APPENDIX B –
HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

Human Health and Ecological Risk Assessment

Kingston Fossil Plant
Harriman, Tennessee

September 19, 2025

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Sign-off Sheet

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Executive Summary

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to Tennessee Valley Authority (TVA) to establish a process for investigating, assessing, and remediating unacceptable risks from management of coal combustion residuals (CCR) at TVA coal-fired plants in the state of Tennessee. TVA constructed the Kingston Fossil Plant (KIF Plant) between 1951 and 1954 on approximately 100 acres and began generating power in 1954. There are three CCR units at the KIF Plant included in the TDEC Order: the Interim Ash Staging Area, Sluice Trench and Area East of Sluice Trench, and the Stilling Pond. Each of the CCR units was previously closed. In accordance with the TDEC Order, TVA and Stantec Consulting Services Inc. (Stantec), on behalf of TVA, prepared an Environmental Investigation Plan (EIP) for the KIF Plant to obtain and provide information requested by TDEC. As specified in the TDEC Order, the primary objective of the EIP was to "identify the extent of soil, surface water, and groundwater contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

Stantec has prepared this human health and ecological risk assessment (HHERA) report to evaluate potential risks to human and ecological receptors from potential exposures to CCR constituents released from the three TDEC Order CCR units at the KIF Plant. Results of this HHERA were used in the Corrective Action/Risk Assessment (CARA) Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors, and if so, provide information for the schedule for corrective action implementation.

The United States Environmental Protection Agency (USEPA) encourages the use of multiple lines of evidence (LOEs) in HHERAs such that a weight of evidence (WOE) approach can be used to characterize risk. In their guidance, USEPA also makes clear that determining "acceptable/unacceptable" risk should go beyond solely calculating numerical risk estimates. It is the combined results of these LOEs rather than any single LOE that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures (i.e., "acceptable/unacceptable levels"). As such, the objective of the HHERA is to provide quantitative and qualitative statements of potential risks to human and ecological receptors, based on multiple LOEs.

Environmental media samples collected as part of the KIF Plant Environmental Investigation (EI) and other ongoing environmental programs being conducted at the plant were analyzed for CCR constituents listed in the USEPA Title 40, Code of Federal Regulations Part 257, Subpart D (CCR Rule), Appendices III and IV and Appendix I of Tennessee Rule 0400-11-01-.04. Collectively these are referred to as "CCR Parameters" and form the basis of the HHERA evaluations.

The EI results characterized the current environmental conditions of the three CCR units included in the TDEC Order (located onsite) at the KIF Plant. Investigations associated with surface stream waters, sediments, and aquatic communities, and human and ecological interactions with these environmental media at the KIF Plant and in the vicinity of the CCR units (located offsite, i.e., the Emory, Clinch, and Tennessee rivers) have been addressed as part of the Kingston Recovery Project (KRP) and subsequent long-term monitoring (LTM). Because the focus of the human health risk assessment (HHRA) is on the

CCR units (not KIF Plant operations or the closure activities themselves), only exposures under anticipated future, post-closure conditions of the TDEC Order CCR units are evaluated in the HHERA. Potential future risks associated with onsite exposures to CCR Parameters in CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system of closed CCR units, such as a worker making repairs to infrastructure associated with the closed CCR units. Potential future risks to human and ecological receptors from exposures to CCR Parameters in offsite abiotic (surface stream water and sediment) and biotic (benthic invertebrate and fish tissue) media assume current environmental conditions are representative of post-closure conditions and consider current and anticipated future land uses.

HHRA: The HHRA process was used to evaluate potential carcinogenic risks and noncarcinogenic hazards to onsite human receptors potentially exposed to CCR material, and to offsite human receptors potentially exposed to CCR Parameters in groundwater, surface stream water, exposed sediment, and fish tissue. The overall HHRA findings are as follows:

- Onsite groundwater is not used for potable purposes under current or reasonably anticipated future land use scenarios.
- The results of the water use survey indicate current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs located downgradient of the KIF Plant.
- No constituents of potential concern (COPCs) were identified for surface stream water.
- COPCs were identified for CCR material and risk from exposure of onsite receptors was assessed quantitively based on CCR material data reported in the KIF Plant EAR.
- COPCs were previously identified in the Emory, Clinch, and Tennessee rivers in a baseline human health risk assessment (BHHRA) prepared by Jacobs (2012) as part of the KRP. For this HHRA, assessment of potential risks to human receptors from offsite exposures to CCR Parameters in surface stream water, seasonally exposed sediment, and sport fish filet tissue from the reach of the Emory River adjacent to the TDEC Order CCR units at the KIF Plant relied on a qualitative review of findings and data generated during the KRP and LTM.
- There are no unacceptable risks to onsite or offsite human receptors potentially exposed to CCR Parameters that could be associated with the TDEC Order CCR units at the KIF Plant.

Ecological Risk Assessment (ERA): The ERA process was used to evaluate potential hazards to aquatic ecological community receptors and to populations of avian and mammalian receptors from exposure to CCR Parameters measured in environmental media samples collected from the Emory, Clinch, and Tennessee rivers. The constituents of potential ecological concern (COPECs) evaluated in this ERA comprised the CCR Parameters defined above with the exception of those identified as non-specific indicators of water quality that do not provide information about the source or effects of contamination (total dissolved solids [TDS] and pH) and those determined likely to be naturally occurring and non-toxic at applicable environmental concentrations (calcium, chloride, fluoride, and sulfate). The assessment endpoints included protection of abundance and diversity of community receptors (i.e.,

benthic invertebrate, aquatic vegetation, fish, and aquatic/riparian feeding amphibian and reptile communities); and protection of populations of avian and mammalian receptors (i.e., aquatic/riparian feeding birds, aquatic/riparian feeding mammals, and aerial-feeding birds and mammals), by limiting acute and chronic effects from exposure to site-related COPECs. Risks to these ecological receptors from exposure to COPECs were previously evaluated as part of the KRP through a baseline ecological risk assessment (BERA) prepared by Arcadis (2012) and LTM. The results of the BERA were used to inform priorities for LTM, that included sediment sampling, sediment toxicity testing, benthic invertebrate bioaccumulation and community surveys, fish bioaccumulation, community surveys and biosurveys, and tree swallow biosurveys and egg tissue evaluations. In this ERA, the results of the BERA and LTM were reviewed and evaluated to support a qualitative evaluation of risk for the ecological receptors identified above due to exposure to identified COPECs in the Emory, Clinch, and Tennessee rivers. Overall, based on a qualitative evaluation of multiple LOE, the final WOE conclusion of this ERA was that:

- There are no unacceptable risks to abundance and diversity in community receptors or populations of avian and mammalian receptors inhabiting or using the Emory, Clinch, and Tennessee rivers related to the TDEC Order CCR units at the KIF Plant.

Confidence in the conclusions of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions for and approaches to important uncertainties in the assessments.

In accordance with the TDEC Order, TVA is submitting the HHERA with the CARA Plan, which includes further evaluations of the risk assessment findings to determine whether corrective measures are needed for the protection of human and ecological receptors. The CARA Plan specifies the actions TVA plans to take at the TDEC Order CCR units (if needed), the basis of those actions, and incorporates any other operational changes planned or in progress by TVA.

Abbreviations

amsl	Above Mean Sea Level
ATSDR	Agency for Toxic Substances and Disease Registry
BERA	Baseline Ecological Risk Assessment (Arcadis 2012)
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment (Jacobs 2012)
CalEPA	California Environmental Protection Agency
CARA	Corrective Action/Risk Assessment
CBR	Critical Body Residue
CCR	Coal Combustion Residuals
CCR Parameters	CCR Constituents listed in 40 CFR 257, Appendices III and IV, and the five inorganic constituents listed in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations Part 257, Subpart D
CERCLA	Comprehensive Environmental Response, Compensation, and Liabilities Act
CFR	Code of Federal Regulations
COPC	Constituent of Potential Concern
COPEC	Constituent of Potential Ecological Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
°F	Degrees Fahrenheit
EAR	Environmental Assessment Report
EC10	10% effect concentration
EE/CA	Engineering Evaluation/Cost Analysis
EI	Environmental Investigation
EIP	Environmental Investigation Plan
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
GSL	Groundwater Screening Level
GWPS	Groundwater Protection Standards
HHERA	Human Health and Ecological Risk Assessment
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
kg	Kilogram
KIF Plant	Kingston Fossil Plant
KRP	Kingston Recovery Project
LMS	Linearized Multistage
LOAEL	Lowest Observed Adverse Effects Level
LOE	Line of Evidence

LTM	Long-Term Monitoring
LTM SAP	Long-Term Monitoring Sampling and Analysis Plan
m^3	Cubic Meters
MCL	Maximum Contaminant Level
mg	Milligrams
MNR	Monitored Natural Recovery
µg	Microgram
µg/L	Micrograms per Liter
NOAEL	No Observed Adverse Effects Level
NPDES	National Pollutant Discharge Elimination System
ORNL	Oak Ridge National Laboratory
%	Percent
PEF	Particulate Emission Factor
PCBs	Polychlorinated Biphenyls
PHA	Public Health Assessment
ppm	Parts per Million
PPRTVs	Provisional Peer Reviewed Toxicity Values
PRG	Preliminary Remediation Goal
QA	Quality Assurance
RAIS	Risk Assessment Information System
RFAI	Reservoir Fish Assemblage Index
RfC	Reference Concentration
RfD	Reference Dose
River System	Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reaches A and B
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SSL_{HH}	Human Health Receptor-Specific Screening Level
Stantec	Stantec Consulting Services Inc.
TCLP	Toxicity Characteristic Leaching Procedure
TDEC	Tennessee Department of Environment and Conservation
TDEC Order	Commissioner's Order OGC15-0177
TDEC Appendix I	Appendix I of TDEC Rule 0400-11-01-.04
TDH	Tennessee Department of Health
TDS	Total Dissolved Solids
TO	Target Organ
TRV	Toxicity Reference Value
TVA	Tennessee Valley Authority
UCL	Upper Confidence Limit
URF	Unit Risk Factor
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WOE	Weight of Evidence

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec), on behalf of the Tennessee Valley Authority (TVA), has prepared this human health and ecological risk assessment (HHERA) report for the Kingston Fossil Plant (KIF Plant), which is an operational TVA coal-fired power plant located in Harriman, Tennessee (Exhibit 1-1). This HHERA evaluates potential risks to human and ecological receptors from potential exposures to coal combustion residuals (CCR) constituents released from CCR units at the KIF Plant. Results of this HHERA were used in the Corrective Action/Risk Assessment (CARA) Plan to evaluate whether corrective measures are needed for the protection of human and ecological receptors, and if so, provide information for the schedule for corrective action implementation.

1.1 BACKGROUND

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued TDEC Commissioner's Order No. OGC15-0177 (TDEC Order) to TVA (TDEC 2015). The TDEC Order established a process whereby TDEC would oversee TVA's implementation of the United States Environmental Protection Agency (USEPA) Title 40, Code of Federal Regulations (CFR) Part 257, Subpart D (CCR Rule) for coordination and compliance with Tennessee's solid waste management program. The three CCR units at the KIF Plant included in the TDEC Order are: the Interim Ash Staging Area, Sluice Trench and Area East of Sluice Trench, and the Stilling Pond (Exhibit 1-1). Per the June 14, 2016, Environmental Investigation Plan request letter from TDEC, the Kingston Recovery Project (KRP) Ash Landfill and Peninsula Disposal Area CCR units were not included in the TDEC Order due to prior considerations and work at those areas. In accordance with the TDEC Order, TVA prepared an Environmental Investigation Plan (EIP) for the KIF Plant (TVA 2018) to obtain and provide information requested by TDEC. Following public review and comment on the draft, the EIP was approved by TDEC on November 16, 2018, and TVA implemented the activities between 2018 and 2021 in accordance with the approved EIP. As specified in the TDEC Order, the objective of the EIP was to "identify the extent of soil, surface water, and ground water contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

The KIF Plant Environmental Assessment Report (EAR; TVA 2024a) presents the results of those investigations and an evaluation of recent and historical data to provide conceptual site models (CSMs) for the TDEC Order CCR units and overall findings for environmental media at the KIF Plant. CSMs describe sources of CCR constituents, pathways by which they can move, and environmental media potentially impacted if they are released. In accordance with the TDEC Order, TVA is submitting this HHERA with the CARA Plan, which includes further evaluation to determine whether corrective measures are needed. The CARA Plan, which will be subject to a public review and comment process, specifies the actions TVA plans to take at the TDEC Order CCR units (if needed), the basis of those actions, and incorporates any other operational changes planned or in progress by TVA.

1.2 OBJECTIVES

As stated in the TDEC Order, the CARA Plan "shall specify all actions TVA plans to take at the site and the basis of those actions" and that "corrective measures may include (1) soil, surface water and ground water remediation; (2) risk assessment and institutional controls; or (3) no further corrective action." This HHERA has been prepared to inform TVA whether the measured CCR constituent(s) in environmental media associated with onsite management of CCR material in the TDEC Order CCR units at the KIF Plant may present unacceptable risks to human health and the environment. As such, the objective of the HHERA is to provide quantitative and qualitative statements of potential risks to human and ecological receptors from exposures to CCR constituents in environmental media based on multiple lines of evidence (LOEs) as outlined in the *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A).

1.3 SCOPE

Environmental media samples collected as part of the Environmental Investigation (EI), and other ongoing environmental programs being conducted at the plant, were analyzed for CCR constituents listed in the CCR Rule, Appendices III and IV (i.e., antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium [total], cobalt, fluoride, lead, lithium, mercury [inorganic], molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids [TDS]). Five additional inorganic parameters listed in Appendix I of Tennessee Rule 0400-11-01-.04 that are not included in the CCR Rule Appendices III and IV were also analyzed to maintain continuity with TDEC environmental programs (i.e., copper, nickel, silver, vanadium, and zinc). The combined CCR Rule Appendices III and IV parameters and TDEC Appendix I inorganic parameters are referenced collectively herein as "CCR Parameters."

As documented in the KIF Plant EAR, the EI was implemented in accordance with the sampling and analysis plans (SAPs). EI results were evaluated and presented in the KIF Plant EAR, with details of each investigation provided in technical evaluation summaries and associated sampling and analysis reports. Applicable EI results and information from investigations, subsequent assessments completed pursuant to the EIP SAPs were evaluated and relied on in the HHERA.

The EI characterized the current environmental conditions of the three TDEC Order CCR units (located onsite) at the KIF Plant. Investigations associated with surface stream waters, sediments, and aquatic communities at the KIF Plant and in the vicinity of the CCR units (located off site, i.e., the Emory, Clinch, and Tennessee rivers) have been addressed as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project). The HHERA focuses on the TDEC Order CCR units, not the historical operations of the KIF Plant or the closure activities. Therefore, potential risks associated with onsite exposures to CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system, such as a worker making repairs to infrastructure associated with the closed CCR units. Potential risks to human and ecological receptors from exposures to CCR Parameters in offsite abiotic (surface stream water and sediment) and biotic (benthic invertebrate and fish tissue) media assume current environmental conditions are representative of post-closure conditions (i.e., closed CCR units covered by geosynthetic cover systems) and consider current and anticipated future land use.

