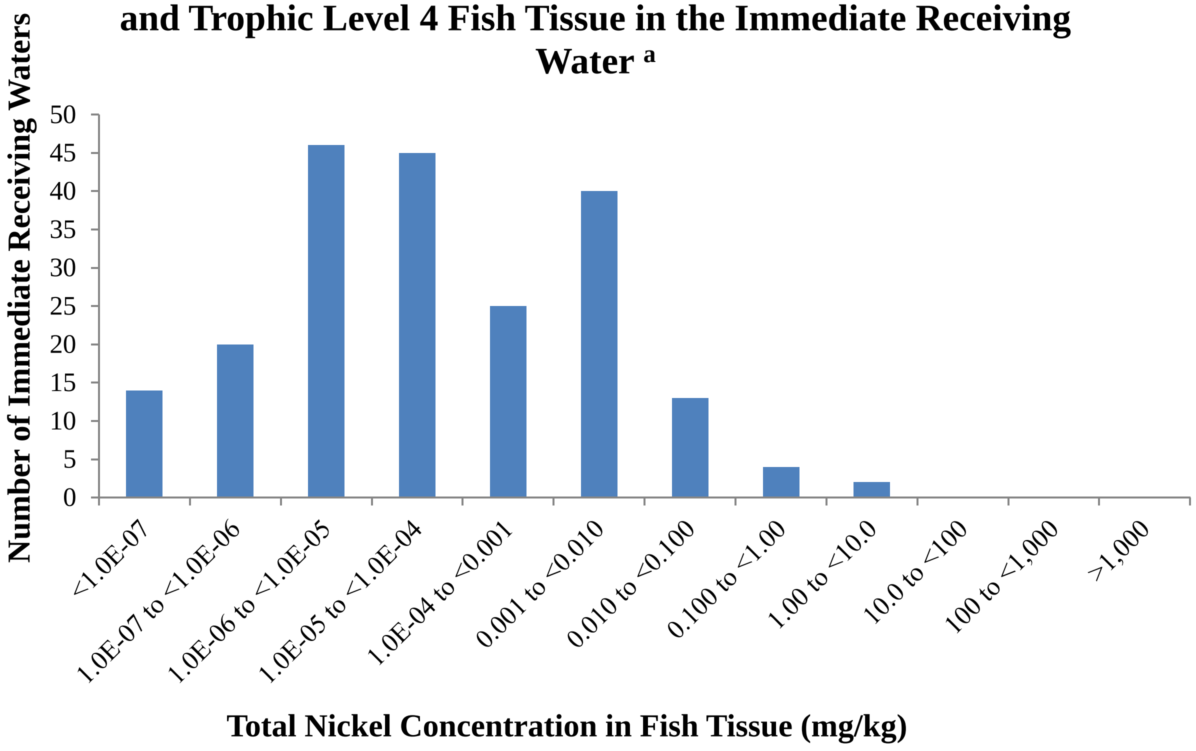
Table H-18. Methylmercury Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.21E-04	6.91E-05	4.07E-05	0	0	0
25th	0.005	0.003	0.002	2.43E-04	0	0
50th	0.044	0.021	0.020	0.006	7.48E-04	3.94E-04
75th	1.93	1.33	1.19	0.190	0.027	0.017
95th	71.5	40.1	40.1	11.3	6.07	0.976
Max	1,762	779	779	779	779	779

Source: ERG, 2015d; ERG, 2015i.

a – EPA calculated methylmercury fish tissue concentrations using bioaccumulation factors which do not fully account for the complexity of biogeochemical reactions that can occur within an aquatic environment and result in lower bioaccumulation rates of mercury in fish. For example, fish are known to bioaccumulate mercury at lower rates when exposed to surface waters with high selenium concentrations. In addition, bioaccumulation factors do not account for a maximum limit a fish could accumulate before a lethal concentration is reached. To address the outliers in mercury fish tissue concentrations, EPA compared fish tissue concentrations to site-specific data available in the national fish advisory database and established calibration factors to lower the outlier values. Fish tissue concentrations presented in the figure and table above represent the uncalibrated values calculated by the wildlife model. For further details on the methodology for selecting calibration factors see ERG memorandum “EA Model Validation and Calibration” (DCN SE04454).

Figure H-18. Total Nickel Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total nickel BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

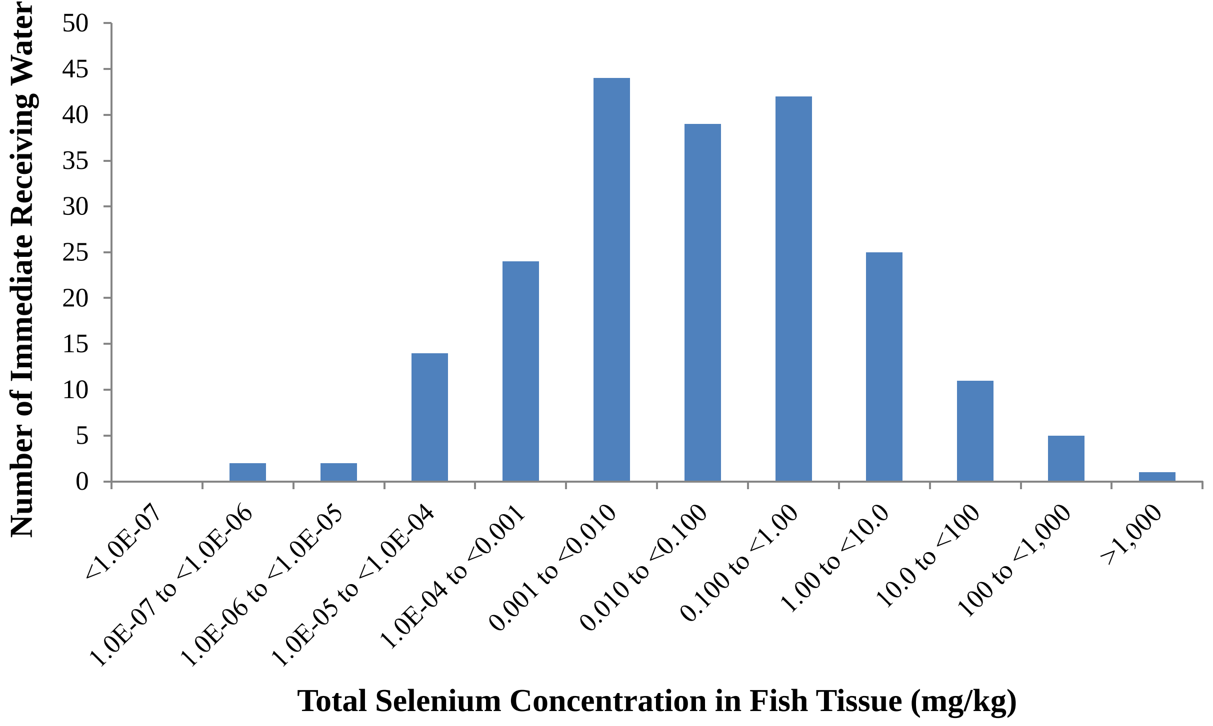
Table H-19. Total Nickel Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	5.71E-08	3.33E-08	2.40E-08	0	0	0
25th	2.65E-06	1.05E-06	8.88E-07	1.49E-07	0	0
50th	2.67E-05	1.44E-05	1.44E-05	3.66E-06	3.34E-07	1.98E-07
75th	0.001	0.001	0.001	1.09E-04	1.30E-05	8.37E-06
95th	0.040	0.027	0.027	0.007	0.003	0.001
Max	1.80	1.80	1.80	1.80	1.80	0.493

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total nickel BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-19. Total Selenium Concentration in Trophic Level 3 Fish Tissue in the Immediate Receiving Water



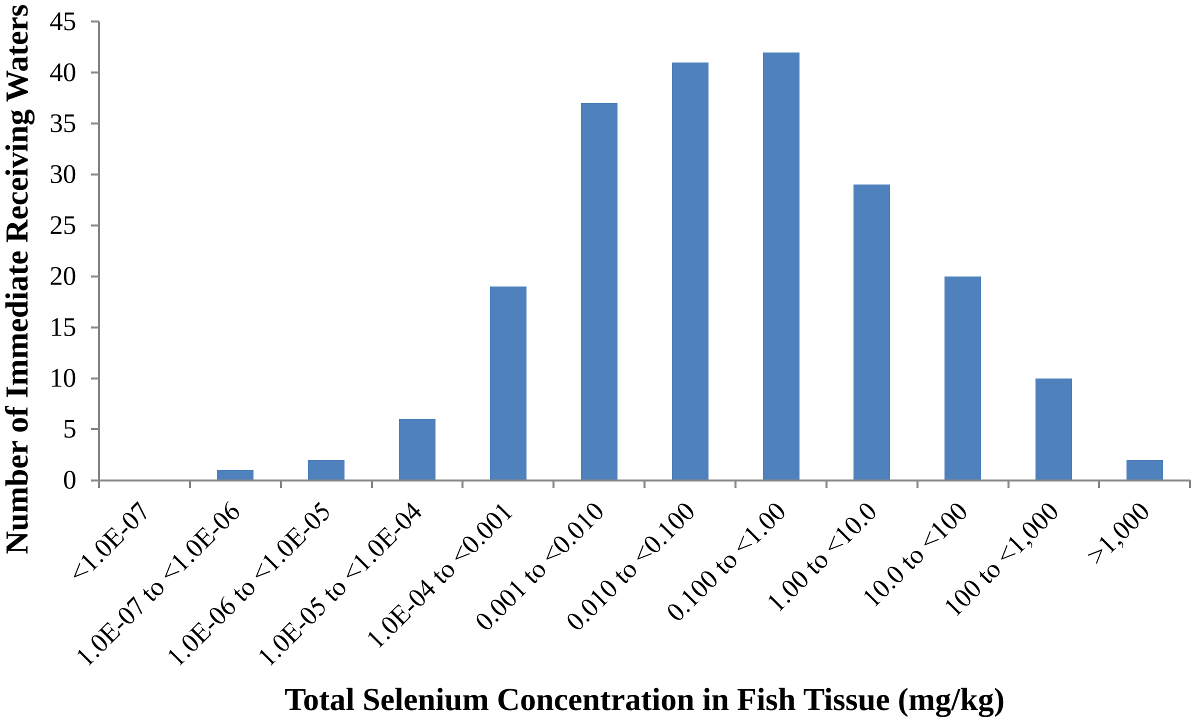
Source: ERG, 2015d; ERG, 2015i.

Table H-20. Total Selenium Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	4.47E-05	1.88E-05	1.01E-05	0	0	0
25th	0.001	0.001	2.45E-04	5.83E-05	0	0
50th	0.027	0.018	0.003	0.001	1.87E-04	1.87E-04
75th	0.428	0.374	0.151	0.047	0.013	0.013
95th	31.6	19.5	8.12	6.55	4.86	4.86
Max	2,638	2,638	2,638	2,638	2,638	2,638

Source: ERG, 2015d; ERG, 2015i.