1.4 REPORT ORGANIZATION

This HHERA report is organized as follows:

- **Executive Summary:** Describes the principal elements and overall findings of the HHERA
- **Chapter 1 – Introduction:** Describes the regulatory framework, objectives, scope, and organization of the HHERA
- **Chapter 2 – Background and Risk Assessment Approach:** Describes the background for the CARA Plan and the general approach for conducting HHERAs for the TDEC Order plants
- **Chapter 3 – Site History and Environmental Characteristics:** Describes the operations, history, and environmental characteristics of the KIF Plant and the TDEC Order CCR units that are relevant to the assessment of potential risks to human and ecological receptors from possible exposure to the CCR Parameters
- **Chapter 4 – Summary of Environmental Investigations and Data for Use in the Risk Assessment:** Describes the data available from the EI, KRP investigations, and other studies that were completed at the KIF Plant, provides a summary of data quality and useability assessment, and provides a summary of data for use in the HHERA
- **Chapter 5 – Human Health Risk Assessment:** Describes the constituents of potential concern (COPCs), human receptors potentially exposed to COPCs, potential exposure routes for COPCs and human receptors, toxicity of the COPCs, the potential cancer risks and noncancer health hazards from exposure to COPCs, weight of evidence (WOE) evaluation and uncertainty assessment
- **Chapter 6 – Ecological Risk Assessment:** Describes the constituents of potential ecological concern (COPECs), ecological receptors potentially exposed to COPECs, potential exposure routes for COPECs and ecological receptors, assessment endpoints and measurement endpoints that are evaluated, various LOEs used to assess the different ecological receptors, the potential ecological risk from exposure to COPECs, WOE evaluation of the LOEs with respect to each receptor, and uncertainty assessment
- **Chapter 7 – Summary:** Summarizes the findings of the HHERA
- **Chapter 8 – References:** Lists the reference documents cited in this HHERA report
- **Tables and Exhibits:** Presented following the main text of this report and are numbered according to the chapter in which they are first discussed
- **Photographs:** Provides relevant photographs of the KIF Plant
- **Appendices:** Includes sources of screening levels and multiple LOEs methodology, detailed calculation tables and statistical outputs supporting the HHERA results described in the main report.

2.0 BACKGROUND AND RISK ASSESSMENT APPROACH

2.1 BACKGROUND

The nature and extent of CCR Parameters in environmental media at the KIF Plant were characterized during the EI, as documented in the KIF Plant EAR. In cases where new data were required to address TDEC information requests, TVA developed SAPs for the KIF Plant as noted in Section 1.3. The data collected during the following investigations and subsequent assessments completed pursuant to the EIP SAPs are applicable for evaluating risks to human and/or ecological receptors:

- Groundwater investigation
- Water use survey
- CCR material characteristics investigation

In the KIF Plant EAR, EI environmental sample data were compared to constituent specific TDEC-approved levels to identify CCR Parameters that require further evaluation in the CARA Plan. Environmental conditions in surface stream water, sediment, biological tissues, and aquatic communities have been evaluated in studies conducted for the KRP and ongoing monitoring in the long-term monitoring (LTM) program and were incorporated by reference in the KIF Plant EAR. The comprehensive data collected and subsequent reports prepared for the KRP were approved by TDEC and USEPA. Groundwater analytical results for CCR Parameters obtained during the EI were compared to TDEC-approved groundwater screening levels (GSLs) (Appendix B.1, Attachment A) to determine compliance with groundwater protection standards (GWPS) as required by the CCR Rule. As briefly explained below, GWPS are a subset of GSLs.

CCR Parameters for groundwater specified by the TDEC Order investigations consist of Federal CCR Rule Appendix III and Appendix IV constituents and additional TDEC Appendix I constituents (not included in CCR Rule Appendix III or IV). TDEC-approved GSLs for constituents in groundwater include primary drinking water standards (MCLs), secondary drinking water standards (SMCLs), health advisory levels and other drinking water quality criteria. GWPS are regulatory standards established by Section 257.95 (h)(1) and (h)(2) of the CCR Rule for concentrations of Appendix IV constituents in groundwater. The CCR Rule requires that CCR Parameter concentrations in groundwater must comply with promulgated drinking water MCLs (antimony, arsenic, barium, beryllium, cadmium, chromium-total, fluoride, mercury, radium 226&228, selenium, and thallium) and establishes GWPS for constituents for which MCLs have not been promulgated (cobalt, lead, lithium, and molybdenum).

In the HHERA, analytical results from the CCR material characteristics investigation conducted during the EI and documented in the KIF Plant EAR were compared to TDEC-approved human health receptor-specific screening levels (SSL_{HH}) (Appendix B.1) to identify COPCs for an onsite worker (Section 5.1.1.3). Concentrations above screening levels do not necessarily mean that adverse health effects are present, but that further evaluation is required in the CARA Plan to determine if an unacceptable risk exists, and if corrective measures are required. Except as noted above, the HHERA relied on interpretation of

qualitative LOE to evaluate potential risks to offsite human and ecological receptors potentially exposed to CCR Parameters in the aquatic environment that may be associated with the TDEC Order CCR units at the KIF Plant. Findings from the comprehensive environmental investigations, studies, and risk assessment reports prepared for the KRP and LTM provide comprehensive and relevant LOE to support the KIF Plant HHERA.

The document, *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), outlined a WOE approach using multiple quantitative and qualitative LOEs such that future CCR management decisions at the TDEC Order plants are informed by assessing risks based on the combined LOEs results rather than any single LOE.

2.2 RISK ASSESSMENT APPROACH

The purpose of the HHERA is to inform management decisions in the CARA Plan by evaluating the risks that potential exposures to concentrations of CCR Parameters in environmental media at the KIF Plant may pose to human and ecological receptors.

The USEPA encourages the use of multiple LOEs in a HHERA such that a WOE approach can be used to characterize risk. In their guidance, USEPA also makes clear that determining unacceptable risk should go beyond solely calculating numerical risk estimates (e.g., USEPA 2000). As such, to achieve the objectives provided in Section 1.2, both quantitative and qualitative LOEs were used in this HHERA.

- Quantitative LOEs include: 1) comparing concentrations of constituents measured in CCR material from the TDEC Order CCR units during the KIF Plant EI to medium-specific and receptor-specific human health screening levels, and 2) calculating carcinogenic risk and noncancer hazard index (HI) for the Human Health Risk Assessment (HHRA).

- Qualitative LOEs include: 1) the use of published information on CCR material and CCR Parameters, 2) results of the EI and other studies conducted at the KIF Plant, and 3) findings from the environmental sampling, biological studies, and HHERAs conducted as part of the KRP and LTM.

In brief, the KRP took place after the 2008 structural failure at the KIF Plant that resulted in the release of approximately 5.4 million cubic yards of CCR material into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee rivers. The primary objective of the environmental investigations and studies conducted for the KRP was to determine impacts to human and ecological receptors from the physical presence of CCR material and associated chemical and radiological constituents that remained in the potentially impacted reaches of the Emory, Clinch, and Tennessee rivers, collectively referred to as “the River System” (Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reaches A and B; Exhibit 2-1), following dredging from the Emory River (TVA 2011). The information and assessments available from the KRP are especially useful because they are directly applicable to the KIF Plant given that data were collected in areas of the Emory, Clinch, and Tennessee rivers that are adjacent to and downstream from the KIF Plant. The aggregation of data and study findings from the KRP by individual river reach are still a valid representation of current

conditions. This information is used in this HHERA to facilitate a focused evaluation of environmental conditions relevant to the TDEC Order CCR units. If the TDEC Order CCR units have impacted the aquatic environment, the effects would be greatest in the Emory River Reach B (Exhibit 2-1) immediately adjacent to those units and coinciding with the areas of groundwater impacts identified in the KIF Plant EAR. Consequently, the environmental investigations conducted for the KRP and LTM within the Emory River Reach B are directly applicable to the evaluation of potential impacts, if any, from the TDEC Order CCR units. Additional details about the KRP and LTM are provided herein as appropriate (Section 4.2).

Confidence in the conclusions of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions and approaches in the assessments. A discussion of these assumptions and how estimated risks most likely represent upper bound estimates of risks for human and ecological receptors can be found in Sections 5.4 and 6.7, respectively.

2.2.1 Human Health Risk Assessment

Consistent with USEPA Guidance, the HHRA consists of the primary steps of data collection and evaluation, exposure assessment, toxicity assessment, risk characterization and uncertainty analysis (USEPA 1989a). Data collection and evaluation were conducted as part of the KIF Plant EI (Section 4.1), and the KRP and LTM (Section 4.2). The exposure assessment consists of: (1) development of a CSM, which includes evaluating potential release mechanisms, identifying potential human receptors and exposure pathways, and selecting COPCs for each medium, (2) derivation of exposure assumptions, chemical-specific parameters, and exposure point concentrations (EPCs), and (3) estimation of exposure dose. The toxicity assessment includes the selection of toxicity values used in the HHRA. Risk characterization includes the components of risk estimation and risk description. Risk estimation combines the results of the exposure assessment and toxicity assessment to quantitatively estimate cancer risk and noncancer hazards for potential human receptors. Risk description provides information for interpreting quantitative results for human receptors evaluated in the HHRA with a WOE approach using multiple LOEs. The uncertainty analysis describes the primary sources of uncertainty for each step of the HHRA and how these might affect the risk estimates, establishing a level of confidence in the HHRA conclusions.

In this HHRA, risk associated with onsite exposures to CCR Parameters in CCR material were evaluated quantitatively based on concentrations of COPCs measured in CCR material from the TDEC Order CCR units during the KIF Plant EI. The assessment of potential risks to human receptors from offsite exposures to CCR Parameters in surface stream water, seasonally exposed sediment, and sport fish filet tissue from the reach of the Emory River adjacent to the TDEC Order CCR units at the KIF Plant relied on a qualitative review of findings and data generated during the KRP and LTM. A water use survey was used to evaluate the potential for offsite residents to be exposed to CCR Parameters in private potable groundwater wells and springs. The baseline human health risk assessment (BHHRA) prepared by Jacobs (2012) and environmental investigations conducted for the KRP provided a comprehensive and relevant evaluation of potential risks to offsite human receptors from CCR Parameters in the Emory River. Although the BHHRA relied on data from samples collected in 2009 or 2010, subsequent LTM evaluations have generally indicated that COPEC concentrations in monitored media (e.g., sediment) have been stable or decreasing over time due to ongoing natural attenuation. Therefore, the data from

the KRP and LTM are considered applicable to assessing current and future conditions adjacent to and downstream of the KIF Plant. Additional quantitative evaluations were not considered necessary. The HHRA is presented in Section 5.0.

2.2.2 Ecological Risk Assessment

Consistent with USEPA Guidance, the Ecological Risk Assessment (ERA) consists of the primary steps of problem formulation, exposure assessment, effects assessment, risk characterization and uncertainty analysis (USEPA 1997 and 1998). The problem formulation consists of the development of a CSM. The exposure assessment and effects assessment sections describe the measures of exposure and effect that are relied on in the ERA. Risk characterization includes two components: risk estimation and risk description. Risk estimation combines the results of the exposure assessment and effects assessment to evaluate potential risks to ecological receptors. For risk description, multiple LOEs are considered in a WOE approach used to characterize risks and potential impacts of CCR Parameters on the selected assessment and measurement endpoints. The uncertainty analysis describes the primary sources of uncertainty for each step of the ERA and how these might affect the risk estimates, establishing a level of confidence in the ERA conclusions. This ERA is based on a qualitative review of findings and data generated during the KRP and LTM. Additional quantitative risk evaluations were not considered necessary. The ERA is presented in Section 6.0.

3.0 SITE HISTORY AND ENVIRONMENTAL CHARACTERISTICS

Sections 3.1 through 3.2.4 summarize information presented in the KIF Plant EAR relevant to this HHERA. Additional details are provided in the KIF Plant EAR.

3.1 SITE OPERATIONS

TVA constructed the KIF Plant between 1951 and 1954 to provide additional electricity generating capacity for the atomic energy installation at Oak Ridge (TVA 1965). TVA commenced power generation at the KIF Plant in 1954 and continues operation today. The KIF Plant annually generates approximately 10 billion kilowatt-hours of electricity, burns approximately 14,000 tons of coal per day, and annually produces approximately 122,000 tons of CCR material in the forms of fly ash, bottom ash, and gypsum (TVA 2022a). Both fly ash and gypsum generated from the KIF Plant operations are beneficially reused as raw manufacturing materials. Of the 122,000 tons of CCR material produced each year, approximately 101,000 tons are beneficially used. On average, approximately 91 percent (%) of the fly ash generated at the KIF Plant is sold for reuse in the concrete industry each year where it is used in dams, roads, bridges, buildings, precast concrete products, airport runways, and driveways. Additionally, approximately 84% of the gypsum generated annually at the KIF Plant is sold to Georgia Pacific for use in the wallboard industry and CEMEX Knoxville to manufacture ready mix concrete.

The KIF Plant has five CCR units, as shown on Exhibit 1-1: the Stilling Pond, Interim Ash Staging Area, Sluice Trench and Area East of Sluice Trench, Peninsula Disposal Area, and KRP Ash Landfill. Three of these CCR units (the Stilling Pond, Interim Ash Staging Area, and Sluice Trench and Area East of Sluice Trench) are TDEC Order CCR units. Except for the currently active Peninsula Disposal Area, each of the CCR units was closed in accordance with applicable regulations in effect at the time of closure. The total area of the CCR units at the KIF Plant is approximately 395 acres. The total area of the TDEC Order CCR units at the KIF Plant is approximately 100 acres.

TVA currently manages CCR material generated by the KIF Plant in the Peninsula Disposal Area. Fly ash that is not beneficially used is transported by truck to the Peninsula Disposal Area for disposal. Dewatered gypsum is temporarily stockpiled in the Peninsula Disposal Area for later beneficial use. Reject gypsum (gypsum fines) are disposed within the Peninsula Disposal Area. Bottom ash is sluiced to the Bottom Ash Dewatering Facility where it is dewatered and then transported by truck to the Peninsula Disposal Area for disposal. A Water Quality Channel conveys process water to the Polishing Pond. Conveyance piping carries treated process water from the Polishing Pond outlet to National Pollutant Discharge Elimination System (NPDES) permitted Outfall 001 where it is discharged to the Plant Intake Channel.