Figure H-20. Total Selenium Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



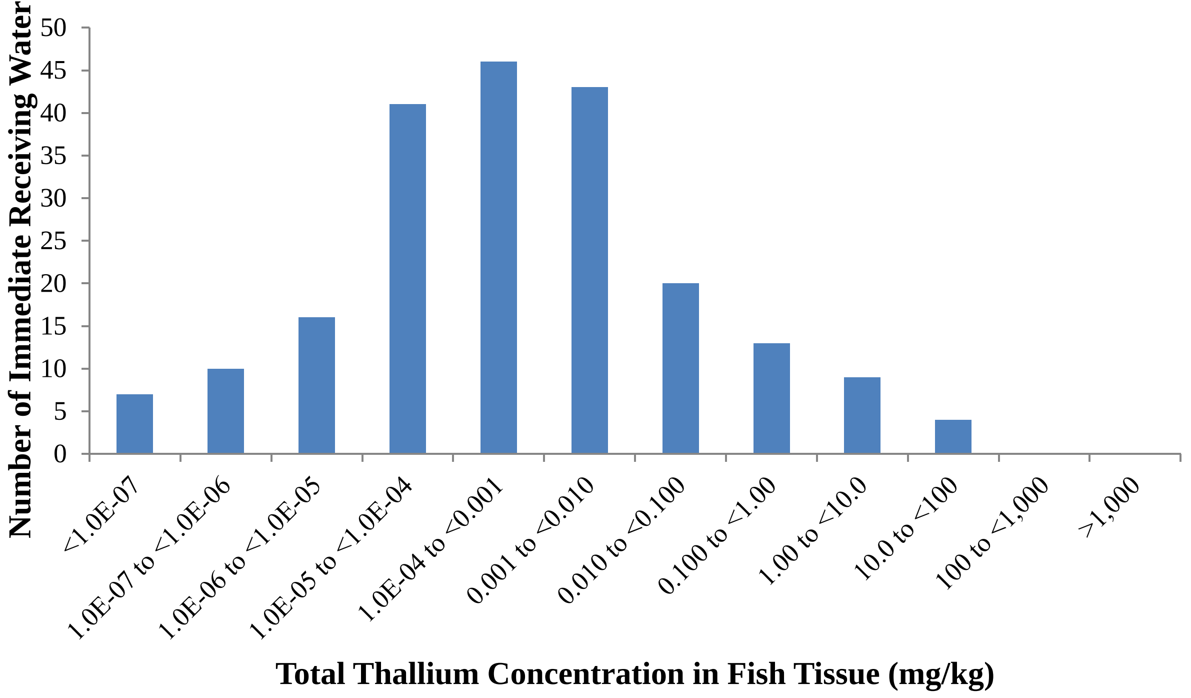
Source: ERG, 2015d; ERG, 2015i.

Table H-21. Total Selenium Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.55E-04	6.54E-05	3.49E-05	0	0	0
25th	0.005	0.004	8.51E-04	2.02E-04	0	0
50th	0.093	0.062	0.009	0.004	6.50E-04	6.50E-04
75th	1.48	1.30	0.523	0.165	0.044	0.044
95th	110	67.5	28.2	22.7	16.9	16.9
Max	9,151	9,151	9,151	9,151	9,151	9,151

Source: ERG, 2015d; ERG, 2015i.

Figure H-21. Total Thallium Concentration in Trophic Level 3 Fish Tissue in the Immediate Receiving Water



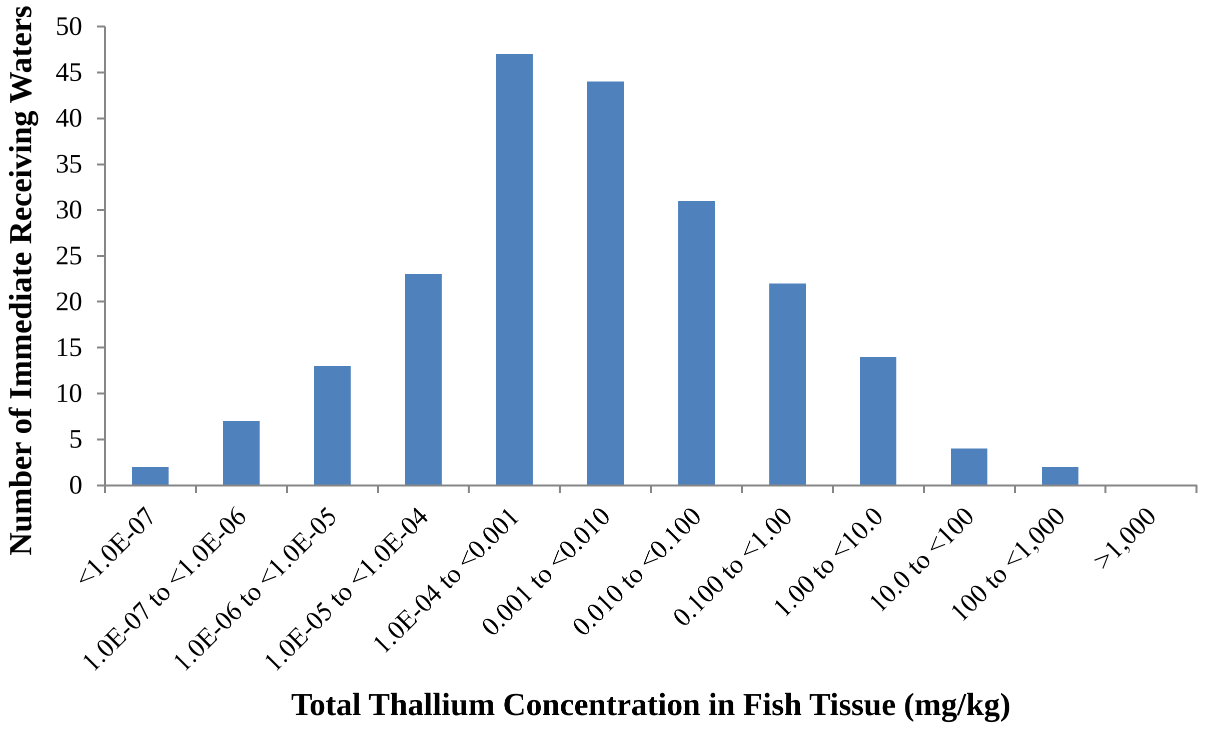
Source: ERG, 2015d; ERG, 2015i.

Table H-22. Total Thallium Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	3.70E-07	2.02E-07	2.02E-07	0	0	0
25th	4.46E-05	2.66E-05	2.66E-05	2.07E-06	0	0
50th	5.05E-04	4.07E-04	4.07E-04	7.91E-05	6.43E-06	6.43E-06
75th	0.006	0.005	0.005	0.001	2.00E-04	2.00E-04
95th	1.20	1.13	1.13	0.131	0.012	0.012
Max	59.6	59.6	59.6	59.6	20.1	20.1

Source: ERG, 2015d; ERG, 2015i.

Figure H-22. Total Thallium Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



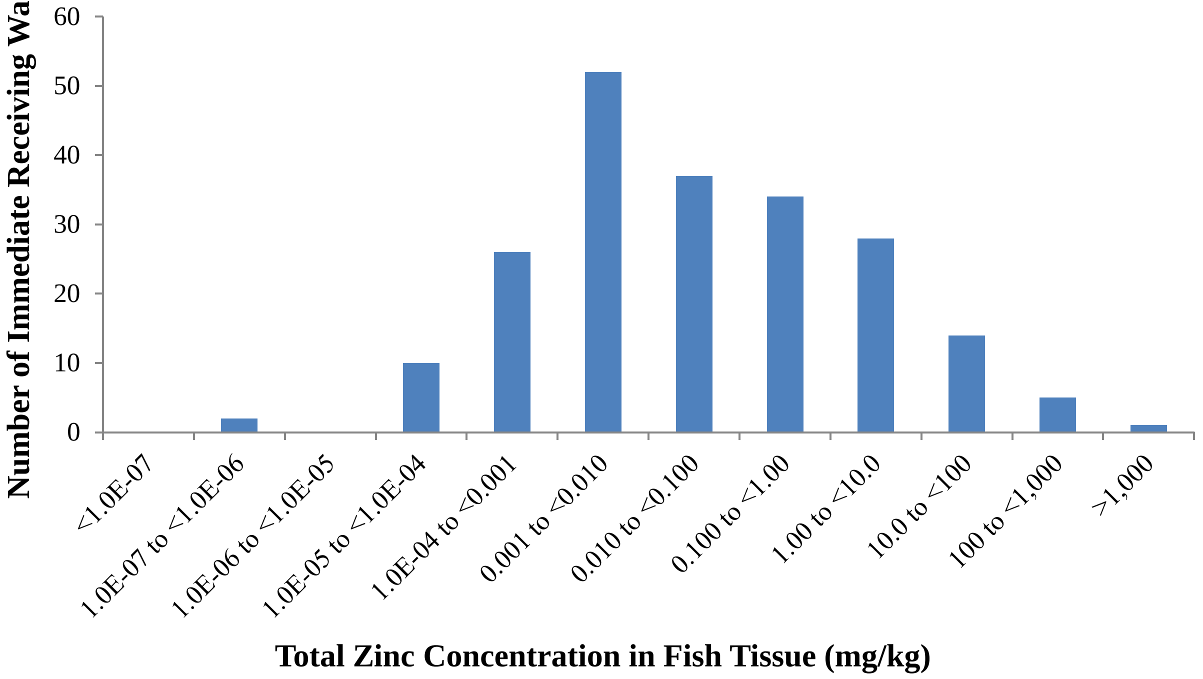
Source: ERG, 2015d; ERG, 2015i.

Table H-23. Total Thallium Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile

	Scenario					
Percentile	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.41E-06	7.74E-07	7.74E-07	0	0	0
25th	1.70E-04	1.02E-04	1.02E-04	7.90E-06	0	0
50th	0.002	0.002	0.002	3.02E-04	2.46E-05	2.46E-05
75th	0.025	0.020	0.020	0.005	7.63E-04	7.63E-04
95th	4.58	4.31	4.31	0.500	0.044	0.044
Max	228	228	228	228	76.8	76.8

Source: ERG, 2015d; ERG, 2015i.

Figure H-23. Total Zinc Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total zinc BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-24. Total Zinc Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	7.25E-05	3.20E-05	3.20E-05	0	0	0
25th	0.002	8.50E-04	8.50E-04	1.63E-04	0	0
50th	0.022	0.007	0.007	0.004	5.04E-04	2.74E-04
75th	0.809	0.687	0.687	0.144	0.027	0.012
95th	28.4	13.6	13.6	11.0	6.59	1.17
Max	3,576	3,576	3,576	3,576	3,576	501

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total zinc BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

APPENDIX I
ANALYSIS FOR ALTERNATE SCENARIO WITH CLEAN POWER PLAN

As discussed in Section 1, the environmental assessment (EA) report presents the methodology and results of the qualitative and quantitative analyses performed to evaluate baseline discharges from steam electric power plants and improvements under the final steam electric effluent limitations guidelines and standards (ELGs). The analyses presented in the report incorporate some adjustments to current conditions in the industry. The analyses in the report, however, do not reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)] (CPP). This appendix presents the results of EPA's quantitative EA analysis that does reflect changes in the industry that may occur as a result of the CPP. Table I-1 presents the number of plants included in this alternate scenario analysis compared to those in the EA report.

Table I-1. Number of Plants Evaluated in the EA Alternate Scenario Analysis Compared to the EA Report

Plant Description	Number of Plants in EA Report	Number of Plants in Alternate Scenario Analysis
Number of Plants in Scope of Final Rule		
Plants that fall under the applicability of the final rule (40 CFR 423)	1,079	1,079
Cost and Loadings Analysis		
Plants for which EPA calculated loadings in the cost and loadings analyses (see Sections 9 and 10 of the TDD)	202	151
Plants that discharge only to surface waters (direct discharger)	191	145
Plants that discharge only to a POTW (indirect discharger)	7	3
Plants that discharge to surface waters and to a POTW (direct and indirect discharger)	4	3
Environmental Assessment		
Plants evaluated in the EA (includes all direct dischargers)[a]	195	148

Acronyms: CFR (Code of Federal Regulations); POTW (publicly owned treatment works); TDD (*Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD)*, Document No. EPA-821-R-15-007)

a – For the pollutant loadings and removals presented in this appendix, EPA included indirect dischargers to protect confidential business information.

The 148 steam electric power plants in the EA alternate scenario analysis discharge to the 172 immediate receiving waters illustrated in Figure I-1 (some plants discharge to multiple receiving waters). Table I-2 presents the count of receiving water types for the 172 immediate receiving waters.

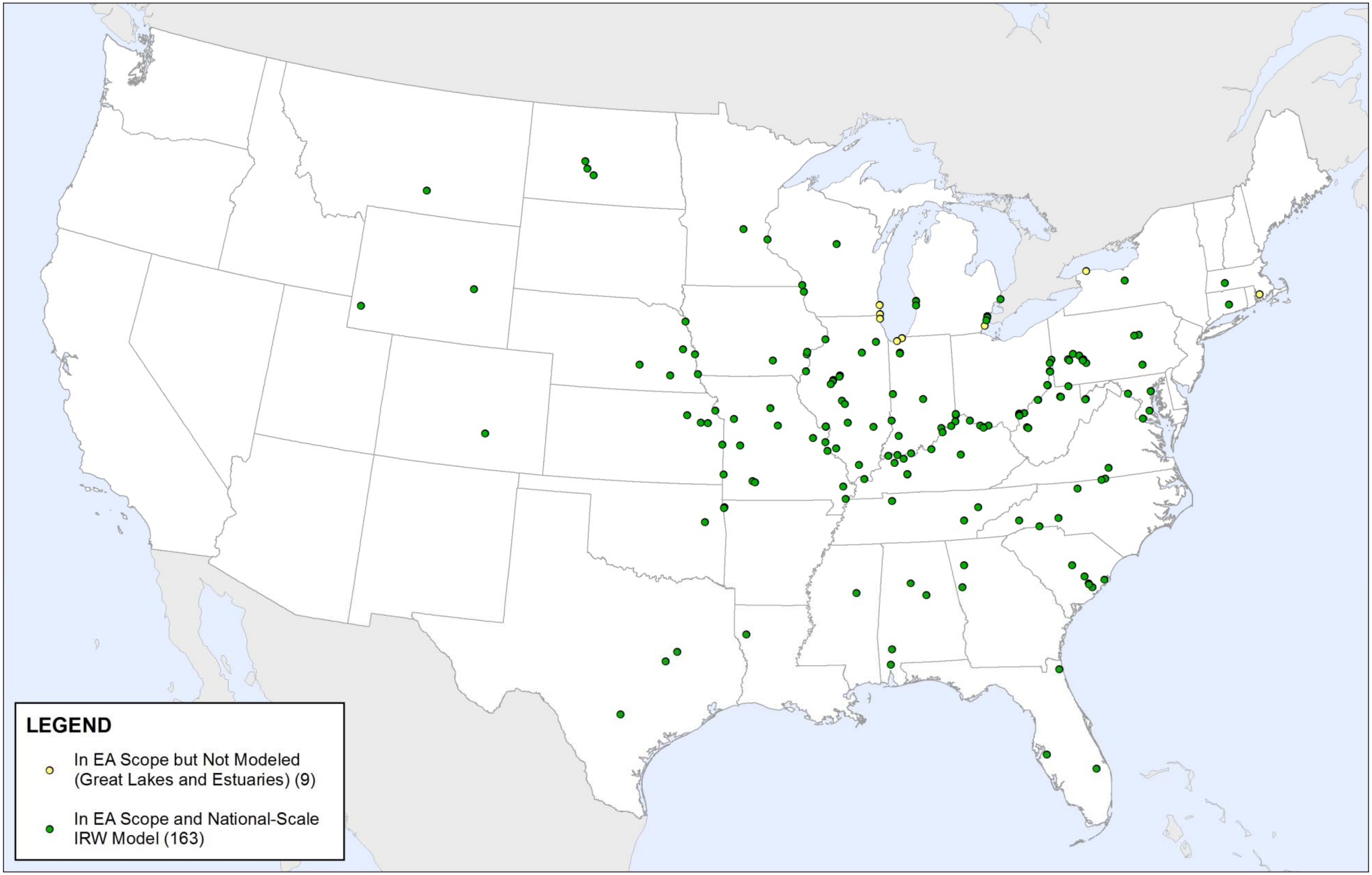


Figure I-1. Locations and Counts of Immediate Receiving Waters in EA Scope and Modeling Analyses

Table I-2. Receiving Water Types for Steam Electric Power Plants Evaluated in the EA

Receiving Water Type	Number (Percentage) of Immediate Receiving Waters in the Alternate Scenario Analysis [a]
River/Stream	144 (84%)
Lake/Pond/Reservoir	19 (11%)
Great Lakes	8 (5%)
Estuary	1 (<1%)
Total Receiving Waters	**172 (100%)**

Source: ERG, 2015d.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The immediate receiving water (IRW) model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

EPA evaluated the annual baseline pollutant discharges of the evaluated wastestreams from steam electric power plants reflecting changes in the industry that may occur as a result of the CPP. Table I-3 presents the annual pollutant loadings in pounds and toxic-weighted pound equivalents (TWPE).[1,2] Table I-4 compares pollutant discharges, as TWPE, from the steam electric power generating industry to discharges from the other top ten discharging point source categories, as estimated by EPA for the 2010 Effluent Guidelines Planning Process [U.S. EPA, 2011d].

---

[1] To calculate the TWPE, EPA multiplies a mass loading of a pollutant in pounds per year (lb/yr) by a pollutant-specific weighting factor, called the toxic weighting factor (TWF), to derive a "toxic equivalent" loading (lb-equivalent/yr), or TWPE. TWFs account for differences in toxicity across pollutants and allow mass loadings of different pollutants to be compared on the basis of their toxic potential. EPA has developed TWFs for more than 1,000 pollutants based on aquatic life and human health toxicity data, as well as physical/chemical property data [U.S. EPA, 2012b].

[2] Prior to finalizing the rulemaking, EPA revised the datasets used to calculate pollutant loadings for bottom ash transport water and fly ash transport water. The final industry loadings calculated using these revised datasets are presented in the TDD. The total industry loadings presented in Appendix I reflect the revised datasets. However, EPA did not rerun the EA models and other analyses to reflect the final loadings dataset. EA analyses used previously calculated version of the steam electric power plant pollutant loadings that were derived following the same methodology. The EA pollutant loadings are included in DCN SE05622. Pollutant-specific loadings and removals presented in this report are based on the previously calculated version. Appendix J presents the results of a sensitivity analysis that evaluated the potential for these loadings revisions to affect the EA analyses.

Table I-3. Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams)

Pollutant [a]	TWF [b]	Annual Discharge, pounds (lbs) [c]	Annual TWPE, pound-equivalent (lb-eq) [c]
Metals and Toxic Bioaccumulative Pollutants			
Manganese	0.103	6,320,000	649,000
Cadmium	22.8	10,900	249,000
Boron	0.00834	24,600,000	205,000
Mercury	110.0	1,180	129,000
Selenium	1.12	113,000	127,000
Thallium	2.85	43,900	125,000
Arsenic	3.47	22,200	77,100
Aluminum	0.0647	1,070,000	69,400
Lead	2.24	14,600	32,700
Vanadium	0.280	55,600	15,600
Copper	0.623	24,000	15,000
Iron	0.00560	2,110,000	11,800
Nickel	0.109	94,200	10,300
Zinc	0.0469	145,000	6,800
Chromium VI	0.517	119	61.4
Nutrients			
Total Nitrogen [d]	Not applicable	13,100,000	Not applicable
Total Phosphorus	Not applicable	154,000	Not applicable
Other			
Chlorides	2.435×10^{-5}	722,000,000	17,600
Total dissolved solids	Not applicable	3,290,000,000	Not applicable
Total Pollutants [e]		**1,700,000,000**	**2,140,000**

Sources: Abt, 2008; ERG, 2015a; ERG, 2015b; ERG, 2015f; U.S. EPA, 2012c.

Note: Numbers are rounded to three significant figures.

a – The list of pollutants included in this table is only a subset of pollutants included in the loadings analysis (see Section 10 of the Technical Development Document (TDD) (EPA-821-R-15-007).

b – TWFs for the following metals apply to all metal compounds: arsenic, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. EPA updated TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium for the steam electric ELGs pollutant loadings analysis.

c – These loadings reflect adjustments to current conditions in the industry to account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants; changes to the industry that are expected to occur as a result of the recent Coal Combustion Residuals (CCR) rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER); and changes to the industry that are expected to occur as a result of the CPP. Data source for pollutant specific loadings is DCN SE05622.

d – Total nitrogen is the sum of total Kjeldahl nitrogen and nitrate/nitrite as N.

e – The totals represent the pollutant loadings in discharges of the evaluated wastestreams – specifically, flue gas desulfurization (FGD) wastewater, fly ash transport wastewater, bottom ash transport wastewater, and combustion residual leachate (see Section 10 of the TDD). Loadings presented are based on the final loadings analysis presented in the TDD. The totals exclude loadings for pollutants not identified as pollutants of concern (POCs) and for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total dissolved solids (TDS), and total suspended solids (TSS).

Table I-4. Pollutant Loadings for the Final 2010 Effluent Guidelines Planning Process: Top 10 Point Source Categories

40 CFR Part	Point Source Category	Total TWPE [a] (lb-eq/yr)
423	Steam Electric Power Generating	2,140,000 [b]
430	Pulp, Paper, And Paperboard	1,030,000
419	Petroleum Refining	1,030,000
421	Nonferrous Metals Manufacturing	994,000
418	Fertilizer Manufacturing	826,000
414	Organic Chemicals, Plastics, And Synthetic Fibers	649,000
440	Ore Mining And Dressing	448,000
415	Inorganic Chemicals Manufacturing	299,000
444	Waste Combustors	254,000
410	Textile Mills	250,000

Source: U.S. EPA, 2011d.