3.1.1 CCR Unit History and Land Use

At the KIF Plant, CCR material was initially placed in the Initial Ash Disposal Area, which was a slack water area created by the impoundment of the Emory River/Watts Bar Reservoir. In 1958, construction of

a perimeter dike system formed the Ash Collection Pond, and CCR material was subsequently directed to the Ash Disposal Area when the Initial Ash Disposal Area reached capacity in 1965. In the late 1970s, TVA raised the elevation of Dike C and constructed the divider dike to form the Stilling Pond, and the Metal Cleaning Ponds were constructed in the footprint of the closed Initial Ash Disposal Area. Interior Dike D was constructed in 1983 reducing the size of the Ash Disposal Area as part of the transition to dredge cell operations.

On December 22, 2008, a structural failure in the northwestern corner of the Ash Disposal Area resulted in the release of approximately 5.4 million cubic yards of CCR material into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee rivers. The initial release traveled upstream as far as Emory River mile 5.75 and was eventually transported downstream of the KIF Plant by high stream flows into the Clinch River traveling as far as Tennessee River mile 564.

TVA undertook immediate response actions beginning on the day of the failure in close coordination with the USEPA, TDEC, and other agencies. TVA and the USEPA signed an Administrative Order and Agreement on Consent that provided the regulatory framework for response and recovery actions under the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA). TDEC also issued a Commissioner's Order to TVA requiring the comprehensive assessment, cleanup and restoration of areas impacted by the release. The recovery and restoration actions discussed herein are collectively referenced as the KRP. These included river dredging, environmental sampling, ecological investigations, embayment restoration, groundwater flow modeling, and construction of the KRP Ash Landfill. TVA's compliance with the Administrative Order and Agreement on Consent is documented in the Kingston Ash Recovery Project Completion Report (TVA 2015).

As a part of removal actions and per approvals from TDEC, the Metal Cleaning Ponds were closed so that the area could serve as a temporary staging area for CCR material during river dredging operations and subsequent construction of the KRP Ash Landfill. A delineation layer of stone and geotextile fabric was placed over the subgrade prior to staging CCR material. This staging area corresponds to the Interim Ash Staging Area. Staged CCR material above the delineation layer was eventually removed from the Interim Ash Staging Area and placed in the Peninsula Disposal Area (AECOM 2016a). TVA completed the geosynthetic soil cover system and closure of the KRP Ash Landfill in 2015 and the soil cover system and closure for the Interim Ash Staging Area in 2016.

In 2015, as part of activities associated with transition from wet to dry CCR material handling, the Stilling Pond and the sluice trench area of the Sluice Trench and Area East of Sluice Trench CCR units were covered by geosynthetic soil cover systems and closed. Additional information on the CCR unit history is provided in the KIF Plant EAR.

3.1.2 Ownership and Surrounding Land Use

The KIF Plant is owned and operated by TVA, a corporate agency of the United States, and is located at the confluence of the Clinch River and the west bank of the Emory River, as shown on Exhibit 1-1.

Land use surrounding the KIF Plant is primarily developed and includes residential and commercial use, with some forested areas. The nearest residence is located approximately 0.4 miles south of the KIF

Plant in Harriman. Additionally, four municipal water departments withdraw water from the Emory River, Little Emory River, and Watts Bar Lake for municipal purposes in the vicinity of the KIF Plant, as follows (TVA 2022b):

- The Roane Central Water District supplies public water to areas west and southwest of the KIF Plant with water sourced from the Rockwood Water Utility approximately five miles southwest and downstream of the plant. The Rockwood Water Utility obtains water from Watts Bar Reservoir near the Postoak Creek inlet.
- The Harriman Utility Board supplies public water to areas north and northwest of the KIF Plant, with water sourced from the Emory River approximately 2.5 miles northwest and upstream of the plant.
- The Kingston Water Department supplies public water to areas south and southeast, including the KIF Plant, with water sourced from Watts Bar Reservoir approximately two miles south and downstream of the plant, but slightly upstream of the confluence of the Emory and Clinch rivers.
- The Cumberland Water Utility supplies public water to areas east and northeast of the KIF Plant with water sourced from the Little Emory River approximately four miles northeast and upstream of KIF.

3.2 ENVIRONMENTAL CHARACTERISTICS

3.2.1 Regional and Site Physiography

The KIF Plant is located within the Valley and Ridge physiographic province of the Appalachian Highlands physiographic division (Fenneman 1938). The Valley and Ridge Physiographic Province consists of a belt of northeast / southwest trending ridges and valleys formed by the differential erosion of a thick sequence of folded and faulted Paleozoic sedimentary rocks (USGS 1995). The elevations within the province range from about 380 feet above mean sea level (amsl) to 4,604 feet amsl (USGS 1995).

The KIF Plant is located in a topographically low area with a higher elevation ridge to the northwest and the Emory River on the east. The KIF Plant pre-construction elevation ranged from approximately 740 to 750 feet amsl.

3.2.2 Regional Geology, Hydrogeology, and Surface Stream Water Hydrology

Regionally, the Valley and Ridge province consists of a belt of northeast-southwest trending ridges and valleys formed by differential erosion of a thick sequence of folded and faulted Paleozoic rocks (USGS 1995). Much of the valleys are made up of limestones and shales, which are more susceptible to erosion, while the more resistant sandstones and conglomerates form the ridges (USGS 1978). The folded strata are the result of the thrust faulting and the various deformation events that produced the Appalachian Mountains (USGS 1979). The folding is less intense in the Tennessee portion of the province, but major faults are common and vertical to overturned beds appear in many places, particularly on the northwestern sides of anticlines (USGS 1997).

3.2.2.1 Regional Geology

Locally, structural geology at the KIF Plant is typical of the Valley and Ridge province and consists of northeast striking and southeast-dipping strata (TVA 1991). Bedding planes dip to the southeast and have been primarily controlled by the Chattanooga Thrust Fault and the Kingston Thrust Fault, which trend in a northeasterly direction and can be traced from northwest Georgia to Central Virginia (TVA 2018). Local geologic mapping indicates the plant is underlain by Cambrian and Ordovician age bedrock of the Rome Formation, Conasauga Group, and the Knox Group. The bedrock primarily consists of shale with interbedded siltstone, limestone, and conglomerate, and are locally of low groundwater-producing capacity. Unconsolidated deposits overlay the bedrock and can be divided into two categories: (1) alluvial clays, silts, sands, and gravels deposited by the Clinch and Emory rivers and its tributaries, and (2) residuum derived from the decomposition of the parent bedrocks (TVA 2004).

3.2.2.2 Surface Stream Water Hydrology

The KIF Plant is located at the confluence of the Emory River and Clinch River (Exhibits 1-1 and 2-1). Surface water hydrology around the KIF Plant is complex. The Emory River enters the vicinity of the KIF Plant from the north and flows in a northwest to southeast direction around the peninsula area of the KIF Plant and then joins the Clinch River to the south. The Clinch River flows in a northeast to southwest direction and joins the Tennessee River. The CCR units addressed by the TDEC Order are bounded by Emory River Reach B, which includes the cooling water Plant Intake Channel for the KIF Plant and the Swan Pond Embayment. The KRP Ash Landfill, which is not a TDEC Order unit, is located at the site of the former failed Dredge Cell responsible for the 2008 CCR release. Even though some of the 2008 CCR release flowed upstream into the lower portion of Emory River Reach C, this stretch of river is upstream of the TDEC Order CCR units. Emory River Reach A is downstream of the TDEC Order units. Reaches of the Clinch and Tennessee rivers evaluated in the KRP are farther downstream of the TDEC Order CCR units.

Both the Emory River and Clinch River are impounded by Watts Bar Dam. In accordance with the TVA Watts Bar Operating Guide (TVA 2022c), normal summer pool for Watts Bar Reservoir is maintained between 740 and 741 feet amsl; normal winter pool is maintained between 735 and 737 feet amsl. Prior to the construction of Watts Bar Dam, Swan Pond Creek followed a meandering course through the KIF Plant footprint and discharged to the Emory River; however, the construction of Watts Bar Dam circa 1942 created a backwater area that impounded Swan Pond Creek along with the Emory and Clinch rivers.

The complex surface water hydrology at the KIF Plant is influenced by structures constructed to divert cold water to the Plant Intake Channel as well as conditions in Watts Bar Reservoir. These structures include an underwater dam located on the Clinch River that diverts cold water upstream along the bottom of the Emory River to the Plant Intake Channel and a skimmer wall that restricts warmer water from flowing into the Plant Intake Channel. Wave action in Watts Bar Reservoir temporarily induces reverse flows in the vicinity of the KIF Plant. Cold water discharges from Melton Hill Dam, located approximately 19 miles upstream of the KIF Plant on the Clinch River, also influence thermal stratification near the KIF Plant.

3.2.2.3 Regional Hydrogeology

The Valley and Ridge province is underlain by carbonate bedrock aquifers of Cambrian, Ordovician, and Mississippian age (USGS 1995). On a regional level, these aquifers underlie more than one-half of the province and are typically present in valleys and rarely present on the broad, dissected ridges.

Groundwater in the Valley and Ridge aquifers primarily is stored in and moves through fractures, bedding planes, and solution openings in the rocks. Groundwater movement in the province in eastern Tennessee is localized in part by the repeating lithology created by thrust faulting and in part by streams. Major streams are parallel to the northeast-trending valleys and ridges, and tributary streams are perpendicular to the valleys and ridges. Older rocks have been displaced over younger rocks along thrust faults forming a repeating sequence of permeable and less permeable hydrogeologic units. The repeating sequence, coupled with the stream network, divides the area into a series of adjacent, isolated, shallow groundwater flow systems. Within these local flow systems, most of the groundwater movement takes place within 300 feet of land surface. The water moves from the ridges toward the adjacent streams that flow parallel to the long axes of the valleys. The majority of the groundwater is discharged directly to local springs or streams, but some of it flows along permeable fractures, bedding planes, and solution zones to finally discharge at more distant springs or streams. Discussion of the uppermost aquifer beneath the TDEC Order CCR units is provided in Appendix H.1 of the KIF Plant EAR.

3.2.3 Local Climate

Locally near the KIF Plant, the average monthly high temperature at weather station USC00404871, Kingston, Tennessee (National Oceanic & Atmospheric Administration 2020) located approximately three miles south of the KIF Plant, ranges between 38 degrees Fahrenheit (°F) in January to 78°F in July, and the average monthly low ranges between 28°F in January to 69°F in July. Average annual precipitation at this location is 55.2 inches, with December being the wettest month, averaging 5.7 inches, and October being the driest month, averaging 3.3 inches.

3.2.4 Cultural and Historical Resources

Historically, the banks of the Clinch River were used as hunting grounds and settlements for the Woodland, Mississippian, and Cherokee Indian Tribes (USDA 2009). In the late 1700s, a battle for the land between the Native Americans and white settlers spanning over 28 years, resulted in the settlement of the Clinch River region by the pioneers (USDA 2009).

Roane County became a hub for the transport of iron, coal, and agricultural products by barge, flatboat, or steamboat and later by rail after the Civil War. Industries including agriculture, iron, and timber were prevalent in the early 1900s (USDA 2009). President Roosevelt signed the Tennessee Valley Authority Act on May 18, 1933, creating the TVA as a federal corporation (TVA 2023a). TVA completed the construction of Watts Bar Dam in January 1942, three weeks after the attack on Pearl Harbor, which provided electricity for the war effort – including the Manhattan Project at nearby Oak Ridge National Laboratory (ORNL). The Watts Bar Reservoir extends from the dam to 72.4 miles northeast to Fort Loudon Dam, including Roane County (TVA 2023b). Today, tourism is a major industry in the area, as

over 700 miles of shoreline along Watts Bar Reservoir is located within Roane County (Roane Alliance 2023).

3.2.5 Habitat, Flora, and Fauna

3.2.5.1 Terrestrial Habitat in the Vicinity of the KIF Plant

Most of the land at the KIF Plant has been altered by construction, maintenance, and operation of the facility for over 50 years. Most of the industrial areas at the KIF Plant are un-vegetated, gravel, or paved lots, but a few isolated locations contain early successional plant communities dominated by non-native weeds. These vegetated areas primarily form the edges of parking lots and roadways. Land cover within a two-mile radius of the plant is primarily deciduous forest, open water, and hay/pasture. Restoration activities, including planting of nearly 7,000 trees of 40 different types over 15-acres, installation of osprey (*Pandion haliaetus*) and heron (*Ardeidae sp.*) platforms, and construction of a three-acre wetland, have corrected damages from the 2008 release and have restored much of the shorebird habitat (TVA 2016, USEPA 2017).

3.2.5.2 Aquatic Habitat in the Vicinity of the KIF Plant

The KIF Plant is located at the confluence of the Emory and Clinch rivers and near the confluence of the Clinch and Tennessee rivers on Watts Bar Reservoir. The Watts Bar Reservoir was formed when TVA constructed Watts Bar Dam in 1942 at Tennessee River mile 529.9. The Watts Bar Reservoir consists of three “arms:” 72 miles of navigable water on the Tennessee River (to Fort Loudoun Dam at Tennessee River mile 602.3), 12 miles of navigable water on the Emory River, and 23 miles of navigable water on the Clinch River (to Melton Hill Dam at Clinch River mile 23.1).

Aquatic habitat is largely affected by watershed land use and bathymetry, which in turn affects the types of aquatic life found in an area. Seawalls and riprap dominate the shoreline along residentially developed areas adjacent to the reservoir. Along undeveloped areas, fallen trees provide shoreline habitat. Bedrock outcrops, shallow shoreline gravel beds, and rubble and cobble beds on steeper shorelines also provide varied aquatic habitats. Aquatic plant bed habitats are rare near Watts Bar Reservoir; high water flows and other factors likely eliminated the (invasive) Eurasian water milfoil (*Myriophyllum spicatum*) beds during the 1990s. Some beds of spiny-leaf naiad (*Najas marina*), another exotic species, do exist (TVA 2009). Aquatic species have different tolerances for temperature, water velocity, dissolved oxygen content, nutrients, and pH that limit where these species can live (e.g., main-stem river versus tributaries).

3.2.5.3 Flora and Fauna

A review of the TVA Natural Heritage Database in March 2024 indicated that of the wildlife listed by the United States Fish and Wildlife Service (USFWS) or TDEC as being of conservation concern, the osprey has been documented to occur within three miles of the KIF Plant, and the bald eagle (*Haliaeetus leucocephalus*), gray bat (*Myotis grisescens)*, little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), Indiana bat (*Myotis sodalis*), tricolored bat (*Perimyotis subflavus*), and meadow jumping mouse (*Zapus hudsonius*) have been documented to occur within Roane County, Tennessee. No caves within three miles of the KIF Plant were identified in the Natural Heritage Database (TVA 2024b).