Note: Numbers are rounded to three significant figures.

a – Only TWPE totals for the steam electric power generating industry include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium. The TWPE for all other point source categories is estimated from discharge monitoring reports (DMRs) and Toxic Release Inventory (TRI) reporting and may include double-counting of certain pollutant discharges (*i.e.*, a facility must report a pollutant on both its DMR and its TRI reporting form).

b –EPA calculated the steam electric power generating industry (40 CFR 423) discharges for the alternate scenario analysis as total of 2,140,000 TWPE annually (see Section 10 of the TDD).

EPA estimated that the total alternate scenario analysis TWPE from steam electric power plant wastewater (see Table I-4) is over two times the amount estimated for the pulp, paper, and paperboard industry; petroleum refining industry; and nonferrous metals manufacturing (second, third, and fourth highest ranking), and it is over five times the TWPE for four of the six other industries identified as the top TWPE dischargers in the Final 2010 Effluent Guidelines Program Plan [U.S. EPA, 2011d].[3]

To provide additional perspective on the magnitude of the pollutant loadings from steam electric power plants in the alternate scenario analysis, EPA compared loadings for the evaluated wastestreams to those of an average publicly owned treatment works (POTW). Table I-5 compares the average steam electric pollutant loadings by wastestream[4] to the pollutant loadings from an average POTW assumed to discharge 3 to 5 MGD. EPA also calculated the equivalent number of typical POTWs that would discharge loadings equal to the 151 steam electric power plants[5] included in the alternate scenario analysis. Table I-6 presents total pollutant loadings for

---

[3] Data sources for the other industry discharges include DMRs and TRI reports. EPA recognizes that the DMR and TRI data have limitations (*e.g.*, only a subset of facilities and a subset of pollutants might be included in the estimated loadings); however, these are the most readily available data sets that represent discharges across the United States.

[4] EPA calculated the average pollutant loadings for each wastestream by dividing the total pollutant loadings for the wastestream by the number of steam electric power plants discharging the wastestream [ERG, 2015a].

[5] The count of 151 steam electric power plants includes three indirect dischargers that discharge wastewater to a POTW and do not discharge any of the evaluated wastestreams directly to surface waters. EPA included these indirect dischargers to protect confidential business information.

the evaluated wastestreams (for the 151 plants) and the number of typical POTWs that would discharge equivalent loadings.

Table I-5. Comparison of Average Pollutant Loadings in the Evaluated Wastestreams to an Average POTW

Pollutant	Average Plant FGD Wastewater Discharge [a,b]		Average Plant Fly Ash Transport Water Discharge [a,c]		Average Plant Bottom Ash Transport Water Discharge [a,d]		Average Plant Combustion Residual Leachate Discharge [a,e]		Average POTW Discharge [a,f]	
	Loadings (lbs/yr)	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**
Aluminum	1,720	111	9,010	583	3,880	251	988	63.9	3,590	215
Arsenic	9.68	33.6	310	1,080	61.1	212	12.7	44.2	45.9	159
Boron	333,000	2,780	19,800	166	2,060	17.2	7,700	64.2	1,540	12.8
Cadmium	91.7	2,090	49.2	1,120	17.7	403	3.39	77.2	3.54	80.6
Chromium VI	(g)	(g)	2.48	1.28	0.145	0.0750	(g)	(g)	17.7	9.02
Copper	19.6	12.2	282	176	83.0	51.7	2.55	1.59	154	95.3
Iron	1,270	7.10	5,740	32.1	6,960	39.0	12,200	68.5	2,530	14.2
Lead	5.82	13.0	157	351	58.6	131	(g)	(g)	48.5	109
Manganese	81,800	8,400	522	53.6	4,340	446	933	95.8	354	36.1
Mercury	6.24	687	7.76	854	3.04	334	0.351	38.7	3,180	350,000
Nickel	701	76.4	188	20.5	275	30.0	15.4	1.68	30.6	3.06
Selenium	1,470	1,640	132	148	29.5	33.1	36.7	41.2	18.5	20.7
Thallium	17.0	48.6	134	384	276	789	0.399	1.14	9.94	28.2
Vanadium	21.0	5.87	209	58.5	12.2	3.42	631	177	No data	No data
Zinc	1,110	52.3	814	38.2	227	10.6	69.8	3.27	453	18.1
Total Nitrogen	132,000	--	25,000	--	22,500	--	(g)	--	123,000	--
Total Phosphorus	453	--	849	--	657	--	(g)	--	17,800	--
Chlorides	10,100,000	246	84,600	2.06	88,500	2.16	142,000	3.45	1,610,000	39.3
TDS	40,800,000	--	1,870,000	--	2,340,000	--	1,200,000	--	No data	--

Note: Numbers are rounded to three significant figures.

a – TWPE presented in the table include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium.

b – Average loadings based on 69 plants assumed to discharge FGD wastewater under baseline conditions [ERG, 2015a].

c – Average loadings based on 40 plants assumed to discharge fly ash transport water under baseline conditions [ERG, 2015a].

d – Average loadings based on 135 plants assumed to discharge bottom ash transport water under baseline conditions [ERG, 2015a].

e – Average loadings based on 70 plants assumed to discharge combustion residual leachate under baseline conditions [ERG, 2015a].

f – Average loadings based on average loadings calculated for POTWs discharging 3 to 5 MGD of wastewater (see DCN SE01961).

g – EPA did not calculate loadings for this pollutant and wastestream. See the Costs and Loads Report (DCN SE05831).

Table I-6. Estimated Number of POTW Equivalents for Total Pollutant Loadings from the Evaluated Wastestreams

Pollutant	Annual Discharge pounds (lbs) [a]	Equivalent Number of Average POTWs [b]
Aluminum	1,070,000	299
Arsenic	22,200	484
Boron	24,600,000	16,000
Cadmium	10,900	3,090
Chromium VI	119	6.72
Copper	24,000	156
Iron	2,110,000	835
Lead	14,600	301
Manganese	6,320,000	17,800
Mercury	1,180	0.370
Nickel	94,200	3,080
Selenium	113,000	6,110
Thallium	43,900	4,410
Vanadium	55,600	No values for comparison
Zinc	145,000	320
Total Nitrogen	13,100,000	107
Total Phosphorus	154,000	8.65
Chlorides	722,000,000	448
TDS	3,290,000,000	No values for comparison

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Annual discharge based on pollutant discharges from 151 steam electric power plants, including three indirect dischargers.

b – Equivalent number of POTWs is estimated by dividing the total annual pollutant loadings from the 151 steam electric power plants by the average POTW loadings presented in Table I-5 for a 4-MGD POTW.

EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located in close proximity to sensitive environments. Table I-7 summarizes the number and percentage of immediate receiving waters in the alternate scenario analysis that are located in sensitive environments.

Table I-7. Number and Percentage of Immediate Receiving Waters Identified as Sensitive Environments

Sensitive Environment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Great Lakes watershed	15 (9%)
Chesapeake Bay watershed	11 (6%)
Impaired water	91 (53%)
Surface water impaired for a subset of pollutants associated with the evaluated wastestreams [b]	45 (26%)
Fish consumption advisory water	116 (67%)
Surface water with a fish consumption advisory for a subset of pollutants associated with the evaluated wastestreams [c]	79 (46%)
Drinking water resource within 5 miles	152 (88%)

a – For the sensitive environment proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – Table B-1 in Appendix B contains a complete list of the impairment categories identified in EPA’s 303(d)-listed waters and designates the subset of pollutants evaluated.

c – Table B-2 in Appendix B contains a complete list of the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

d – The values presented in Section 3.4.5 of the report are based on an analysis of habitat locations that reflect changes in the industry as a result of the CPP.

Table I-8 and Table I-9 present the pollutant loadings to the Great Lakes watershed and the Chesapeake Bay watershed, respectively, accounting for changes in the industry baseline as a result of the CPP. Table I-10 presents the number of immediate receiving waters classified as impaired in the alternate scenario analysis.

Based on a review of immediate receiving waters that reflect changes in the industry as a result of the CPP, EPA determined that 116 immediate receiving waters (67 percent) are under fish consumption advisories; 79 of the immediate receiving waters (46 percent) are under an advisory for a pollutant associated with the evaluated wastestreams.[6] All of these 79 immediate receiving waters are under a fish consumption advisory for mercury and one of the receiving waters is also under a fish consumption advisory for lead.

The results of the threatened and endangered species analysis presented in Section 3.4.5 already account for changes in the industry as a result of the CPP. Table I-11 presents the number of steam electric power plants located within five miles of a drinking water resource and the number of drinking water resources located within five miles of a steam electric power plant.

---

[6] Table B-2 in Appendix B lists the types of advisories identified under the sensitive environment proximity analysis, including advisories for pollutants that are not associated with the evaluated wastestreams.

Table I-8. Pollutant Loadings to the Great Lakes Watershed from the Evaluated Wastestreams [a]

Pollutant	Annual Discharge to the Great Lakes Watershed (lbs)	Annual TWPE Discharge to the Great Lakes Watershed (lb-eq)
Arsenic	1,030	3,590
Boron	760,000	6,340
Cadmium	286	6,520
Chromium VI	0.548	0.283
Copper	1,170	728
Lead	869	1,950
Manganese	112,000	11,500
Mercury	37.5	4,130
Nickel	4,310	470
Selenium	3,540	3,960
Thallium	4,320	12,300
Zinc	3,860	181
Total Nitrogen	646,000	--
Total Phosphorus	10,900	--
Chlorides	24,100,000	587
Total Dissolved Solids	116,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Pollutant loadings based on 14 steam electric power plants discharging to 15 immediate receiving waters in the Great Lakes watershed.

Table I-9. Pollutant Loadings to the Chesapeake Bay Watershed from the Evaluated Wastestreams [a]

Pollutant	Annual Discharge to the Chesapeake Bay Watershed (lbs)	Annual TWPE Discharge to the Chesapeake Bay Watershed (lb-eq)
Arsenic	680	2,360
Boron	1,080,000	9,000
Cadmium	199	4,530
Chromium VI	0	0
Copper	765	477
Lead	571	1,280
Manganese	106,000	10,900
Mercury	24.4	2,690
Nickel	2,880	313
Selenium	4,710	5,290
Thallium	2,880	8,210
Zinc	2,630	123
Total Nitrogen	670,000	--
Total Phosphorus	7,920	--
Chlorides	34,200,000	832
Total Dissolved Solids	139,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Pollutant loadings based on seven steam electric power plants discharging to 11 immediate receiving waters in the Chesapeake Bay watershed.

Table I-10. Number and Percentage of Immediate Receiving Waters Classified as Impaired for a Pollutant Associated with the Evaluated Wastestreams

Pollutant Causing Impairment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Mercury	21 (12%)
Metals, other than mercury [b]	24 (14%)
Nutrients	15 (9%)
TDS, including chlorides	2 (1%)
Total for Any Pollutant [c]	**56 (33%)**

a – For the impaired waters proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – The EPA impaired water database listed 24 immediate receiving waters as impaired based on the “metal, other than mercury” impairment category. Of those 24 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals in the EA analysis (arsenic, cadmium, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

c – Total does not equal the sum of the immediate receiving waters listed in the table. Some immediate receiving waters are impaired for multiple pollutants.

Table I-11. Comparison of Number and Percentage of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource

Type of Drinking Water Resource	Number of Drinking Water Resources within 5 Miles of a Steam Electric Power Plant	Number (Percentage) of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource [a]
Intakes and reservoirs	87	52 (35%)
Public wells [b]	1,530	116 (78%)
Sole-source aquifers	5	5 (3%)

Sources: ERG, 2015c; ERG, 2015d.

a – For the drinking water resource proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams from 148 steam electric power plants.

b – Counts include two springs and 29 wellheads.

Current impacts from the steam electric power generating industry under the alternate scenario analysis include water quality impacts (Table I-12); wildlife impacts (Table I-13 and Table I-14); impacts to benthic organisms (Table I-15); human health impacts to national-scale cohorts representing recreational and subsistence fishers (Table I-16 through Table I-19); and human health impacts to cohorts representing recreational and subsistence fishers by race or Hispanic origin (Table I-20 and Table I-21, respectively).

The ecological risk modeling results under the alternate scenario analysis indicate that 16 percent of the lakes, ponds, and reservoirs (3 out of 19) and 13 percent of the rivers and streams (18 out of 144) that receive discharges of the evaluated wastestreams present an elevated risk of negative reproductive impacts to fish. For mallards, the counts are slightly higher, with the same number of lakes, ponds, and reservoirs and 15 percent of the rivers and streams (22 out of 144) presenting these risks.

Selecting the 90th percentile modeled egg/ovary concentration, meaning there is a 10 percent probability that the egg/ovary concentrations are greater than the selected concentration, reveals that 19 percent of the immediate receiving waters (31 out of 163) present reproductive risks to at least 10 percent of the exposed fish population. The results for mallards (20 percent) are very similar. These counts are considerably higher than the results obtained using the median modeled egg/ovary concentration, indicating the potential for more widespread ecological impacts among those waterbodies and food webs that tend to experience higher bioaccumulation of selenium.

Table I-12. Number and Percentage of Immediate Receiving Waters with Estimated Water Concentrations that Exceed the Water Quality Criteria

Evaluation Criterion		Number of Immediate Receiving Waters Exceeding a Criterion [a]			
		Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters [b]	
				Number Exceeding	Percentage Exceeding
Aquatic Life Criteria	Freshwater Acute NRWQC	7	0	7	4%
	Freshwater Chronic NRWQC	25	3	28	17%
Human Health Criteria	Human Health Water and Organism NRWQC	61	12	73	45%
	Human Health Organism Only NRWQC	44	7	51	31%
	Drinking Water MCL	25	4	29	18%
Total Number of Unique Immediate Receiving Waters [c]		61	12	73	45%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NRWQC (National Recommended Water Quality Criteria); MCL (maximum contaminant level).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceeded at least one criterion.

Table I-13. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Waterbody Type)

Evaluation Criterion	Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [a,b]	
			Number Exceeding	Percentage Exceeding
Mink fish consumption NEHC	38	8	46	28%
Eagle fish consumption NEHC	48	8	56	34%
Total Number of Unique Immediate Receiving Waters [c]	48	8	56	34%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i

Acronyms: NEHC (No Effect Hazard Concentration).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceed a criterion.

Table I-14. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Pollutant)

	Mink			**Eagle**		
	Fish Consumption NEHC (ug/g) [a]	**Immediate Receiving Waters**		**Fish Consumption NEHC (ug/g)** [a]	**Immediate Receiving Waters**	
Pollutant		**Number Exceeding** [b]	**Percentage Exceeding**		**Number Exceeding** [b]	**Percentage Exceeding**
Arsenic	7.65	0	0%	22.4	0	0%
Cadmium	5.66	5	3%	14.7	4	2%
Chromium VI	17.7 [c]	0	0%	26.6 [c]	0	0%
Copper	41.2	0	0%	40.5	0	0%
Lead	34.6	0	0%	16.3	2	1%
Mercury	0.37	43	26%	0.5	55	34%
Nickel	12.5	0	0%	67.1	0	0%
Selenium	1.13	33	20%	4	33	20%
Thallium	ID	NC	NC	ID	NC	NC
Zinc	904	1	1%	145	4	2%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified in the wildlife analysis for thallium); NC (Not calculated); NEHC (No Effect Hazard Concentration); ug/g (micrograms/gram).

a – The wildlife fish consumption NEHC represents the maximum pollutant concentration in the fish that will result in no observable adverse effects in wildlife (*i.e.*, minks or eagles) [USGS, 2008].

b – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

c – An NEHC benchmark is not available for chromium VI; therefore, EPA used the total chromium benchmark.

Table I-15. Number and Percentage of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding TELs for Sediment Biota

Pollutant	Sediment Benchmark (mg/kg)	Number of Immediate Receiving Waters Exceeding TELs for Sediment Biota			
		Rivers and Streams	Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters	
				Number [a]	Percent
Arsenic	5.90	5	0	5	3%
Cadmium	0.596	19	3	22	13%
Chromium VI [b]	37.3	0	0	0	0%
Copper	35.7	4	1	5	3%
Lead	35	3	1	4	2%
Mercury	0.174	33	7	40	25%
Nickel	18.0	24	3	27	17%
Selenium	ID	NC	NC	NC	NC
Thallium	ID	NC	NC	NC	NC
Zinc	123	12	1	13	8%
Total Number of Unique Immediate Receiving Waters		**33**	**7**	**40**	**25%**

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified); NC (Not calculated).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.

Table I-16. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [c]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	4	0	4	2%
	6 to <11 years	5	4	0	4	2%
	11 to <16 years	5	4	0	4	2%
	16 to <21 years	5	4	0	4	2%
Adult recreational fisher		49	7	2	9	6%
Child subsistence fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	5	0	5	3%
	6 to <11 years	5	6	0	6	4%
	11 to <16 years	5	4	0	4	2%
	16 to <21 years	5	4	0	4	2%
Adult subsistence fisher		49	19	2	21	13%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

c – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Table I-17. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [b]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	62	13	75	46%
	2 to <3 years	1	62	13	75	46%
	3 to <6 years	3	61	13	74	45%
	6 to <11 years	5	60	12	72	44%
	11 to <16 years	5	57	10	67	41%
	16 to <21 years	5	57	10	67	41%
Adult recreational fisher		49	57	10	67	41%
Child subsistence fisher	1 to <2 years	1	76	14	90	55%
	2 to <3 years	1	76	14	90	55%
	3 to <6 years	3	70	14	84	52%
	6 to <11 years	5	67	14	81	50%
	11 to <16 years	5	63	13	76	47%
	16 to <21 years	5	63	13	76	47%
Adult subsistence fisher		49	65	13	78	48%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Table I-18. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline by Pollutant

Pollutant	Oral Reference Dose (mg/kg/day)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]	
		Number Exceeding	**Percentage Exceeding**
Inorganic arsenic	0.0003 [b]	3	2%
Cadmium	0.001 [b]	27	17%
Chromium VI	0.003 [b]	0	0%
Copper	0.01 [c]	4	2%
Lead	ID	NC	NC
Mercury (as methylmercury)	0.0001 [b]	84	52%
Nickel (soluble salts)	0.02 [b]	0	0%
Selenium	0.005 [b]	41	25%
Thallium (soluble salts)	0.00001 [d]	72	44%
Zinc	0.3 [b]	7	4%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NC (Not calculated); ID (Insufficient data; there is no current reference dose for lead).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – U.S. EPA, 2011c.

c – ATSDR, 2010a.

d – U.S. EPA, 2010a.

Table I-19. Comparison of T4 Fish Tissue Concentrations to Fish Advisory Screening Values

Pollutant	Recreational Fishers			Subsistence Fishers		
	Screening Value (ppm)[a]	Number Exceeding [b]	Percentage Exceeding	Screening Value (ppm) [a]	Number Exceeding [b]	Percentage Exceeding
Inorganic arsenic (noncarcinogen)	1.2	0	0%	0.147	3	2%
Inorganic arsenic (carcinogen)	0.026	4	2%	0.00327	7	4%
Cadmium	4.0	6	4%	0.491	18	11%
Mercury (as methylmercury)	0.4	58	36%	0.049	77	47%
Selenium	20	19	12%	2.457	36	22%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ppm (parts per million).

a – Screening values are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as threshold values against 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 risk should be conducted [U.S. EPA, 2000a, Table 5-3].

b – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

Table I-20. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,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	3	3	4	4	4	4	9
	Non-Hispanic Black	3	3	4	4	4	4	11
	Mexican-American	4	4	4	4	4	4	14
	Other Hispanic	4	4	4	4	4	4	13
	Other, including Multiple Races	4	4	4	4	4	4	15
Subsistence	Non-Hispanic White	4	4	4	5	5	5	21
	Non-Hispanic Black	4	4	4	5	5	5	22
	Mexican-American	4	4	4	6	6	6	23
	Other Hispanic	4	4	4	5	5	5	23
	Other, including Multiple Races	4	4	5	7	7	7	26

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

Table I-21. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Pollutant Exceeds a Non-Cancer Reference Dose [a]						
		Inorganic Arsenic	**Cadmium**	**Copper**	**Mercury [b]**	**Selenium**	**Thallium [c]**	**Zinc**
Recreational, Child Fisher	Non-Hispanic White	0 (0%)	8 (5%)	3 (2%)	63 (39%)	26 (16%)	44 (27%)	4 (2%)
	Non-Hispanic Black	0 (0%)	9 (6%)	4 (2%)	64 (39%)	27 (17%)	45 (28%)	4 (2%)
	Mexican-American	0 (0%)	11 (7%)	4 (2%)	66 (40%)	27 (17%)	48 (29%)	4 (2%)
	Other Hispanic	0 (0%)	10 (6%)	4 (2%)	64 (39%)	27 (17%)	47 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	11 (7%)	4 (2%)	68 (42%)	28 (17%)	48 (29%)	4 (2%)
Subsistence, Child Fisher	Non-Hispanic White	0 (0%)	8 (5%)	3 (2%)	63 (39%)	26 (16%)	44 (27%)	4 (2%)
	Non-Hispanic Black	0 (0%)	9 (6%)	4 (2%)	64 (39%)	27 (17%)	45 (28%)	4 (2%)
	Mexican-American	0 (0%)	11 (7%)	4 (2%)	66 (40%)	27 (17%)	48 (29%)	4 (2%)
	Other Hispanic	0 (0%)	10 (6%)	4 (2%)	64 (39%)	27 (17%)	47 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	11 (7%)	4 (2%)	68 (42%)	28 (17%)	48 (29%)	4 (2%)
Recreational, Adult Fisher	Non-Hispanic White	3 (2%)	17(10%)	4 (2%)	74 (45%)	33 (20%)	58 (36%)	4 (2%)
	Non-Hispanic Black	3 (2%)	18 (11%)	4 (2%)	74 (45%)	34 (21%)	58 (36%)	4 (2%)
	Mexican-American	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other Hispanic	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other, including Multiple Races	3 (2%)	24 (15%)	4 (2%)	79 (48%)	38 (23%)	67 (41%)	5 (3%)
Subsistence, Adult Fisher	Non-Hispanic White	3 (2%)	17(10%)	4 (2%)	74 (45%)	33 (20%)	58 (36%)	4 (2%)
	Non-Hispanic Black	3 (2%)	18 (11%)	4 (2%)	74 (45%)	34 (21%)	58 (36%)	4 (2%)
	Mexican-American	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other Hispanic	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other, including Multiple Races	3 (2%)	24 (15%)	4 (2%)	79 (48%)	38 (23%)	67 (41%)	5 (3%)

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – Mercury, as methylmercury.

c – Reference dose based on thallium (soluble salts).