Colonial wading birds have also been observed within a three-mile radius of the KIF Plant. The Natural Heritage Database (TVA 2024b) also identified the lake sturgeon (*Acipenser fulvescens*), rainbow mussel (*Cambarunio iris*), Tennessee dace (*Chrosomus tennesseensis*), oyster mussel (*Epioblasma capsaeformis*), spotfin chub (*Erimonax monachus*), redlips darter (*Etheostoma maydeni*), spike (*Eurynia dilatata*), spiny riversnail (*Io fluvialis*), wavy-rayed lampmussel (*Lampsilis fasciola*), pocketbook (*Lampsilis ovata*), Alabama lampmussel (*Lampsilis virescens*), tangerine darter (*Percina aurantiaca*), longhead darter (*Percina macrocephala*), sheepnose (*Plethobasus cyphyus*), Tennessee pigtoe (*Pleuronaia barnesiana*), pink heelsplitter (*Potamilus alatus*), and Tennessee bean (*Venustaconcha trabalis*) as aquatic species of concern documented to occur in the vicinity of the KIF Plant. Possible historical observations have also included 16 aquatic species: Emory River crayfish (*Cambarus sp.*), highfin carpsucker (*Carpiodes velifer*), spectaclecase (*Cumberlandia monodonta),* blue sucker (*Cycleptus elongatus*), fanshell (*Cyprogenia stegaria*), shiny pigtoe pearlymussel (*Fusconaia cor*), fine-rayed pigtoe (*Fusconaia cuneolus*), pink mucket (*Lampsilis abrupta*), ornate rocksnail (*Lithasia geniculata*), ring pink mussel (*Obovaria retusa*), sickle darter (*Percina williamsi*), white wartyback (*Plethobasus cicatricosus*), orange-foot pimpleback (*Plethobasus cooperianus*), Tennessee clubshell (*Pleurobema oviforme*), pyramid pigtoe (*Pleurobema rubrum),* and slabside pearlymussel (*Pleuronaia dolabelloides*).

As stated above, heron and osprey platforms were installed as part of restoration activities. In addition, 11 osprey nests have been reported within three miles of the TDEC Order CCR units; however, only seven of these were extant as of 2016 (TVA 2016). The closest record of an extant osprey nest as of 2016 is approximately 310 feet from the TDEC Order CCR units on a lighting structure next to the railroad tracks (TVA 2016).

4.0 SUMMARY OF ENVIRONMENTAL INVESTIGATION AND DATA FOR USE IN THE RISK ASSESSMENT

4.1 SUMMARY OF ENVIRONMENTAL INVESTIGATIONS

In accordance with the TDEC Order, TVA and Stantec, on behalf of TVA, prepared an EIP for the KIF Plant to obtain and provide information requested by TDEC. Following public review and comment on the draft, the EIP was approved by TDEC on November 16, 2018, and TVA implemented the EI activities between 2018 and 2021 in accordance with the approved EIP and associated SAPs. As specified in the TDEC Order, the objective of the EIP was to "identify the extent of soil, surface water, and groundwater contamination by CCR" from onsite management of CCR material in impoundments and landfills. In addition, per TDEC's information requests, the EIP included assessment of CCR unit structural stability and integrity.

EI results were evaluated and presented in the KIF Plant EAR. The EI investigation characterized the current environmental conditions of the TDEC Order CCR units at the KIF Plant.

The investigations and subsequent assessments completed pursuant to the EIP SAPs at the KIF Plant TDEC Order CCR units are listed below:

- Background Soil Investigation
- CCR Material Investigations: Geotechnical Investigation (Exploratory Drilling), CCR Material Characteristics Investigation, Material Quantity Assessment
- Hydrogeological Investigations: Hydrogeological Investigation, Groundwater Investigation (Sampling), Geochemical Evaluation, Water Use Survey
- Seep Investigation.

The results and findings of the EI relevant to this HHERA (i.e., CCR material characteristics investigation and water use survey) are summarized below. The findings of the EI are discussed in greater detail in the KIF Plant EAR. The results of investigations conducted during the KRP and LTM were incorporated by reference in the EI and the major findings for the River System are summarized in Section 4.2.

4.1.1 CCR Material Characteristics

To evaluate the characteristics of CCR material in the CCR units, TVA reviewed information from historical studies, and performed investigations as part of the EI including an exploratory drilling field program. The CCR material characteristics investigation included collecting CCR material samples (saturated and unsaturated) from within the Interim Ash Staging Area and Sluice Trench and Area East of Sluice Trench (Exhibit 4-1). Collected samples were analyzed for CCR Parameters and additional parameters of interest for the CCR material characteristics investigation (i.e., total organic carbon, iron,

and manganese). The CCR material sampling results and statistical analyses relevant to the HHERA are provided in Appendix C.1.

4.1.2 Groundwater Quality Evaluation

The groundwater quality evaluation was based on a statistical evaluation of constituents listed in TDEC Appendix I and Appendices III and IV of the CCR Rule. Groundwater sampling results and the statistical summary from the KIF Plant EAR are provided in Appendix C.1 of this HHERA for reference. The dataset compiled for statistical analysis included available analytical data for groundwater samples collected between June 2009 and December 2022, although the specific start date and frequency of sampling may have varied between wells based on date of well installation and the applicable monitoring program. This time period was selected because it included data that met the requirements of the data quality objectives for the TDEC Order program.

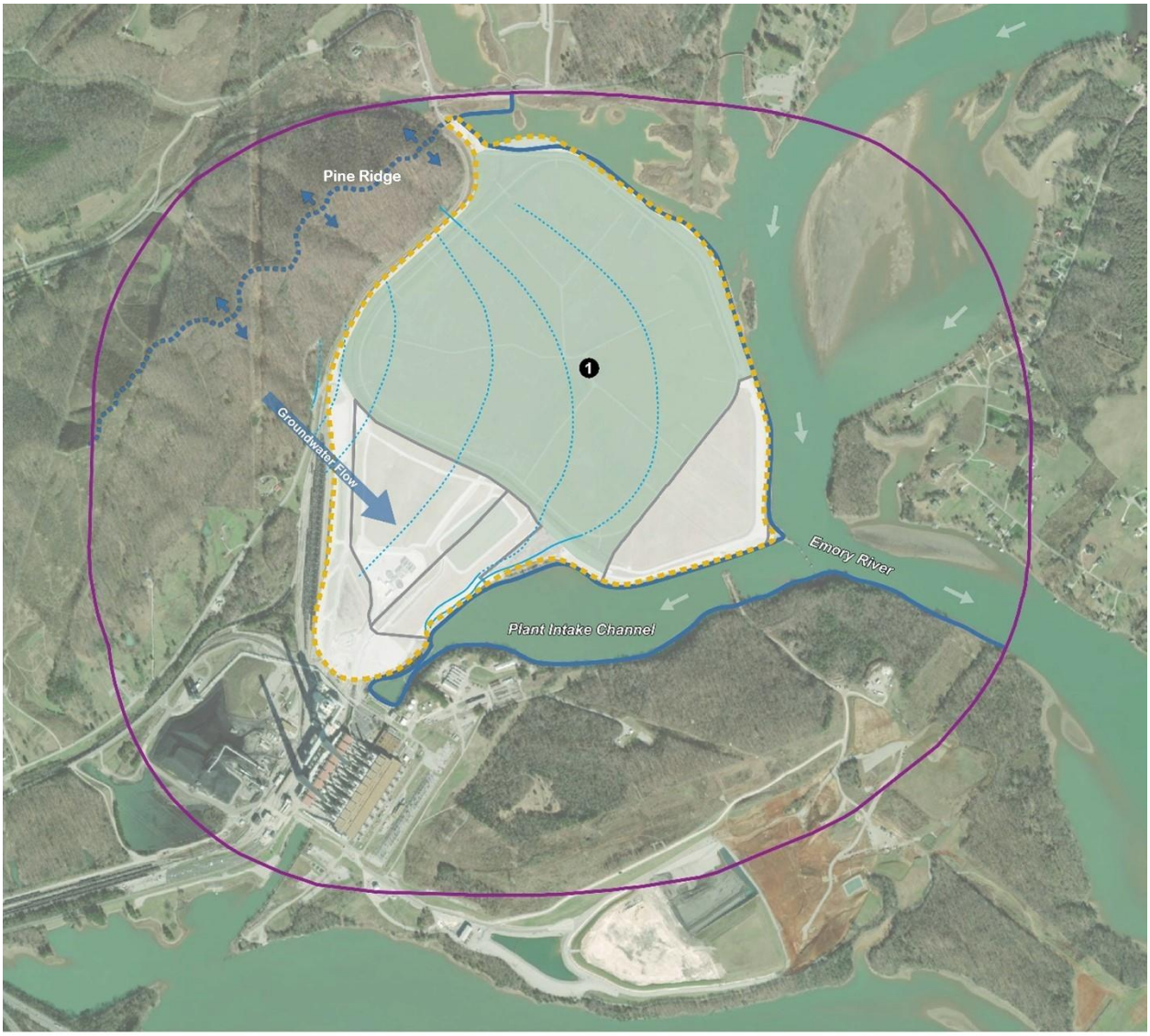
Downgradient of the TDEC Order CCR units, one CCR Rule Appendix IV CCR constituent, cobalt (which is also a TDEC Appendix I constituent), had statistically significant concentrations in onsite groundwater above a GSL in five wells, including 6AR, AD-2, KIF-103, KIF-104, and KIF-105. Further evaluation in the CARA Plan is required to determine the need for corrective action based on statistically significant concentrations above an established GWPS. The groundwater impacts are limited to downgradient areas onsite, along the perimeter of the TDEC Order CCR units.

4.1.3 Water Use Survey

The water use survey began with a desktop review, which identified usable private water supply wells and surface stream water sources potentially being used for domestic purposes within 0.5-mile of the boundary of the KIF Plant. In addition, a review of geologic and hydrogeological conditions (e.g. hydrogeological barriers such as rivers and streams, topography, groundwater flow direction, and watershed boundaries) was undertaken to identify offsite areas where groundwater has the potential to be affected by the KIF Plant TDEC Order CCR units. As shown on the following figure, groundwater flow in the unconsolidated materials and bedrock at the KIF Plant CCR units is generally to the east-southeast toward the Emory River or Plant Intake Channel (part of the Emory River), and groundwater flow in the vicinity of the CCR units is bounded to the east and southeast by the Emory River and Plant Intake Channel. Pine Ridge, which is located to the west and upgradient of the plant, serves as a topographic divide to groundwater flow. Overall, because of the groundwater flow directions and hydraulic barriers, it is unlikely that groundwater in areas located west of the KIF Plant and Pine Ridge or east and northeast of the Emory River have been impacted by the KIF Plant TDEC Order CCR units.

Considering the geologic and hydrogeologic conditions present at and in the vicinity of the KIF Plant, one parcel, shown below, has the potential of being impacted by CCR management operations; however, no known water supply wells or springs are documented on the portion of the parcel located within the area of interest. Based on the overall results of the water use survey, current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs located in the vicinity of the KIF Plant.

WATER USE SURVEY AREA



4.2 OTHER SOURCES OF DATA FOR THE KIF PLANT

As discussed in Section 2.2, the KRP was initiated after the 2008 structural failure at the Ash Disposal Area, which resulted in the release of CCR material into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee rivers. The CCR material release traveled upstream as far as Emory River mile 5.75 and was eventually transported downstream of the KIF Plant through the Clinch River as far as Tennessee River mile 564. The KRP evaluations included environmental and ecological investigations to evaluate potential risks to human health and ecological receptors, development of remedial action plans, and implementation of SAPs to monitor recovery for the River System. Reference data were also collected from unimpacted locations in the Emory River, Little Emory River, Clinch River, and Tennessee River. To facilitate data collection and evaluation in the KRP, each river was divided into reaches delineated by river mile relative to its downstream confluence (Exhibit 2-1). Reaches of the Clinch and Tennessee rivers evaluated in the KRP are downstream of the TDEC Order CCR units.

The primary objective of the environmental investigations and studies conducted for the KRP was to determine impacts to human and ecological receptors from the physical presence of CCR material and associated chemical and radiological constituents that remained in the River System following dredging from the Emory River (TVA 2011). Data collection for the KRP was designed to evaluate conditions over a relatively large geographic area based on the known extent of the CCR material release and transport through the River System. In contrast, the objective of this HHERA is a more narrowly defined evaluation of potential impacts on the Emory River from the TDEC Order CCR units. The aggregation of data and study findings from the KRP by individual river reach facilitates a focused evaluation of environmental conditions relevant to the TDEC Order CCR units.

If the TDEC Order CCR units have impacted the aquatic environment, the effects would be greatest in the Emory River Reach B (Exhibit 2-1) immediately adjacent to those units and coinciding with the areas of groundwater impacts identified in the KIF Plant EAR. Consequently, the environmental investigations conducted for the KRP and LTM within the Emory River Reach B are directly applicable to the evaluation of potential impacts, if any, from the TDEC Order CCR units.

Overall findings from the KRP characterize environmental conditions in the River System as a whole and provide context for regional distribution of CCR Parameters not related to the TDEC Order CCR units or the 2008 material release.

The following sections provides a brief overview of the environmental sampling, biological studies, and baseline HHERAs conducted as part of the KRP that were relied on to inform this HHERA.

4.2.1 Surface Streams, Sediment, and Ecological Investigations

The scope of the KRP ecological investigations included approximately 20,000 samples of water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses; toxicity testing of both water and sediments (including partial life-cycle tests); field and laboratory studies conducted by TVA staff, consultants, government research agencies, and universities; all of which culminated in approximately 50 papers published in peer-reviewed journals. Due to the existing extensive ecological

analytical results and ongoing ecological data collection activities conducted as part of the LTM (described below), additional ecological and surface stream water sampling was not proposed in the EIP for the KIF Plant that was approved by TDEC.

Sections 4.2.1.1 through 4.2.1.4 summarize findings from the KRP ecological investigations. The KRP documents use the term “ash” to refer to the released material. For consistency within this HHERA, the term “CCR material” is used when referring to the released material.

4.2.1.1 Baseline Ecological Risk Assessment

In August 2012, the USEPA approved a Baseline Ecological Risk Assessment (BERA) (Arcadis 2012) for the KRP. That BERA was used to evaluate potential ecological effects on biota from CCR material in the River System at the KIF Plant release site. The BERA focused primarily on data collected after dredging in the Emory River was completed and was developed in support of the *Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System Engineering Evaluation/Cost Analysis (EE/CA)* (*River System EE/CA*; TVA 2012a), which evaluated alternatives for restoration of the River System impacted by the 2008 CCR material release.