EPA evaluated environmental improvements as a result of the regulatory options, reflecting changes in the industry as a result of the CPP. Table I-22 and Table I-23 present pollutant removals under the regulatory options.

Table I-22. Steam Electric Power Generating Industry Pollutant Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, lbs/yr (Percent Reduction) [a]				
	Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	12,500 (56%)	12,500 (56%)	18,500 (83%)	20,700 (93%)	21,300 (96%)
Boron	3,150,000 (13%)	3,150,000 (13%)	3,350,000 (14%)	3,420,000 (14%)	3,420,000 (14%)
Cadmium	7,900 (72%)	7,900 (72%)	9,650 (88%)	10,300 (94%)	10,400 (95%)
Chromium VI	99.1 (83%)	99.1 (83%)	115 (96%)	119 (>99%)	119 (>99%)
Copper	12,200 (51%)	12,200 (51%)	20,500 (85%)	23,400 (98%)	23,500 (98%)
Lead	6,340 (43%)	6,340 (43%)	12,100 (83%)	14,200 (98%)	14,200 (98%)
Manganese	4,520,000 (72%)	4,520,000 (72%)	4,950,000 (78%)	5,110,000 (81%)	5,110,000 (81%)
Mercury	728 (62%)	736 (63%)	1,040 (89%)	1,140 (97%)	1,160 (99%)
Nickel	55,100 (58%)	55,300 (59%)	82,300 (87%)	92,400 (98%)	93,100 (99%)
Selenium	24,100 (21%)	106,000 (94%)	109,000 (96%)	110,000 (97%)	110,000 (97%)
Thallium	5,640 (13%)	5,640 (13%)	32,700 (74%)	42,800 (98%)	42,800 (98%)
Zinc	107,000 (74%)	107,000 (74%)	130,000 (89%)	138,000 (95%)	141,000 (97%)
Nitrogen, total [b]	1,590,000 (12%)	10,000,000 (76%)	12,200,000 (93%)	13,100,000 (99%)	13,100,000 (99%)
Phosphorus, total	33,900 (22%)	33,900 (22%)	98,300 (64%)	122,000 (79%)	122,000 (79%)
Chlorides	3,380,000 (<1%)	3,380,000 (<1%)	12,000,000 (2%)	15,300,000 (2%)	15,300,000 (2%)
TDS	684,000,000 (21%)	684,000,000 (21%)	913,000,000 (28%)	999,000,000 (30%)	999,000,000 (30%)

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); lbs/yr (pounds per year).

Note: Pollutant removals are rounded to three significant figures.

a – .>0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-23. Steam Electric Power Generating Industry TWPE Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, TWPE/year (Percent Reduction) [a]				
	Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	43,400 (56%)	43,400 (56%)	64,200 (83%)	71,900 (93%)	73,900 (96%)
Boron	26,200 (13%)	26,200 (13%)	28,000 (14%)	28,600 (14%)	28,600 (14%)
Cadmium	180,000 (72%)	180,000 (72%)	220,000 (88%)	234,000 (94%)	236,000 (95%)
Chromium VI	51.2 (83%)	51.2 (83%)	59.2 (96%)	61.3 (>99%)	61.3 (>99%)
Copper	7,630 (51%)	7,630 (51%)	12,800 (85%)	14,600 (98%)	14,600 (98%)
Lead	14,200 (43%)	14,200 (43%)	27,200 (83%)	31,900 (98%)	31,900 (98%)
Manganese	464,000 (72%)	464,000 (72%)	508,000 (78%)	524,000 (81%)	524,000 (81%)
Mercury	80,100 (62%)	80,900 (63%)	115,000 (89%)	126,000 (97%)	128,000 (99%)
Nickel	6,000 (58%)	6,020 (59%)	8,970 (87%)	10,100 (98%)	10,100 (99%)
Selenium	27,000 (21%)	119,000 (94%)	122,000 (96%)	123,000 (97%)	123,000 (97%)
Thallium	16,100 (13%)	16,100 (13%)	93,300 (74%)	122,000 (98%)	122,000 (98%)
Zinc	5,040 (74%)	5,040 (74%)	6,090 (89%)	6,470 (95%)	6,630 (97%)
Nitrogen, total	N/A	N/A	N/A	N/A	N/A
Phosphorus, total	N/A	N/A	N/A	N/A	N/A
Chlorides	82.2 (<1%)	82.2 (<1%)	293 (2%)	372 (2%)	372 (2%)
TDS	N/A	N/A	N/A	N/A	N/A

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); TWPE (Toxic Weighted Pound Equivalents).

Note: Pollutant removals are rounded to three significant figures.

N/A – The TWPE/year is not provided for total nitrogen, total phosphorus, and TDS because EPA has not established a toxic weighting factor (TWF) for these pollutants.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-24 presents key environmental improvements as a result of the regulatory options and reflecting changes in the industry as a result of the CPP. Table I-25 shows environmental improvements for benthic organisms. Key environmental improvements based on reduced discharges of arsenic, mercury, selenium, cadmium, and thallium are included in Table I-26 through Table I-30.

Table I-24. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	**Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions** [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	7	4%	5 (29%)	5 (29%)	5 (29%)	3 (57%)	2 (71%)
Freshwater Chronic NRWQC	28	17%	27 (4%)	22 (21%)	18 (36%)	16 (43%)	16 (43%)
Human Health Water and Organism NRWQC	73	45%	70 (4%)	70 (4%)	55 (25%)	42 (42%)	35 (52%)
Human Health Organism Only NRWQC	51	31%	48 (6%)	48 (6%)	36 29%)	28 (45%)	22 (57%)
Drinking Water MCL	29	18%	27 (7%)	26 (10%)	12 (59%)	6 (79%)	6 (79%)
Wildlife Results							
Fish Ingestion NEHC for Minks	46	28%	46 (0%)	41 (11%)	25 (46%)	19 (59%)	18 (61%)
Fish Ingestion NEHC for Eagles	56	34%	52 (7%)	48 (14%)	34 (39%)	23 (59%)	20 (64%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	75	46%	69 (8%)	67 (11%)	51 (32%)	38 (49%)	30 (60%)
Non-Cancer Reference Dose for Adult (recreational)	67	41%	60 (10%)	58 (13%)	44 (34%)	32 (52%)	23 (66%)
Non-Cancer Reference Dose for Child (subsistence)	90	55%	81 (10%)	79 (12%)	59 (34%)	43 (52%)	39 (57%)
Non-Cancer Reference Dose for Adult (subsistence)	78	48%	72 (8%)	71 (9%)	54 (31%)	40 (49%)	32 (59%)

Table I-24. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Arsenic Cancer Risk for Adult (recreational)	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Arsenic Cancer Risk for Child (subsistence)	6	4%	6 (0%)	6 (0%)	5 (17%)	3 (50%)	2 (67%)
Arsenic Cancer Risk for Adult (subsistence)	21	13%	19 (10%)	19 (10%)	13 (38%)	11 (48%)	4 (81%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-25. Number of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding TELs for Sediment Biota Under the Regulatory Options

Pollutant	**Modeled Immediate Receiving Waters Exceeding CSCLs Under Baseline Conditions**[a]	**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options**[b]				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	5 (3%)	4 (20%)	4 (20%)	4 (20%)	3 (40%)	2 (60%)
Cadmium	22 (13%)	17 (23%)	17 (23%)	12 (45%)	10 (55%)	8 (64%)
Chromium VI[c]	0 (0%)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Copper	5 (3%)	4 (20%)	4 (20%)	4 (20%)	2 (60%)	2 (60%)
Lead	4 (2%)	3 (25%)	3 (25%)	3 (25%)	1 (75%)	1 (75%)
Mercury	40 (25%)	36 (10%)	35 (13%)	20 (50%)	16 (60%)	7 (83%)
Nickel	27 (17%)	22 (19%)	22 (19%)	12 (56%)	10 (63%)	4 (85%)
Selenium	NC	NC	NC	NC	NC	NC
Thallium	NC	NC	NC	NC	NC	NC
Zinc	13 (8%)	7 (46%)	7 (46%)	7 (46%)	6 (54%)	2 (85%)
Total	**40 (25%)**	**36 (10%)**	**35 (13%)**	**21 (48%)**	**17 (58%)**	**8 (80%)**

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NC (Not calculated; no benchmark for comparison).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – EPA used the total chromium benchmark for this analysis.

Table I-26. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Freshwater Chronic NRWQC	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	1 (75%)
Human Health Water and Organism NRWQC	73	45%	70 (4%)	70 (4%)	55 (25%)	42 (42%)	35 (52%)
Human Health Organism Only NRWQC	51	31%	48 (6%)	48 (6%)	36 (29%)	28 (45%)	22 (57%)
Drinking Water MCL	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Wildlife Results							
Fish Ingestion NEHC for Minks	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Fish Ingestion NEHC for Eagles	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	2	1%	1 (50%)	1 (50%)	1 (50%)	1 (50%)	0 (100%)
Non-Cancer Reference Dose for Adult (recreational)	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Non-Cancer Reference Dose for Child (subsistence)	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Non-Cancer Reference Dose for Adult (subsistence)	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)

Table I-26. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	**Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]**		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]**				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Arsenic Cancer Risk for Adult (recreational)	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Arsenic Cancer Risk for Child (subsistence)	6	4%	6 (0%)	6 (0%)	5 (17%)	3 (50%)	2 (67%)
Arsenic Cancer Risk for Adult (subsistence)	21	13%	19 (10%)	19 (10%)	13 (38%)	11 (48%)	4 (81%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-27. Key Environmental Improvements for Mercury Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Freshwater Chronic NRWQC	1	1%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	4	2%	4 (0%)	4 (0%)	4 (0%)	2 (50%)	1 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	43	26%	40 (7%)	39 (9%)	23 (47%)	17 (60%)	8 (81%)
Fish Ingestion NEHC for Eagles	55	34%	48 (13%)	48 (13%)	34 (38%)	23 (58%)	17 (69%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	72	44%	65 (10%)	62 (14%)	46 (36%)	35 (51%)	27 (63%)
Non-Cancer Reference Dose for Adult (recreational)	64	39%	55 (14%)	54 (16%)	41 (36%)	30 (53%)	20 (69%)
Non-Cancer Reference Dose for Child (subsistence)	84	52%	74 (12%)	73 (13%)	55 (35%)	41 (51%)	37 (56%)
Non-Cancer Reference Dose for Adult (subsistence)	75	46%	68 (9%)	66 (12%)	49 (35%)	37 (51%)	29 (61%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-28. Key Environmental Improvements for Selenium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	27	17%	25 (7%)	17 (37%)	16 (41%)	14 (48%)	14 (48%)
Human Health Water and Organism NRWQC	8	5%	7 (13%)	3 (63%)	3 (63%)	2 (75%)	2 (75%)
Human Health Organism Only NRWQC	1	1%	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Drinking Water MCL	10	6%	9 (10%)	4 (60%)	4 (60%)	3 (70%)	3 (70%)
Wildlife Results							
Fish Ingestion NEHC for Minks	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Fish Ingestion NEHC for Eagles	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Negative Reproductive Effects in Fish [c]	21	13%	17 (19%)	9 (57%)	9 (57%)	8 (62%)	8 (62%)
Negative Reproductive Effects in Mallards [c]	25	15%	21 (16%)	13 (48%)	12 (52%)	11 (56%)	11 (56%)

Table I-28. Key Environmental Improvements for Selenium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Non-Cancer Reference Dose for Adult (recreational)	26	16%	23 (12%)	14 (46%)	14 (46%)	13 (50%)	13 (50%)
Non-Cancer Reference Dose for Child (subsistence)	41	25%	39 (5%)	31 (24%)	28 (32%)	24 (41%)	24 (41%)
Non-Cancer Reference Dose for Adult (subsistence)	34	21%	32 (6%)	23 (32%)	19 (44%)	17 (50%)	17 (50%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.

Table I-29. Key Environmental Improvements for Cadmium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]**				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	7	4%	4 (43%)	4 (43%)	4 (43%)	3 (57%)	2 (71%)
Freshwater Chronic NRWQC	23	14%	18 (22%)	18 (22%)	13 (43%)	11 (52%)	9 (61%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	8	5%	6 (25%)	6 (25%)	5 (38%)	3 (63%)	2 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	5	3%	4 (20%)	4 (20%)	4 (20%)	2 (60%)	2 (60%)
Fish Ingestion NEHC for Eagles	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	13	8%	9 (31%)	9 (31%)	7 (46%)	5 (62%)	3 (77%)
Non-Cancer Reference Dose for Adult (recreational)	8	5%	6 (25%)	6 (25%)	5 (38%)	3 (63%)	2 (75%)
Non-Cancer Reference Dose for Child (subsistence)	27	17%	22 (19%)	22 (19%)	17 (37%)	15 (44%)	10 (63%)
Non-Cancer Reference Dose for Adult (subsistence)	18	11%	13 (28%)	13 (28%)	9 (50%)	7 (61%)	4 (78%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-30. Key Environmental Improvements for Thallium Under the Regulatory Options

	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		**Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options** [b]				
Evaluation Benchmark	**Number**	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Water and Organism NRWQC	39	24%	36 (8%)	36 (8%)	22 (44%)	12 (69%)	12 (69%)
Human Health Organism Only NRWQC	35	21%	32 (9%)	32 (9%)	18 (49%)	8 (77%)	8 (77%)
Drinking Water MCL	27	17%	25 (7%)	25 (7%)	11 (59%)	5 (81%)	5 (81%)
Wildlife Results							
Fish Ingestion NEHC for Minks	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Fish Ingestion NEHC for Eagles	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	55	34%	54 (2%)	54 (2%)	36 (35%)	23 (58%)	23 (58%)
Non-Cancer Reference Dose for Adult (recreational)	43	26%	41 (5%)	41 (5%)	26 (40%)	16 (63%)	16 (63%)
Non-Cancer Reference Dose for Child (subsistence)	72	44%	69 (4%)	69 (4%)	47 (35%)	30 (58%)	30 (58%)
Non-Cancer Reference Dose for Adult (subsistence)	58	36%	58 (0%)	58 (0%)	39 (33%)	25 (57%)	25 (57%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Under the alternate scenario analysis, EPA evaluated environmental improvements to sensitive waters as a result of the regulatory options and reflecting changes in the industry as a result of the CPP. EPA determined that 91 of the immediate receiving waters are 303(d)-listed waterbodies, designated as impaired for one or more pollutants found in the evaluated wastestreams.[7] Table I-31 presents the pollutant removals to impaired waters under the regulatory options.

EPA determined that 79 of the 172 immediate receiving waters included in the alternate scenario analysis are under a fish advisory for mercury. Under the final rule, the number of immediate receiving waters with fish that exceed EPA's mercury screening value for recreational fishers (based on steam electric power plant discharges only) will decrease by 59 percent, thereby reducing the potential threat to human health from consuming contaminated fish.

Under the alternate scenario analysis, EPA identified 14 steam electric power plants that discharge into the Great Lakes watershed. Table I-32 presents the pollutant removals to the Great Lakes watershed under the regulatory options considered by EPA.

Under the alternate scenario analysis, EPA identified seven steam electric power plants that discharge to the Chesapeake Bay watershed. Under the final rule, EPA estimates the following pollutant removals to the Chesapeake Bay watershed:

- 603 pounds of arsenic annually (89 percent reduction).
- 167 pounds of cadmium annually (84 percent reduction).
- 555 pounds of lead annually (97 percent reduction).
- 22.8 pounds of mercury annually (93 percent reduction).
- 4,550 pounds of selenium annually (96 percent reduction).
- 2,830 pounds of thallium annually (98 percent reduction).
- 667,000 pounds of total nitrogen annually (>99 percent reduction).
- 6,450 pounds of total phosphorus annually (81 percent reduction).

Finally, EPA evaluated the improvements to downstream receiving waters. Table I-33 presents the number of river miles impacted by steam electric power plant discharges at baseline and under the regulatory options for the alternate scenario analysis. The table also presents the percent reduction in number of impacted river miles.

---

[7] The count of impaired waters excludes the general impairment category "metals (not mercury)" and includes receiving waters impaired for arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, selenium, zinc, phosphorous, nutrients, TDS, or chlorides.

Table I-31. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	**Pollutant**	**Baseline Loadings (lbs/yr)**	**Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction)** [a]				
			Option A	**Option B**	**Option C**	**Option D**	**Option E**
Mercury-Impaired Receiving Waters							
21	Mercury	123	52.3 (42%)	52.6 (43%)	100 (81%)	123 (99%)	123 (>99%)
Metals (Not Mercury)-Impaired Receiving Waters							
24	Arsenic	4,020	2,660 (66%)	2,660 (66%)	3,540 (88%)	3,830 (95%)	3,880 (96%)
	Boron	4,420,000	312,000 (7%)	312,000 (7%)	344,000 (8%)	353,000 (8%)	353,000 (8%)
	Cadmium	1,810	1,360 (75%)	1,360 (75%)	1,630 (90%)	1,710 (94%)	1,720 (95%)
	Chromium VI	25.6	22.0 (86%)	22.0 (86%)	25.5 (>99%)	25.6 (>99%)	25.6 (>99%)
	Copper	4,150	2,410 (58%)	2,410 (58%)	3,690 (89%)	4,060 (98%)	4,060 (98%)
	Lead	2,500	1,300 (52%)	1,300 (52%)	2,170 (87%)	2,440 (98%)	2,440 (98%)
	Manganese	1,030,000	718,000 (70%)	718,000 (70%)	778,000 (76%)	800,000 (78%)	800,000 (78%)
	Nickel	14,700	9,210 (62%)	9,250 (63%)	13,200 (89%)	14,500 (99%)	14,600 (99%)
	Selenium	20,000	3,250 (16%)	19,100 (95%)	19,500 (98%)	19,700 (98%)	19,700 (98%)
	Thallium	6,620	1,190 (18%)	1,190 (18%)	5,070 (77%)	6,450 (97%)	6,450 (97%)
	Zinc	23,600	18,400 (78%)	18,400 (78%)	21,700 (92%)	22,800 (96%)	23,100 (98%)

Table I-31. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	**Pollutant**	**Baseline Loadings (lbs/yr)**	**Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction)** [a]				
			Option A	**Option B**	**Option C**	**Option D**	**Option E**
Nutrient-Impaired Receiving Waters							
15	Total Nitrogen	242,000	0 (0%)	158,000 (65%)	212,000 (87%)	241,000 (99%)	241,000 (99%)
	Total Phosphorous	2,870	0 (0%)	0 (0%)	1,520 (53%)	2,330 (81%)	2,330 (81%)
TDS and Chlorides-Impaired Receiving Waters							
2	Chlorides	CBI	CBI	CBI	CBI	CBI	CBI
	TDS	CBI	CBI	CBI	CBI	CBI	CBI

Source: ERG, 2015c.

Acronyms: CBI (Confidential business information); lbs/yr (pounds per year).

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – For the impaired waters proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams.

c – The EPA impaired water database listed 24 immediate receiving waters as impaired based on the “metal, other than mercury” impairment category. Of those 24 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals (arsenic, cadmium, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

d – Total phosphorous and total nitrogen loadings are presented with this impairment category. Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-32. Pollutant Removals to the Great Lakes Watershed Under the Regulatory Options

Pollutant	Baseline Loadings to the Great Lakes Watershed (lbs/yr)	Pollutant Removals (lbs/yr) to Great Lakes Watershed Under the Regulatory Options (Percent Reduction) [a]				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	1,030	46.7 (5%)	46.7 (5%)	509 (49%)	955 (92%)	1,000 (97%)
Boron	760,000	1,380 (<1%)	1,380 (<1%)	14,700 (2%)	27,300 (4%)	27,300 (4%)
Cadmium	286	6.03 (2%)	6.03 (2%)	134 (47%)	257 (90%)	266 (93%)
Chromium VI	0.548	0.471 (86%)	0.471 (86%)	0.548 (>99%)	0.548 (>99%)	0.548 (>99%)
Copper	1,170	26.6 (2%)	26.6 (2%)	596 (51%)	1,140 (98%)	1,150 (98%)
Lead	869	18.8 (2%)	18.8 (2%)	446 (51%)	856 (99%)	856 (99%)
Manganese	112,000	47.3 (<1%)	47.3 (<1%)	34,700 (31%)	68,300 (61%)	68,300 (61%)
Mercury	37.5	1.20 (3%)	1.48 (4%)	19.1 (51%)	35.7 (95%)	37.1 (99%)
Nickel	4,310	20.6 (<1%)	29.3 (1%)	2,150 (50%)	4,210 (98%)	4,260 (99%)
Selenium	3,540	20.9 (1%)	2,890 (82%)	3,120 (88%)	3,350 (95%)	3,350 (95%)
Thallium	4,320	21.8 (1%)	21.8 (1%)	2,190 (51%)	4,280 (99%)	4,280 (99%)
Zinc	3,860	55.5 (1%)	55.5 (1%)	1,790 (46%)	3,470 (90%)	3,760 (97%)
Nitrogen, total [b]	646,000	2,420 (<1%)	299,000 (46%)	474,000 (73%)	643,000 (>99%)	643,000 (>99%)
Phosphorus, total	10,900	135 (1%)	135 (1%)	5,080 (47%)	9,850 (91%)	9,850 (91%)
Chlorides	24,100,000	11,400 (<1%)	11,400 (<1%)	693,000 (3%)	1,350,000 (6%)	1,350,000 (6%)
TDS	116,000,000	187,000 (<1%)	187,000 (<1%)	18,400,000 (16%)	36,100,000 (31%)	36,100,000 (31%)

Source: ERG, 2015a; ERG, 2015c.