The results of the BERA were also presented in a special series of seven articles presented in the journal “Integrated Environmental Assessment and Management”, Volume 11, Number 1. As described in the letter to the editor introducing this special series, this BERA incorporated ecological surveys, sediment toxicity testing, benthic community analysis, and quantitative risk assessments of risk to indigenous fish and riparian and aquatic wildlife (Bradley 2014). The BERA identified benthic macroinvertebrate exposure to CCR material, arsenic, and selenium in sediment and potential dietary exposure to insectivorous birds that feed on benthic macroinvertebrates (killdeer and tree swallow) as the critical receptors and pathways requiring actions to manage risks. The BERA (Arcadis 2012) identified benthic macroinvertebrate exposure to CCR material, arsenic and selenium in sediment, and potential dietary exposure to insectivorous birds that feed on benthic macroinvertebrates (killdeer and tree swallow) as the critical receptors and pathways requiring actions to manage risks. Natural attenuation of residual CCR in the river system with LTM was selected as the preferred remedy.. Given that this conclusion was based on an evaluation of potential toxicity to 17 different ecological receptors representing a broad range of species, feeding habits, and trophic levels, it was concluded that the BERA provided a high level of confidence to support cleanup and restoration decisions in the River System (Bradley 2014).

4.2.1.2 Phase 3 Action Memorandum for the River System

In November 2012, TVA submitted the *Phase 3 Action Memorandum for the River System* (*Action Memorandum*; TVA 2012b), which USEPA approved. The *Action Memorandum* recommended monitored natural recovery (MNR) as the preferred removal action. MNR relies on natural processes such as mixing, scouring/redeposition and sedimentation (burial) to reduce the relatively low risks posed to benthic macroinvertebrates and to birds that prey on them. Remedial action objectives and remedial goals were established as part of this *Action Memorandum* (TVA 2012b). Objectives for monitoring the natural recovery of the River System were to confirm that risks associated with the CCR material release remain low and that CCR material-related metals concentrations in sediment and benthic invertebrate tissue decline with time.

4.2.1.3 Long-Term Monitoring (First Five-Year Monitoring Period; 2013-2017)

In May 2013, the USEPA approved a *Long-Term Monitoring Sampling and Analysis Plan* (*LTM SAP*) (TVA 2013) for a five-year period for the River System near the KIF Plant to monitor the effectiveness of the MNR removal action. In September and October 2010, TVA collected surface water samples from the Emory, Clinch, and Tennessee rivers. Surface stream analytical results for the Emory River Reach B adjacent to the KIF Plant were summarized in Tables 4 and 5 of the *River System EE/CA* (TVA 2012a). Concentrations of CCR related constituents in surface water were below Federal and State of Tennessee standards for drinking water and below criteria for protection of aquatic life. As a result, surface stream water sampling in the Emory and Clinch rivers was not included in the *LTM SAP*.

Sediment sampling was a component of the *LTM SAP* to evaluate the effectiveness of MNR; to support sediment transport modeling, monitoring CCR Parameter concentrations, and toxicity testing; and to provide additional information used in evaluations of benthic community survey results. Sediment transport modeling and monitoring of CCR Parameters in sediment indicated continued deposition of native sediments over residual CCR material deposits and successful dilution of CCR Parameters in native sediments. Sediment toxicity tests found no impacts to benthic invertebrate growth or survival. Sediment and biota tissue concentrations of arsenic and selenium, and sediment % ash declined over time and were below their respective remedial goals and/or tissue monitoring endpoints during the first five-year monitoring period.

Biosurveys of benthic communities were conducted biennially to evaluate the response of benthic invertebrate communities to CCR material through their exposure in CCR material-contaminated sediments and sediment pore water. Each benthic invertebrate community sample was analyzed for taxonomic identification and enumeration of benthic invertebrates, with results reported for taxa abundance, richness, and diversity as indicators of environmental quality. Community studies for benthic invertebrates did not identify negative relationships between arsenic or selenium concentrations, or sediment % ash relative to key benthic invertebrate community metrics (e.g., abundance, diversity, or richness).

Aerial-feeding birds were considered to be at low risk in the BERA due to bio-uptake of selenium in their diet. Therefore, annual sampling of tree swallow eggs was conducted from a colony established near Emory River mile 1.0 and a reference colony at Tennessee River mile 572. Egg contents (excluding shells) were analyzed for metals and metalloids. These surveys also documented deformity incidences, clutch size, hatching success, and 15-day hatchling survival. Tree swallow biosurveys and egg tissue evaluations found no negative relationships between selenium concentrations and overall tree swallow fecundity, indicating no adverse impacts to the overall reproduction of the tree swallow population near the release. As a result, the tree swallow investigations were discontinued after 2015.

Fish sampling was included in the *LTM SAP* to evaluate recovery of the ecological function and recreational use of the River System and for natural resources assessment. Community health and reproductive studies for fish did not identify any negative relationships between arsenic or selenium concentrations, or sediment % ash relative to key fish community metrics or spring sportfish surveys, or visible impacts to overall fish health and reproduction. Studies conducted through 2017 indicated that fish

and benthic communities continued to be present in numbers and conditions typically observed for similar water bodies (Arcadis 2020).

Based on the review of the 2017 data, the results for the sediment transport monitoring, sediment toxicity tests, benthic invertebrate bioaccumulation and community surveys, and fish bioaccumulation, community surveys and biosurveys all indicated that the selected MNR remedy is functioning as intended. The results of the first five-year monitoring period demonstrated that risks associated with the CCR material release remain low, that CCR material-related metal concentrations in sediment and biota tissue will likely continue to decline over time, and that all the remedial targets were achieved (Arcadis 2020).

In addition to the *LTM SAP* program, TVA submitted biological monitoring data from Fall 2013, 2015, and 2017 as part of the application for its KIF Plant NPDES permit renewal. The biological monitoring data for the sites upstream and downstream of the KIF Plant were similar and within the acceptable range of variation, such that these data meet requirements of a balanced indigenous population (TDEC 2018), further supporting the effectiveness of the MNR remedy.

4.2.1.4 Long-Term Monitoring (Second Five Year Monitoring Period; 2019-2023)

Since the remedial targets were met during the first five-year monitoring period, the results supported a reduction in LTM requirements for the second five-year monitoring period. The second five-year *LTM SAP* (TDEC 2021) described the data quality objectives, sampling design, and sampling procedures that were used for collecting the data necessary to assess the continued effectiveness of the selected removal action for the second five-year review period, from 2019 to 2023.

Sediment and benthic community sampling was conducted in 2019 and 2021 in the Emory and Clinch rivers. The sediment sampling was conducted concurrent with the fall benthic invertebrate community surveys. Samples of larval mayflies were collected for chemical analysis and were analyzed for % moisture and whole-body metals and metalloids to support the MNR evaluation. Sampling for fish bioaccumulation continued during the second five-year monitoring period in order to support evaluation of restoration of ecological function and recreational use of the River System to pre-release conditions. Biennial biosurveys of the fish community were conducted in the fall of 2019 and 2020 for comparisons with historical surveys. Studies conducted during the second five-year monitoring period confirmed that remedial targets and risk management recommendations related to fish and benthic invertebrates provided in the BERA (Arcadis 2012) continue to be met. The results for the sampling conducted in accordance with the second *LTM SAP* will be reported in a separate future submittal.

4.2.2 Human Health

Potential risks to public health from the 2008 CCR material release were evaluated in two reports as summarized below.

Immediately following the CCR release, local residents petitioned the Tennessee Department of Health (TDH) to conduct a public health assessment (PHA) to address concerns about the health effects of CCR material in their yards, in coves of the Emory River adjacent to their homes, and airborne CCR particles (TDH 2010). TDH conducted the PHA under a cooperative agreement with the Agency for Toxic

Substances and Disease Registry (ATSDR) and relied on analytical results for released CCR material, surface stream water, groundwater, drinking water, and air. The samples were collected by TVA, TDEC, and USEPA starting December 23, 2008, the day after the release, through May 2009. TDH also interviewed residents and collected general information relevant to community health. The major conclusions of the PHA were that coal ash and metals in coal ash did not:

- Impact private wells or spring water within four miles of the KIF Plant
- Impact municipal drinking water from the Kingston and Rockwood water treatment plants
- Limit recreational opportunities, such as swimming and boating, except in the immediate vicinity of the CCR material release and cleanup
- Increase particulate matter or metals concentrations in ambient air.

The KRP was also supported by a BHHRA (Jacobs 2012). The objective of the BHHRA was to develop quantitative and qualitative estimates of potential cancer risks and noncancer hazards for human receptors exposed to environmental media impacted by residual CCR material that could not be removed from the River System. Risk assessment findings and conclusions specific to Emory River Reach B adjacent to the KIF Plant are directly relevant to the evaluation of potential risks to offsite receptors from CCR Parameters associated with the TDEC Order CCR units, especially offsite human receptors that could be exposed to CCR Parameters in surface stream water, seasonally exposed sediment, and consumption of sport fish (swimmers, beachcombers, fishers). Jacobs (2012) relied on data collected during the KRP investigations (2010 to 2011) and aggregated by river reaches in the Emory, Clinch, and Tennessee rivers as defined in the *River System EE/CA* (TVA 2012a). Overall, Jacobs (2012) concluded that there were no unacceptable cancer risks or noncancer hazards from CCR material associated COPCs to any of the human receptors assessed in the BHHRA.

4.2.2.1 CCR Material Characteristics

In 2008 and 2009, TVA, TDEC, and USEPA conducted chemical characterization of CCR material as part of the KRP (TVA 2011). CCR material samples were collected and analyzed for total metals and Toxicity Characteristic Leaching Procedure (TCLP) metals. TVA collected additional samples in April 2009 for TCLP analyses for waste characterization purposes as part of the KRP.

In 2012, 2013, and 2016, TVA conducted additional chemical characterization studies of the CCR material produced by operations at the KIF Plant (AECOM 2016b). CCR material samples were collected and tested for physical and chemical characteristics, including leachability and total metals. The collected samples included dry fly ash, bottom ash, gypsum, and gypsum fines.

Pore water and CCR material were collected from the Stilling Pond in November 2017 (Stantec 2018). The pore water and CCR material samples were subjected to CCR Parameter and Synthetic Precipitation Leaching Procedure analyses, similar to the samples collected under the EI as described below.

4.3 DATA QUALITY AND USEABILITY FOR RISK ASSESSMENT

Data collected during the EI at the KIF Plant and reported and evaluated in the KIF Plant EAR were considered usable for quantitative evaluation in the Human Health Risk Assessment (HHRA). Consistent with the KIF Plant EAR, additional data collected in November 2017 from the Stilling Pond were considered usable for quantitative evaluation in the HHRA. Data and findings from the KRP and LTM described in Section 4.2 were used as qualitative LOE in the HHERA for the KIF Plant under the TDEC Order. The EI data and 2017 Stilling Pond data were further reviewed to identify data acceptable for risk assessment use (Section 4.4). In addition to the criteria followed per the Quality Assurance (QA) program, the following general criteria, based on USEPA guidance (USEPA 1992a), were followed in the KIF Plant EAR and in generating risk assessment datasets:

- Estimated values (flagged with a “J” qualifier) were treated as detected concentrations
- Where field duplicate data were present, the primary sample was used in the quantitative evaluation
- Statistical outlier screening in the KIF Plant EAR (Appendix C.1) consisted of visual inspection of data using side-by-side box plots. If suspected visual outliers were identified, then statistical procedures (i.e., Tukey’s procedure and Dixon or Rosner’s Test) were used to determine whether the potential outliers were statistically significant outliers. Multiple LOEs, such as verification of whether data points were errors (e.g., laboratory or transcriptional error) and review of final outlier disposition (e.g., frequency of detection, spatial and temporal variability), were then considered to determine whether statistical outliers were suitable for removal from further statistical analysis. Statistical outliers identified in the KIF Plant EAR were reviewed and considered for exclusion from the risk assessment dataset. Statistical outliers were not identified for CCR material data. As a result, no statistical outliers were excluded from the risk assessment dataset.

Environmental investigations and monitoring conducted as part of the KRP and LTM were governed by a comprehensive QA program, which ultimately served as the basis for the QA Program developed for the KIF Plant EI. Similar to the KIF EI QA Program, the KRP QA program included third-party field audits, field documentation review, laboratory audits, laboratory analytical data validation, and a comprehensive integrated data management process. Accordingly, the analytical data generated under the KRP are considered to be of comparable quality to the data generated under the KIF EI. Additional information regarding the QA program for data utilized in the KIF Plant EAR is provided in the *TVA KIF Ash Recovery Project Quality Assurance Project Plan* (EnvStds 2009, 2010, and 2013) and the *LTM SAP* (TVA 2013). Additional information regarding the quality of the KRP data utilized in the KIF Plant EAR is provided in the BERA (Arcadis 2012) and the *River System EE/CA* (TVA 2012a).

4.4 SUMMARY OF DATA FOR USE IN THE RISK ASSESSMENT

As described in Section 2.2, the KIF Plant HHERA relies primarily on qualitative LOEs based on findings and data generated during the KRP and LTM. Only CCR material data from TDEC Order CCR units collected during the KIF Plant EI and 2017 Stilling Pond data were used quantitatively in the HHRA. The dataset for the KIF Plant HHRA consists of data selected following the general criteria provided in Section

4.3, and as described in Section 5.1.1. Additional criteria applied to data selection are discussed below. The data used in the HHRA are summarized in Table 4-1 and Appendix C. This dataset was further refined for the risk evaluation as described in Section 5.1.3.

4.4.1 CCR Material

The use of CCR material data is limited to the HHRA evaluation. Ecological receptors are not expected to be exposed to CCR material (i.e., incomplete exposure pathway) as described in Section 6.1.1. As described in Sections 4.1.1 and 4.2.2, CCR material data were collected in the Interim Ash Staging Area, Sluice Trench and Area East of Sluice Trench, and the Stilling Pond and combined into a single dataset for COPC identification. The CCR material data summary is provided in Table 4-1. The results of the KIF Plant EAR statistical analyses are presented in Appendix C.1.1. Additional analysis of the CCR material datasets used in the HHRA for risk evaluation are summarized in Appendix C.2. The rationale for these additional analyses for the HHRA is provided in Section 5.0.

4.4.2 Groundwater

As described in the *Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})* (Appendix B.1), the potential migration of CCR Parameters in onsite groundwater to offsite locations where there may be private potable wells or springs was addressed by the water use survey. In addition, analytical results of groundwater samples collected as part of the EI were compared to approved GSLs and presented in the KIF Plant EAR. These approved human health screening levels for CCR Parameters in groundwater are based on regulatory standards. Summary statistics of CCR Parameters in groundwater are provided in Appendix E.3 of Appendix C.1. Based on the overall results of the water use survey as discussed in Section 4.1.3 (i.e., groundwater flow bounded by Emory River and Plant Intake Channel, groundwater flow directions and hydraulic barriers making it unlikely that groundwater in areas located west of the KIF Plant and Pine Ridge or east and northeast of the Emory River have been impacted, and no water supply wells or springs identified on parcels with the potential of being impacted by CCR), current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs located downgradient of the KIF Plant. Therefore, exposure pathways associated with offsite use of groundwater and springs as a drinking water source were not considered complete, and as a result, no further quantitative assessment of groundwater is presented in this report. However, TVA will implement corrective actions to meet GWPS as part of the CARA Plan.