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

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-33. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Water Quality Results						
Freshwater Acute NRWQC	412	395 (4%)	395 (4%)	393 (5%)	388 (6%)	388 (6%)
Freshwater Chronic NRWQC	605	592 (2%)	560 (8%)	542 (10%)	514 (15%)	514 (15%)
Human Health Water and Organism NRWQC	4,050	3,390 (16%)	3,390 (16%)	2,480 (39%)	1,930 (52%)	1,710 (58%)
Human Health Organism-only NRWQC	1,500	1,230 (18%)	1,230 (18%)	1,030 (31%)	781 (48%)	713 (52%)
Drinking Water MCL	751	725 (3%)	720 (4%)	629 (16%)	487 (35%)	487 (35%)
Wildlife Results						
Fish Ingestion NEHC for Minks	1,070	893 (17%)	862 (19%)	720 (33%)	524 (51%)	503 (53%)
Fish Ingestion NEHC for Eagles	1,870	1,580 (15%)	1,560 (16%)	1,260 (32%)	957 (49%)	899 (52%)
Human Health Results—Non-Cancer						
Non-cancer reference dose for child (recreational)	5,800	4,380 (24%)	4,380 (25%)	2,890 (50%)	2,250 (61%)	2,080 (64%)
Non-cancer reference dose for adult (recreational)	3,420	2,830 (17%)	2,820 (17%)	1,960 (43%)	1,430 (58%)	1,350 (61%)
Non-cancer reference dose for child (subsistence)	9,240	7,790 (16%)	7,760 (16%)	5,520 (40%)	4,490 (51%)	4,080 (56%)
Non-cancer reference dose for adult (subsistence)	6,540	5,050 (23%)	5,050 (23%)	3,330 (49%)	2,620 (60%)	2,410 (63%)

Table I-33. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	**Option B**	**Option C**	**Option D**	**Option E**
Human Health Results—Cancer						
Cancer risk for child (recreational)	227	216 (5%)	216 (5%)	211 (7%)	210 (8%)	207 (9%)
Cancer risk for adult (recreational)	286	263 (8%)	263 (8%)	251 (12%)	246 (14%)	245 (14%)
Cancer risk for child (subsistence)	262	241 (8%)	241 (8%)	239 (9%)	235 (10%)	231 (12%)
Cancer risk for adult (subsistence)	414	375 (9%)	375 (9%)	355 (14%)	328 (21%)	304 (26%)

Source: ERG, 2015i; ERG, 2015l.

Note: River miles are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – EPA evaluated a total of 72,100 river-miles in the downstream receiving water analysis for toxic, bioaccumulative pollutants. Downstream receiving water concentrations are calculated until one of three conditions occurs: 1) the discharge travels 300 kilometers (km) downstream; 2) the discharge travels downstream for a week; or 3) the concentration reaches 1 x 10^{-9} milligrams per liter (mg/L).

APPENDIX J
EA LOADINGS AND TDD LOADINGS: SENSITIVITY ANALYSIS

As discussed in Section 3, the analyses presented in the environmental assessment (EA) report are based on loadings datasets that differ from those that are summarized in the *Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD)*, Document No. EPA-821-R-15-007. This appendix presents a sensitivity analysis that evaluates the difference between the two pollutant loadings datasets (the “EA loadings” and the “TDD loadings”) and estimates the change in counts of environmental exceedances that would have resulted from use of the TDD loadings dataset. The analyses in this section reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)] (CPP).

Table J-1 quantifies the difference in baseline loadings between the EA loadings and TDD loadings for each of the ten pollutants that are modeled in the EA analyses.

Impacts to Exceedances across All Pollutants

To estimate the influence that using the TDD loadings would have on the overall counts of exceedances identified in the EA Report, EPA took the following steps:

1. EPA determined how many immediate receiving waters had exceedances that were due, in part or in whole, to selenium, thallium, or chromium VI. Because the EA loadings for these pollutants are equal to (or, in the case of selenium, slightly greater than) the corresponding TDD loadings, each immediate receiving water in this group would have had exceedances if EPA had used the TDD loadings.
2. Of the remaining receiving waters with exceedances, EPA determined how many had exceedances that were due, in part or in whole, to arsenic (whose loadings are 9.4 percent lower using the TDD loadings). By assuming that the difference in loadings would result in an equal change in the count of exceedances, EPA assumed that use of the TDD loadings would have resulted in 9.4 percent fewer exceedances among this group of immediate receiving waters.
3. Of the remaining receiving waters with exceedances, EPA determined how many had exceedances that were due, in part or in whole, to zinc (whose loadings are 14 percent lower in the TDD loadings). By assuming that the difference in loadings would result in an equal change in the count of exceedances, EPA assumed that use of the TDD loadings would have resulted in 14 percent fewer exceedances among this group of immediate receiving waters.
4. EPA repeated this process for the remaining modeled pollutants (in order of increasing change between the EA loadings and TDD loadings) until all immediate receiving waters with exceedances were taken into account.

Table J-2 presents the results of this analysis, which demonstrates that use of the TDD loadings in place of the EA loadings would have only minimal effect on the overall counts of exceedances identified by the immediate receiving water (IRW) model. The benchmark exceedances that would be most affected by use of the TDD loadings are exceedances of chemical stressor concentration limits (CSCLs) for sediment biota. Exceedances of this benchmark under baseline conditions would be approximately 4 percentage points lower (41 percent versus 45 percent) based on use of the TDD loadings instead of the EA loadings. All other benchmark exceedances change by 2 percentage points or less.

This analysis assumes a linear relationship between a loadings reduction and a change in exceedances for that pollutant. As discussed below, however, this assumption likely overestimates the effect of a loadings change on the count of exceedances.

Impacts to Individual Pollutant Exceedances

Table I-22 in Appendix I presents the industry-wide pollutant-specific removals under the regulatory options (reflecting changes in the industry as a result of the CPP). Table I-25 through Table I-30 present the pollutant-specific environmental improvements under the regulatory options. A comparison of the values in these tables indicates that an industry-wide pollutant loading reduction of *x* under the regulatory options usually results in a reduction in benchmark exceedances of *less than x*. For example, looking at Option A:

- *Cadmium*: Loadings reduced by 72 percent; exceedances reduced by approximately 19 to 43 percent.
- *Mercury*: Loadings reduced by 62 percent; exceedances reduced by approximately 7 to 14 percent.
- *Arsenic*: Loadings reduced by 56 percent; exceedances reduced by approximately 4 to 33 percent.
- *Selenium*: Loadings reduced by 21 percent; exceedances reduced by approximately 3 to 19 percent.
- *Thallium*: Loadings reduced by 13 percent; exceedances reduced by approximately 0 to 9 percent.

This suggests that the use of the TDD loadings instead of the EA loadings would have a less-than-linear effect on the number of exceedances in the EA for each pollutant. Based on this observation, EPA estimates that use of the TDD loadings would result in the following approximate effects in the baseline counts of pollutant-specific exceedances identified using the EA loadings:

- *Selenium, thallium, and chromium VI*: No decrease in exceedances.
- *Arsenic, zinc, mercury*: Approximately 10 percent fewer exceedances.
- *Cadmium, copper, and nickel*: Approximately 20 percent fewer exceedances.
- *Lead*: Approximately 25 percent fewer exceedances.

Table J-1. Comparison of Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams), EA Loadings versus TDD Loadings

	Baseline Loadings			Option D Removals			Option D Removals		
Pollutant	**EA Version (lbs/yr)**	**TDD Version (lbs/yr)**	**Percent Change**	**EA Version (lbs/yr)**	**TDD Version (lbs/yr)**	**Percent Change**	**EA Version (%)**	**TDD Version (%)**	**Percent Change**
Arsenic	22,200	20,100	-9.4%	20,700	18,700	-10%	93%	93%	-0.73%
Cadmium	10,900	8,290	-24%	10,300	7,660	-26%	94%	92%	-1.9%
Chromium (VI)	119	119	0%	119	119	0%	100%	100%	0%
Copper	24,000	16,400	-32%	23,400	15,800	-33%	98%	97%	-1.1%
Lead	14,600	7,670	-47%	14,200	7,340	-48%	98%	96%	-2.0%
Mercury	1,180	992	-16%	1,150	961	-16%	97%	97%	-0.47%
Nickel	94,200	61,900	-34%	92,400	60,200	-35%	98%	97%	-0.87%
Selenium	113,000	115,000	1.4%	110,000	111,000	1.4%	97%	97%	0.032%
Thallium	43,900	43,900	0%	42,800	42,800	0.0%	98%	98%	-0.020%
Zinc	145,000	124,000	-14%	138,000	117,000	-15%	95%	95%	-0.79%

Source: ERG, 2015o.

Note: Loadings and pollutant removals are rounded to three significant figures. Percentages are rounded to two significant figures.

Table J-2. Comparison of Modeled Baseline Exceedances (Using EA Loadings) and Approximated Baseline Exceedances (Using TDD Loadings)

Evaluation Benchmark	Baseline Exceedances in Appendix I (EA Loadings Version)		Baseline Approximated Exceedances (TDD Loadings Version)	
	Number [a]	Percentage	Number [a]	Percentage
Freshwater Acute NRWQC	7	4%	5.85	4%
Freshwater Chronic NRWQC	28	17%	27.8	17%
Human Health Water and Organism NRWQC	73	45%	69.8	43%
Human Health Organism Only NRWQC	51	31%	49.5	30%
Drinking Water MCL	29	18%	29.0	18%
Fish Ingestion NEHC for Minks	46	28%	44.0	27%
Fish Ingestion NEHC for Eagles	56	34%	52.4	32%
CSCLs for Sediment Biota	40	25%	34.2	21%
Negative Reproductive Effects in Fish from Selenium [b]	21	13%	21.0	13%
Negative Reproductive Effects in Mallards from Selenium [b]	25	15%	25.0	15%
Non-Cancer Reference Dose for Child (recreational)	75	46%	72.7	45%
Non-Cancer Reference Dose for Adult (recreational)	67	41%	64.2	39%
Non-Cancer Reference Dose for Child (subsistence)	90	55%	87.8	54%
Non-Cancer Reference Dose for Adult (subsistence)	78	48%	75.7	46%

Source: ERG, 2015o.

Acronyms: CSCL (Chemical stressor concentration limit); MCL (Maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.