5.0 HUMAN HEALTH RISK ASSESSMENT

The HHRA process was used to evaluate potential carcinogenic risks and noncarcinogenic hazards to onsite human receptors potentially exposed to CCR material, and to offsite human receptors potentially exposed to CCR Parameters in groundwater, surface stream water, exposed sediment, and fish tissue. Results of this HHRA were used in the CARA Plan to evaluate whether corrective measures are needed for the protection of human receptors. Potential human health risks were evaluated in the HHRA assuming:

- Potential risks associated with onsite exposures to CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system.
- The concentrations of CCR Parameters in abiotic media and fish filet tissue documented in the KRP and LTM (and incorporated by reference in the KIF Plant EAR) represent current and future conditions in the Emory River Reach B adjacent to the TDEC Order CCR units at the KIF Plant.
- The findings of the BHHRA (Jacobs 2012) and the underlying datasets for the reaches of the Emory River adjacent, upstream, and downstream of the KIF Plant characterized “worst case” conditions following removal of as much CCR material as feasible from the channel of the Emory River following the December 2008 dredge cell failure.
- Potential impacts, if any, to the Emory River from the TDEC Order CCR units would have been represented by investigations conducted during the KRP and LTM.

The HHRA methodology described herein is in accordance with the following USEPA guidance documents and/or reference materials:

- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a)
- *Guidelines for Exposure Assessment* (USEPA 1992b)
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002)
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004)
- *Guidelines for Carcinogen Risk Assessment* (USEPA 2005)
- *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA 2009)
- *Exposure Factors Handbook: 2011 Edition* (USEPA 2011)
- *Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil* (USEPA 2012)

- *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors* (USEPA 2014)
- *Region 4 Human Health Risk Assessment Supplemental Guidance* (USEPA 2018a)
- *Preliminary Remediation Goals (PRGs) for Radionuclides* (USEPA 2021)
- *Regional Screening Levels (RSLs) – User's Guide* (USEPA 2024).

The general framework for conducting HHRAs is provided in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a). Consistent with this guidance, the HHRA consists of the following primary steps:

- Data collection and evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis.

The methods and procedures to perform the exposure assessment, toxicity assessment, and risk characterization steps are described in the following subsections. Data collection and evaluation, conducted as part of the KIF Plant EAR and as part of the KRP and LTM, are summarized in Section 4.

5.1 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of human exposure to CCR Parameters potentially associated with the TDEC Order CCR units at the KIF Plant. The exposure assessment includes development of a CSM, derivation of exposure assumptions and EPCs, and estimation of doses. The methods and assumptions used in the quantification of exposure are presented in Sections 5.1.2 through 5.1.4. Sections 5.1.2 through 5.1.3 present the exposure assumptions and chemical-specific parameters and describe how EPCs were estimated. Section 5.1.4 references the equations used to calculate exposure doses for COPCs.

5.1.1 Conceptual Site Model for the Human Health Risk Assessment

The human health CSM for the KIF Plant presents the potential human receptors and pathways through which those receptors could be exposed to CCR Parameters associated with the TDEC Order CCR units. The human health CSM includes the identification of COPCs and describes the relationships between the CCR Parameter source, release mechanisms to environmental (exposure) media, transport mechanisms, and routes of exposure to potential human receptors. An exposure pathway is considered potentially complete if the following elements are present: 1) a source and mechanism for release of CCR Parameters, 2) a transport or retention medium, 3) a point of potential human contact (exposure point)

with affected medium, and 4) an exposure route at the exposure point (USEPA 1989a). The CSM for the KIF Plant HHRA is presented as Exhibit 5-1.

5.1.1.1 Release Mechanisms

The EI assessed the potential current and future releases of CCR Parameters from the potential loss of structural integrity of the TDEC Order CCR units. It also assessed the potential movement of dissolved CCR Parameters in pore water from the CCR units to groundwater, and subsequently into adjacent surface water streams. As described in the KIF Plant EAR, there are no known active seeps at the KIF Plant; therefore, seeps are not a current release mechanism.

Investigations and studies conducted during the KRP and LTM assessed impacts from CCR Parameters associated with CCR material released to the River System in December 2008. The KRP Landfill was constructed on the location of the failed dredge cell, which no longer exists. The KRP Landfill is not addressed by the TDEC Order. As stated previously, investigations conducted during the KRP and LTM would also have assessed impacts, if any, from the TDEC Order CCR units to the Emory River adjacent to the KIF Plant.

There have been no known releases of CCR material from the TDEC Order CCR units, including during the December 2008 dredge cell failure. Potential issues with structural integrity of the TDEC Order CCR units identified during the TDEC Order EI will be addressed to prevent potential future release of CCR material. An onsite worker engaged in minor repairs to the infrastructure of the closed CCR units (e.g., piping, surface water management) could be exposed to small quantities of CCR material, but these activities would not be considered a substantive release mechanism.

Movement of dissolved CCR Parameters in pore water to groundwater beneath the TDEC Order CCR units and into the Emory River adjacent to the KIF Plant was considered a potential release mechanism. However, based on the overall results of the water use survey, current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs located in the vicinity of the KIF Plant. Therefore, exposure pathways associated with offsite use of groundwater and springs as drinking water sources were not considered complete and were not quantitatively evaluated in the HHRA. The influence of geochemical processes on groundwater quality were further evaluated in the CARA Plan as part of the assessment of corrective measures for each of the TDEC Order CCR units.

5.1.1.2 Receptor Identification

A human receptor is a hypothetical person (child or adult) who resides, visits, or works on or near the KIF Plant and is, or could potentially be, exposed to COPCs from the TDEC Order CCR units. General physical and behavioral characteristics specific to the receptor type (e.g., body weight, breathing rate, amount of fish consumed) are used to estimate the amount of chemical exposure for each receptor.

Since people have varying physical features, lifestyles, and habits, it is not possible to evaluate every type of individual. Due to differences in physiological characteristics and activity patterns between young children and adults, the exposures received by a young child and an adult will be different. Consequently, the potential risks estimated for the same COPC will differ depending on the receptor. The HHRA must be

sufficiently comprehensive and robust to confirm that the receptors with the greatest potential for exposure to COPCs and have the greatest sensitivity or potential for developing adverse health effects from such exposures are included in the evaluation. Consequentially, the HHRA is based on hypothetical receptors with exaggerated behaviors and activity patterns. If no potential for adverse health risks is identified for these more exposed and more sensitive receptors, then no adverse health effects would be expected for less exposed, less sensitive receptors.

For the purposes of the HHRA, human receptors have been grouped as described below:

- Onsite receptors, who may be present on or near the TDEC Order CCR units
- Offsite receptors, who may use the Emory River for recreation or as a public water supply, or who use groundwater and springs as sources of potable water.

The human receptors proposed for the KIF Plant HHRA are described below.

5.1.1.2.1 Potential Onsite Receptors

Land use within the KIF Plant is industrial (the active KIF Plant generating facility). There are no planned changes in land use. The focus of the HHRA is on the TDEC Order CCR units, not the historical operations of the KIF Plant or the closure activities. Because the HHRA is based on anticipated future, post-closure condition of the TDEC Order CCR units, potential risks associated with onsite exposures to CCR material are limited to exposure scenarios where receptors could reasonably be expected to penetrate the geosynthetic cover system, such as a worker making repairs to infrastructure associated with the TDEC Order CCR units during post closure. TVA employees and contractors who work at the active KIF Plant are not relevant receptors for the purpose of the TDEC Order as reflected in the approved EIP as they would not be expected to penetrate the geosynthetic cover system.

Trespasser

Casual unauthorized visitors (trespassers) might access closed CCR units in locations where there are no physical barriers (e.g., fencing or barricades). Although the KIF Plant is not fully fenced, it is an operating facility and a trespasser identified on or around the TDEC Order CCR units would be quickly intercepted. While a person may walk along seasonally exposed sediments at the base of the TDEC Order CCR units where they border the Emory River, this scenario is considered an offsite exposure (see Section 5.1.1.2.2), and it is considered highly unlikely that a trespasser would enter the KIF Plant from along the Emory River. The post-closure CCR units are covered by geosynthetic cover systems that preclude potential exposures by casual trespassers. As such, trespassers were not assessed further in the HHRA.

Onsite Worker

An onsite worker is defined as an adult receptor engaged in minor repairs to the infrastructure (e.g., piping, surface water management) of the TDEC Order CCR units during post closure. Such projects would be conducted in response to a specific situation (e.g., a broken or leaking pipe), would be limited to shallow depths (i.e., 0 to 10 feet below ground surface [bgs]), and not associated with routine maintenance of the geosynthetic cover systems of closed CCR units. These one-time events are

expected to be infrequent, non-recurring, and of short duration (i.e., no more than 20 days within a single one-year period), which is consistent with the excavation worker scenario included in the Risk Assessment Information System (RAIS) Chemical Risk Calculator (RAIS 2024a). If substantive repairs that would take more than 20 days to complete are necessary, a site-specific health and safety plan specifying procedures to protect onsite workers would be required. Other excavation and construction activities are considered part of ongoing operations at the KIF Plant and are not considered as relevant receptors per the requirements of the TDEC Order.

5.1.1.2.2 Potential Offsite Receptors

Land use surrounding the KIF Plant is primarily developed and includes residential and commercial use, with some forested areas. The nearest residence is located approximately 0.4 miles south of the KIF Plant in Harriman. While there are several local recreational opportunities associated with the Emory River near the KIF Plant, including the restored Lakeshore Park on the Swan Pond Embayment, there are a limited number of human receptors possibly relevant to the scope of the TDEC Order.

Potential future offsite receptor scenarios identified for the KIF Plant under current and reasonable future land use are as follows:

- Residential use of the Emory River as a public water supply
- Private residential use of groundwater and springs for potable water
- Recreational use of the Emory River (recreational user - beachcomber, recreational user - swimmer, and consumers of fish taken from the Emory River).

These receptor scenarios are described in more detail below.

Resident

Residents are defined as adults, adolescents, young children, and infants who use potable water from municipal water departments that withdraw water from the Emory River in the vicinity of the KIF Plant or who reside within a 0.5-mile radius of the KIF Plant parcel boundary and use groundwater or springs as a potable water source. While Harriman has a public drinking water supply, some residents may have private potable groundwater wells from which they obtain water. As described in Section 4.1.3, based on the overall results of the water use survey, current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs near the KIF Plant; therefore, ingestion of groundwater is not a complete pathway. As described in Section 1.3, the focus of the HHERA is on the anticipated future, post-closure conditions of the TDEC Order CCR units at the KIF Plant. As there would not be any exposed CCR material post closure (and therefore no source of particulates), the offsite resident exposure to CCR material via particulate migration pathway is incomplete and not further assessed.

Recreational Users

An important part of TVA's mission is to support recreational use of the Tennessee Valley's environmental resources. The rivers and reservoirs around the KIF Plant are used for recreational activities year-round. Fishing from the shore and from boats occurs almost all year in the Emory River, with springtime being particularly popular for sport fishing. Water sports such as swimming, water skiing, and jet skiing occur primarily during the warmer months of the year and coincide with high pool levels in the reservoir sections of the major rivers. The cooler months coincide with lower pool levels, which results in areas of seasonally exposed sediments near the shoreline of the Emory River.

Restoration of the aquatic and wetland habitat from the 2008 CCR material release, and development of what is now Lakeshore Park with amenities such as a boat ramp, fishing areas, and walking trails provides recreational opportunities. The photograph below from a site visit in October 2019 and online information about Lakeshore Park (Roane Alliance 2024) illustrates the environmental setting for recreational activities associated with Emory River Reach B immediately adjacent to the KIF Plant.

Looking North at the Lakeshore Park Boardwalk from dock at Lakeshore Park (October 23, 2019)

The cooling water Plant Intake Channel for the KIF Plant is part of Emory River Reach B. However, boat access to the Plant Intake Channel and to the TDEC Order CCR units bordering the Plant Intake Channel is restricted by physical barriers at the northeast tip of the Stilling Pond.

Consistent with the BHHRA (Jacobs 2012), recreational users of the Emory, Clinch, and Tennessee rivers were further grouped by their primary activities: swimmers, beachcombers, and consumers of locally-caught sport fish, as defined in more detail below.

- *Recreational User - Swimmer*

  Swimming, wading, and other water-contact activities within the Emory River near the KIF Plant occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. The same individual may be a recreational user - swimmer or water skier from April through September and a beachcomber from October through March. A recreational user - swimmer may come into contact with CCR Parameters in river or stream water via incidental ingestion of surface stream water and dermal contact with surface stream water. Contact with submerged sediment in the stream channel while wading or swimming is not a complete pathway of exposure (USEPA 2018a) because particles are assumed to be quickly washed from the skin. Therefore, sediments in the stream channels that are submerged under water all year are not a complete pathway of exposure for this receptor and will not be evaluated in the HHRA.

- *Recreational User - Beachcomber*

  During the cooler months, people engage in activities such as beachcombing, camping, and fishing along the riverbanks and accessible areas of seasonally exposed sediments in the Emory River. For the HHRA, seasonally exposed sediment is defined as sediment in near-shore areas of lakes and streams that is not completely covered by water during seasonally low water levels, thus is accessible to humans and wildlife during those periods. Sediments in the stream channels that are submerged under water all year are not a complete pathway of exposure for this receptor and will not be evaluated in the HHRA.

- *Recreational User - Consumer of Locally Caught Sport Fish*

  Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages eat locally-caught sport fish. In some cases, recreational user - beachcombers also consume fish that they have caught. Fish are also assumed to be consumed by members of an angler's family who do not themselves catch the fish.

5.1.1.3 Pathways of Exposure

Exposure pathways identified in the HHRA CSM (Exhibit 5-1) for the KIF Plant are classified as:

- Potentially complete
- Potentially complete but contribution to exposure is negligible
- Incomplete.

As discussed in Section 5.1.1, an exposure pathway is considered complete when there is potential for a receptor to be exposed to COPCs in an exposure media through an identified exposure route, as defined for relevant onsite and offsite human receptors in Section 5.1.1.2. For each of the potential human receptors identified above, potential exposure media and exposure pathways for the KIF Plant are evaluated and classified below.

For onsite receptors (a scenario not evaluated in the BHHRA [Jacobs 2012]), maximum detected concentrations of CCR Parameters measured in CCR material and reported in the KIF Plant EAR were compared to risk-based SSL_{HH} to identify COPCs. The SSL_{HH} were developed using a scientifically defensible, risk-based approach that incorporated protective assumptions and values. For example, the SSL_{HH} were calculated using risk-based targets that are ten times more protective than TDEC regulatory targets (i.e. ILCR = 1 x 10^{-5}, and noncancer HI = 1). As a result, CCR Parameters with concentrations higher than the SSL_{HH} should not be interpreted as evidence of unacceptable human health risk. The methods used to derive SSL_{HH} are described in *Proposed Receptor-Specific Screening Levels for Human Health* (SSL_{HH}) (Appendix B.1).

For offsite receptors (receptor scenarios that were evaluated in the BHHRA [Jacobs 2012]), qualitative interpretation of information and findings reported in the BHHRA were used to evaluate potential exposure to CCR Parameters in environmental media associated with the TDEC Order CCR units at the KIF Plant.

5.1.1.3.1 Onsite Worker

An onsite worker engaged in minor repairs to the infrastructure of the TDEC Order CCR units during post closure may come into direct contact with CCR material beneath the geosynthetic cover system. This receptor can be exposed to COPCs in CCR material via incidental ingestion and dermal contact with CCR material and inhalation of particulates released from CCR material for a short duration (i.e., a few days to a few weeks). External exposure to radiation emitted from radionuclides in CCR material may also occur. External exposure to radiation refers to the ability of energy released from radionuclides from an external source to penetrate through the skin (this is different from dermal exposure which occurs when a chemical is absorbed through the skin). Many TVA CCR units are subject to the requirements of the CCR Rule. The CCR Rule focuses on meeting GWPS in compliance wells immediately downgradient of the unit (i.e., onsite), consistent with regulatory requirements, and independent of the results of the HHERA. There are no potable groundwater wells at the KIF Plant, and there are no plans to install potable groundwater wells in the future.

COPC Screening

Although an onsite worker making minor repairs would likely only be exposed to CCR material within 0 to 10 feet bgs, data for CCR material samples collected from all sampling depths were screened against the lowest SSL_{HH} for an onsite worker (Appendix B.1). The SSL_{HH} for onsite workers are based on an exposure frequency of 20 days (five days per week for four weeks) over a one-year exposure duration, and risk targets that are ten times more protective than regulatory targets. CCR material data summary and comparisons to human health screening levels are provided in Table 4-1. The following criteria were applied to identify COPCs in CCR material for further evaluation in the HHRA.

1. If a CCR Parameter was not detected in the potential exposure media and the maximum reporting limit for samples collected from that potential exposure media was equal to or below the respective screening level, then the CCR Parameter was not identified as a COPC for the exposure scenario.

2. If a CCR Parameter was detected in the potential exposure media and the maximum detected concentration was equal to or less than the respective screening level, then the CCR Parameter was not identified as a COPC for the exposure scenario.

3. If calcium, chloride, and/or sulfate were detected in the potential exposure media, these CCR Parameters were not identified as COPCs for the exposure scenario. These CCR Parameters are not evaluated in the HHRA because they are essential mineral ions. Calcium is generally toxic only in very high concentrations and is a naturally occurring element known to be essential or beneficial to animal life (e.g., calcium plays an important role in functions such as proper bone development, nerve transmission, and muscle function) (IOM 2011). Chloride is naturally occurring in the environment and is an essential dietary mineral in animals and humans (Deane et al. 1952). It is an important electrolyte in all body fluids where it maintains acid/base balance, it is also critical to neural transmission, heart and muscle contraction, and regulates liquid flow in and out of cells (Raut et al. 2024). Sulfate is an essential mineral in animals and humans (National Academies 2005). It is the fourth most common anion in our blood, a component of vitamin D3, an integral constituent of the myelin sheaths surrounding neuronal axons and prevents blood from coagulating during transit through capillaries. Laboratory studies in animals have shown that growth is stunted when sulfate is eliminated from the diet (National Academies 2005).

4. If a CCR Parameter was not detected in the potential exposure media, but the maximum reporting limit for samples collected from that potential exposure media was greater than the respective screening level, then the CCR Parameter was further evaluated to determine if it should be identified as a COPC for the exposure scenario.

5. If a CCR Parameter was detected in CCR material and the maximum detected concentration was greater than the respective screening level, then the CCR Parameter was identified as a COPC for the exposure scenario.

A summary of COPCs identified for quantitative evaluation of the onsite worker exposed to CCR material is presented in Table 5-1.

5.1.1.3.2 Resident

As discussed in Section 5.1.1.2.2, current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs near the KIF Plant; therefore, ingestion of groundwater is not a complete pathway. Both current and future offsite residents may potentially be exposed to CCR Parameters in surface stream water with public water utilities intakes. Offsite residents using potable water from the Roane Central Water District, Harriman Utility Board, Kingston Water Department, and Cumberland Water Utility may be exposed to CCR Parameters via ingestion of drinking water and dermal contact during household uses such as ingestion of tap water, beverages, and foods prepared with potable water; and dermal contact while bathing, washing dishes or clothing, and performing other domestic activities.

5.1.1.3.3 Recreational User - Swimmer

A recreational user - swimmer may be exposed to COPCs in surface stream water in the Emory River adjacent to the KIF Plant while engaged in activities such as swimming, wading, and other water-contact activities that occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. The same individual may be a recreational user - swimmer or water skier from April through September and a beachcomber from October through March. A recreational user - swimmer may come into contact with CCR Parameters in river or stream water via incidental ingestion of and dermal contact with surface stream water. Contact with submerged sediment in the stream channel while wading or swimming is not a complete pathway of exposure (USEPA 2018a) because particles are assumed to be quickly washed from the skin.

5.1.1.3.4 Recreational User - Beachcomber

A recreational user - beachcomber may incidentally ingest or have dermal contact with seasonally exposed sediment along the banks of the Emory River while hiking or beachcombing for driftwood, rocks, or other objects. Beachcomber receptors include people who may camp or fish from areas of exposed sediments along the shore of the Emory River. External exposure to radiation emitted from radionuclides in seasonally exposed sediment may also occur. External exposure to radiation refers to the ability of energy released from radionuclides from an external source to penetrate through the skin (this is different from dermal exposure which occurs when a chemical is absorbed through the skin). Seasonally exposed sediment remains damp, therefore inhalation of windborne dust is not a complete route of exposure. Beachcombing activities are assumed to occur from October through March when water levels in the Emory River are at winter low pool. Water temperatures during the winter season are too cold for wading or swimming.

5.1.1.3.5 Recreational User - Consumer of Locally-Caught Sport Fish

Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages (adults [ages 16 years and older], adolescents [6 to <16 years of age] and children [0 to <6 years of age]) eat locally-caught sport fish. There is a public boat launch and fishing access at Lakeshore Park opposite the KRP Landfill. Except for the cooling water Plant Intake Channel, the Emory River adjacent to the KIF Plant is accessible for fishing from the shore and from boats.

Consumption of locally caught sport fish that may have accumulated CCR Parameters originating from the TDEC Order CCR units in edible tissue is a potentially complete exposure pathway for a recreational user - consumer of locally-caught sport fish for the Emory River.

5.1.2 Exposure Assumptions

The exposure parameters used in the HHRA for the onsite worker and the specific sources and rationale for these parameters are presented in Table 5-2. The sources for the exposure parameters used to evaluate the onsite worker include:

- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)* (USEPA 1989a)

- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002)
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004)
- *Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil* (USEPA 2012)
- *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors* (USEPA 2014)

As noted above, for HHRAs conducted under the TDEC Order for TVA fossil plants, the onsite worker scenario was adapted from the Excavation Worker scenario described in the RAIS on-line calculator. It is not one of the receptor scenarios evaluated in the BHHRA (Jacobs 2012) and has its own unique set of exposure assumptions.

As described in Section 5.1.1.3, this HHRA relies on qualitative interpretation of findings from the BHHRA (Jacobs 2012) to evaluate potential risks to offsite receptors from CCR constituents in surface stream water, seasonally exposed sediment, and sport fish filet from the Emory River Reach B near the TDEC Order CCR units at the KIF Plant. The offsite receptor scenarios developed by Jacobs for the BHHRA represent human activities known or likely to occur around the KIF Plant and align with the scenarios established for the TDEC Order program. Exposure parameters and references used by Jacobs (2012) are provided in Appendix B, Tables 4-1 through 4-4 of the BHHRA (Jacobs 2012). Uncertainties related to differences in assumptions and variable values between the BHHRA (Jacobs 2012) and current TDEC Order HHRAs are discussed in the Uncertainties Analysis (Section 5.4) of this HHRA.

5.1.3 Exposure Point Concentrations

The EPC describes the level of a COPC in CCR material, seasonally exposed sediment, or fish filet to which a receptor is potentially exposed (USEPA 1989a). The EPC serves as the basis for quantifying pathway-specific exposure doses. The process for deriving EPCs described below pertains to the onsite worker; the process used by Jacobs (2012) to derive EPCs for surface stream water, seasonally exposed sediment, and fish filet tissue datasets is described in Section 1.2.1 of the BHHRA and discussed in the Uncertainties Analysis (Section 5.4) of this HHRA.

When there were five or more detected results, EPCs for measured media were the lower of the upper confidence limit (UCL) on the mean concentration or the maximum detected concentration. When there were less than 10 total samples with less than five detected results, the selected EPCs for measured media were the maximum concentrations. If there were 10 or more samples with less than five detected results, EPCs for measured media were the lower of the maximum detected concentration or the median concentrations. For datasets with low detection frequencies, the median may provide a better estimate of the population measure of central tendency (USEPA 2022). Distributions and recommended UCLs on the mean concentrations were calculated and selected using USEPA's ProUCL software version 5.2 (USEPA 2022). ProUCL typically recommends a 95% UCL. For datasets with small sample sizes or high result variability, ProUCL may recommend a UCL on the mean associated with a higher confidence level. Measured data used in the EPC derivation for COPCs in each medium are described below.

EPCs for COPCs identified in CCR material (Section 5.1.1.3.1) were derived for the TDEC Order CCR units (Interim Ash Staging Area, the Sluice Trench and Area East of the Sluice Trench, and the Stilling Pond), as summarized in Appendix C.2.

- CCR material data collected from all sampling depths in the three TDEC Order CCR units specified above were included in the CCR material dataset to establish EPCs for these CCR units.
- EPCs were only calculated for COPCs in CCR material from a given unit if the maximum detected concentration in samples collected from that CCR unit was above the respective screening level presented in Table 4-1.

The ProUCL outputs, including the recommended 95% UCL on the mean concentration, are provided in Appendix C.3.

5.1.4 Estimation of Exposure Dose for Chemicals

Exposure doses were estimated for onsite workers potentially exposed to COPCs in CCR material using equations for potentially complete pathways provided in Appendix D.1. For carcinogens, exposure was averaged over a 70-year lifetime; for noncarcinogens, exposure was averaged over the period of exposure (i.e., the exposure duration). The equations and methodology used by Jacobs (2012) to quantify exposures to offsite receptors is described in Section 1.2.3 of the BHHRA.

5.2 TOXICITY ASSESSMENT

The human health toxicity assessment process described herein is in accordance with USEPA guidance (USEPA 1989a). Toxicity assessment is the process of using existing toxicity information from human or animal studies to identify potential health risks at various dose levels in exposed populations and generally consists of two steps: (1) hazard identification and (2) dose-response assessment (USEPA 1989a).

Hazard identification is a qualitative evaluation of whether exposure to a stressor is likely to cause adverse health effects in humans. A key component of hazard identification involves evaluating the WOE regarding a chemical's potential to cause adverse human health effects.

The dose-response assessment step of the HHRA process involves characterizing the relationship between the absorbed dose of a chemical agent and the magnitude or likelihood of adverse health effects (USEPA 1989a). For chemicals that are known or suspected to cause cancer, the dose-response assessment defines the relationship between dose of the risk agent and probability of inducing carcinogenic effects in humans or animal species of interest. For systemic toxicants, or chemicals that give rise to toxic endpoints other than cancer and gene mutations (i.e., noncarcinogenic effects), the dose-response assessment determines a threshold value below which the adverse noncarcinogenic effects are not expected in the general population, including sensitive subgroups.

These two steps of the toxicity assessment have been completed by the agencies that publish toxicity values, and a high-level summary of the methods used are presented in Sections 5.2.1 and 5.2.2. The

published toxicity values used in this HHRA, as described in Section 5.2.3, were derived by the agencies as part of the dose-response assessment steps. These toxicity values (which describe the bodily response to a daily dose) together with the estimated exposures to the COPC (i.e., estimated dose to individuals) are used in the risk characterization step to estimate the likelihood of adverse effects occurring.

5.2.1 Carcinogenic Dose-Response Assessment Methodology

It has been demonstrated that exposure to some chemicals can result in cancer. The USEPA assumes that a relatively small number of molecular events can elicit changes in a cell, ultimately resulting in uncontrolled cell proliferation and cancer. This is referred to as the non-threshold or “one hit” theory of chemical carcinogenesis. The USEPA uses a two-part evaluation to calculate potential carcinogenic effects of COPCs: (1) assigning a WOE classification, and (2) calculating a cancer slope factor (CSF) or a unit risk factor (URF) (USEPA 1989a).

The system for assigning a WOE classification is based on USEPA guidelines (USEPA 1986 and 2005). It describes the likelihood that a chemical is a human carcinogen based on the supporting evidence of carcinogenicity in human and animal studies. This WOE classification system for carcinogenicity also follows the 1986 or 2005 USEPA guidelines, depending on when the dose-response assessment was completed for each chemical. Although some carcinogens have a mutagenic mode of action, none of the carcinogenic COPCs are classified as mutagens by the USEPA.

The USEPA only derives CSFs and URFs for chemicals that they have determined to be carcinogenic or to have carcinogenic potential.

5.2.2 Noncarcinogenic Dose-Response Assessment Methodology

Substances that produce adverse noncarcinogenic effects are generally thought to have a threshold dose below which the adverse effect is not likely to be observed over the period of exposure (USEPA 1989a). Chemical doses that are expected to result in no adverse effects to humans are referred to by USEPA as reference doses (RfDs), and air concentrations that would not result in adverse effects are termed reference concentrations (RfCs). A chronic RfD or RfC is used to evaluate potential noncarcinogenic hazards associated with long-term chemical exposures while sub-chronic RfDs or RfCs are used to evaluate exposures over shorter time periods.

Exposures that are less than the RfD or RfC are not likely to be associated with adverse health effects. As the frequency and level of exposures exceeding the RfD or RfC increases, the likelihood for adverse effects also increases.

5.2.3 Selection of Toxicity Values for the Human Health Risk Assessment

Toxicity values for quantitative risk evaluation for onsite worker exposure to COPCs in CCR material in the TDEC Order CCR units were obtained from the following sources cited in USEPA’s RSL Tables (USEPA 2024). The general order of preference for selecting toxicity values provided below is consistent with USEPA (2003):

- Integrated Risk Information System (IRIS) Database
- Provisional Peer Reviewed Toxicity Values (PPRTVs)
- ATSDR Toxicological Profiles
- California Environmental Protection Agency (CalEPA) Toxicity Values
- PPRTV Appendix Screening Toxicity Values
- Health Effects Assessment Summary Tables.

The current HHRA relies on qualitative interpretation of findings reported in the BHHRA (Jacobs 2012) for evaluation of potential risks to potential offsite receptors from CCR Parameters in environmental media potentially associated with the TDEC Order CCR units at the KIF Plant. Although some toxicity values may have been updated in the intervening decade, Jacobs (2012) refers to the same hierarchy (USEPA 2003) to select toxicity values for use in the BHHRA.

Subchronic RfDs and RfCs, where available, were used for scenarios associated with an assumed exposure duration of between two weeks and seven years (i.e., onsite workers with an assumed exposure duration of one year [Table 5-2]). A subchronic RfD and subchronic RfC are not available for arsenic, so the chronic RfD and RfC were used to estimate hazard quotients (HQs) for an onsite worker potentially exposed to arsenic in CCR material. The toxicity values for COPCs in CCR material are presented in Table 5-3. In addition to toxicity values, Table 5-3 presents the target organ (TO) or organ system associated with the critical effect for each noncancer RfD and RfC. The potentially impacted TOs vary among COPCs; when multiple COPCs potentially impact the same TO, the effects are generally considered to be additive (USEPA 1989a). Noncancer TO analysis is described further in Section 5.3.1.

Inorganic mercury is listed as a CCR Parameter. However, inorganic mercury is converted to methyl mercury by biological processes in the aquatic environment, which then accumulates in biological tissues including fish filet. Jacobs (2012) evaluated human exposure from consumption of mercury in fish filet tissue using the chronic oral RfD for organic methyl mercury. The current methyl mercury chronic RfD (0.0001 milligrams [mg] per kilogram [kg] per day [mg/kg-day] from USEPA 2024) is the same as that used in Jacobs (2012). HHRAs conducted under the TDEC Order also assume mercury in fish filet tissue is methyl mercury.

5.2.4 Dermal Toxicity Values

Although USEPA has developed toxicity criteria for the oral and inhalation routes of exposure, toxicity criteria for the dermal route of exposure have not been developed. USEPA has guidance for extrapolating oral toxicity criteria to the dermal route in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004). Jacobs (2012) references the same USEPA guidance for evaluating dermal exposures in the BHHRA.

This USEPA guidance states that the adjustment of the oral toxicity factor for dermal exposures is necessary only when the oral-gastrointestinal absorption efficiency of a constituent is less than 50% (due

to the variability inherent in absorption studies). Adjustment of oral toxicity criteria to derive dermal RfDs and CSFs was conducted as follows:

$$\text{Dermal RfD} = \text{Oral RfD} \times \text{ABS}_{GI}$$

$$\text{Dermal CSF} = \frac{\text{Oral CSF}}{\text{ABS}_{GI}}$$

Where:

ABS_{GI}	=	Oral absorption efficiency
CSF	=	Cancer slope factor
RfD	=	Reference dose

For COPCs lacking an oral-gastrointestinal absorption efficiency value, the oral absorption efficiency is assumed to be 100%, and the oral RfD or CSF is used to estimate toxicity via the dermal route.

5.3 RISK CHARACTERIZATION

Risk characterization consists of two major components: risk estimation and risk description. Risk estimation combines results of the exposure assessment and toxicity assessment to derive a quantitative evaluation of potential risks to human receptors. For the risk estimation component, calculated exposure doses for each COPC identified for each medium were used to estimate COPC-specific and cumulative cancer risks, as well as noncancer HQs and HI estimates. The risk description component provides information important for interpreting the risk estimates. As highlighted in Section 2.2 and provided in the document titled *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), these components were captured through a WOE approach using multiple LOEs.

The HHRA relies on qualitative interpretation of findings reported in Jacobs (2012) for evaluation of potential risks to potential offsite receptors. As such, the detailed methods outlined in Section 5.3.1 are only applicable for an onsite worker.

5.3.1 Methods for Estimating Cancer Risk and Noncancer Hazard for Chemicals

The pathway-specific incremental lifetime cancer risks (ILCRs) from exposure to carcinogenic COPCs in CCR material were estimated using the following general equation (USEPA 1989a and 2009):

$$\text{ILCR (unitless)} = \text{Dose (or Concentration)} \times \text{CSF (or URF)}$$

Where:

ILCR	=	Incremental lifetime cancer risk (unitless)
CSF	=	Cancer slope factor $(mg/kg\text{-}day)^{-1}$

URF	=	Unit risk factor (micrograms [µg] per cubic meters [m^3] [$µg/m^3$])$^{-1}$
Dose	=	Exposure dose (mg/kg-day)
Concentration	=	Exposure concentration ($µg/m^3$)

The HQ is the ratio of the potential exposure to a substance and the level at which no adverse noncarcinogenic effects are expected. Pathway-specific HQs for COPCs in CCR material were estimated using the following general equation (USEPA 1989a and 2009):

$$\text{HQ (unitless)} = \frac{\text{Dose (or Concentration)}}{\text{RfD (or RfC)}}$$

Where:

HQ	=	Hazard quotient (unitless)
Dose	=	Exposure dose (mg/kg-day)
Concentration	=	Exposure concentration (mg/m^3)
RfD	=	Reference dose (mg/kg-day)
RfC	=	Reference concentration (mg/m^3)

A COPC-specific HQ is derived by summing pathway-specific HQs. An HQ greater than 1 indicates that the estimated exposure for that COPC may not be protective of noncarcinogenic health effects. An HQ equal to or less than 1 suggests that noncarcinogenic health effects should not occur. To account for potential cumulative impacts from exposure to multiple COPCs, COPC-specific ILCR and HQ estimates were summed to produce cumulative ILCR and noncancer HI estimates, respectively. As described in Appendix A, the State of Tennessee currently considers a cumulative excess lifetime cancer risk estimate of 1×10^{-5} and a noncancer cumulative HI of 1 as the acceptable cancer risk criterion and noncancer threshold, respectively, for making risk management decisions concerning a site (TDEC 2019).

If an HI estimate is greater than 1, it is generally appropriate to derive separate HIs for each TO or organ system potentially impacted by a COPC (i.e., TO-specific HIs [TO HIs]) (USEPA 1989a). This is because the toxicological effects associated with exposure to multiple COPCs may not be additive. As with the HQ, a TO HI equal to or less than 1 suggests that noncarcinogenic health effects should not occur. A TO HI was estimated for the onsite worker by summing the HQs for COPCs that affect the same TO/system listed in Table 5-3. If a COPC is associated with critical effects in multiple TO/systems, the HQ for that COPC is included in the TO HI for each impacted TO/system. The maximum TO HI for all potentially impacted TOs/systems is presented as the final TO HI.

5.3.2 Risk Estimation Results

A summary of cancer risk and noncancer hazard estimates for onsite workers potentially exposed to chemical COPCs in CCR material is presented in Table 5-4. Detailed cancer risk and noncancer hazard

calculations for the onsite worker are presented in Appendix D.2. ILCR and HI estimates for the onsite worker are summarized in Section 5.3.2.1 below.

Risk estimates for offsite receptors from potential exposure to CCR constituents in surface stream water, seasonally exposed sediments, and sport-caught fish from the Emory River Reach B, as reported in the BHHRA (Jacobs 2012), are summarized below in Sections 5.3.2.2 through 5.3.2.5. In addition to CCR constituents, samples of environmental media collected for the KRP were analyzed for a wide range of chemical and radiological constituents, including PAHs, PCBs, chlorinated pesticides, and non-CCR metals and radionuclides. The total ILCR and HI estimates for receptors and pathways presented in the BHHRA (Jacobs 2012) are the sum of ILCR and HQ estimates for CCR and non-CCR constituents. When discussing the findings of the BHHRA, ILCR and HI estimates specifically attributable to CCR constituents (such as arsenic) are identified and compared to regulatory target levels of 1×10^{-5} for ILCR and 1 for HI.

5.3.2.1 Onsite Worker

A summary of the cumulative ILCR and HI estimates for an onsite worker exposed to chemical COPCs in CCR material is provided in the table below.

	Onsite Worker	
TDEC Order CCR Unit	**Cumulative ILCR (Chemical)**	**HI**
Interim Ash Staging Area	2E-07	0.5
Sluice Trench and Area East of Sluice Trench	2E-07	0.5
Stilling Pond	3E-07	0.7

The cumulative ILCR and HI estimates for an onsite worker exposed to chemical COPCs in CCR material within the Interim Ash Staging Area and Sluice Trench and Area East of Sluice Trench are 2×10^{-7} and 0.5, respectively (Table 5-5). The cumulative ILCR and HI estimates for an onsite worker exposed to chemical COPCs in CCR material within the Stilling Pond are 3×10^{-7} and 0.7, respectively. The cumulative ILCR is less than TDEC's acceptable cancer risk criterion of 1×10^{-5} and the HI is less than the noncancer threshold of 1 for each CCR unit.

5.3.2.2 Offsite Resident – Potable Use of Surface Stream Water

As reported in the BHHRA (Jacobs 2012), the cumulative ILCR estimates for an adult and child resident exposed to chemical COPCs in surface stream water from Emory River Reach B were 3×10^{-5} and 2×10^{-5}, respectively, as presented in Appendix B, Tables 7.13 and 7.14 of the BHHRA. The cumulative ILCR estimates were attributable to arsenic at an EPC (2.2 micrograms per liter [µg/L]) lower than the federal drinking water maximum contaminant level (MCL) of 10 µg/L. As such, the BHHRA concluded that "*Results of the risk characterization indicated no unacceptable cancer risk or noncancer hazard to any human receptor due to exposure to residual ash*".

ILCR estimates for radiological COPCs were 1×10^{-6} and 2×10^{-7} for an adult and child resident, respectively, as presented in Appendix B, Tables 8.9 and 8.10 of the BHHRA. CCR Parameters radium 226 & 228 were not detected in the surface stream water dataset for Emory River Reach B.

The HI estimates for an adult and child resident exposed to chemical COPCs in surface stream water from Emory River Reach B were 0.3 and 0.8, respectively, which are less than the noncancer threshold of 1 (Jacobs 2012).

The screening protocol established for HHERAs conducted under the TDEC Order would have excluded arsenic (and other detected CCR Parameters) from further consideration because the maximum detected concentrations in the Emory River Reach B were lower than drinking water standards and domestic potable use criteria approved as screening levels by TDEC (Appendix B.1, Attachment A). Furthermore, surface stream water sampling was discontinued in 2013 (TVA 2013) based at least partially on findings of negligible risk to human receptors in the BHHRA.

5.3.2.3 Recreational User – Swimmer

As reported in the BHHRA (Jacobs 2012), the cumulative ILCR estimates for an adult and adolescent swimmer exposed to chemical COPCs in surface stream water from the Emory River Reach B were 2×10^{-7} and 1×10^{-7} respectively, as presented in Appendix B, Tables 7.15 and 7.16 of the BHHRA (Jacobs 2012). The ILCR estimates for both receptors exposed to radionuclide COPCs were less than 1×10^{-8}, as presented in Appendix B, Tables 8.11 and 8.12 of the BHHRA.

The HI estimates for an adult and adolescent recreational user - swimmer exposed to chemicals in surface stream water from Emory River Reach B were 0.006 and 0.009, respectively, which are less than the noncancer threshold of 1 (Jacobs 2012).

The recreational swimmer would not have been evaluated under the protocol for HHERAs conducted under the TDEC Order because detected CCR Parameter concentrations in the Emory River Reach B dataset (Jacobs 2012) were lower than drinking water standards and potable use criteria.

5.3.2.4 Recreational User – Beachcomber

As reported in the BHHRA (Jacobs 2012), the cumulative ILCR estimates for an adult and adolescent recreational beachcomber exposed to chemical COPCs in seasonally exposed sediment within the Emory River Reach B were 8×10^{-6} and 4×10^{-6} respectively, as presented in Appendix B, Tables 7.15 and 7.16 of the BHHRA. Arsenic accounted for ILCR estimates of 7×10^{-6} for an adult and 4×10^{-6} for an adolescent recreational beachcomber (Appendix B, Tables 9.15 and 9.16 of the BHHRA). Other chemical COPCs not listed as CCR Parameters accounted for the balance of the ILCR estimates.

The cumulative ILCR estimates for an adult and adolescent recreational user – beachcomber exposed to radionuclides in seasonally exposed sediment within the Emory River Reach B were 2×10^{-5} and 8×10^{-6}, respectively, as presented in Appendix B, Tables 8.11, and 8.12 of the BHHRA. The cumulative ILCR are the sum of ILCR estimates for incidental ingestion and exposure to external radiation from eleven radionuclide COPCs detected in seasonally exposed sediment. ILCR estimates attributable to radium-226 and radium-228, which are CCR Parameters, were 1×10^{-5} for an adult and 5×10^{-6} for an adolescent recreational beachcomber (Appendix B, Tables 9.15 and 9.16 of the BHHRA). The sum of the ILCR for chemical (arsenic) and radiological (radium-226 and radium-228) CCR Parameters in seasonally exposed

sediment within the Emory River Reach B was 2 x 10^{-5} for an adult and 9 x 10^{-6} for an adolescent beachcomber.

There are uncertainties associated with summing cumulative ILCRs for chemical and radionuclide COPCs because potential interaction and synergies are still poorly understood between chemicals and radionuclides (Health Canada 2023). In addition, the toxicity data that form the basis of chemical and radiological risk assessments also differ (i.e., typically based on laboratory experiments for chemicals and human epidemiology for radionuclides).

The HI estimates for an adult and adolescent recreational user – beachcomber were 0.08 and 0.1, respectively, which are less than the noncancer threshold of 1 (Jacobs 2012).

As described in the BHHRA (Jacobs 2012), seasonally exposed sediment samples were collected within about a year following the December 2008 release from locations within the Emory River Reach B where CCR material was visible or likely to have been deposited. As a result, it is reasonable to assume that the evaluation of exposure and cancer risk in the BHHRA is based on "worst case" conditions and represents potential risks from residual CCR material released during the December 2008 Dredge Cell failure rather than potential impacts from the TDEC Order CCR units.

5.3.2.5 Recreational User – Consumer of Locally-Caught Sport Fish

As reported in the BHHRA (Jacobs 2012), the cumulative ILCR estimates for an adult and child recreational user – consumer of locally-caught sport fish exposed to chemical COPCs in fish harvested from the Emory River Reach B were 1 x 10^{-4} and 9 x 10^{-5}, respectively, for bass and 3 x 10^{-4} and 2 x 10^{-4}, respectively, for catfish. Risk results are presented in Appendix B, Tables 7.17 to 7.24 of the BHHRA. These ILCR estimates were primarily attributable to polychlorinated biphenyls (PCBs, Aroclors 1254, and 1260), which are not CCR Parameters or COPCs specified by the TDEC Order.

The cumulative ILCR estimates for an adult and child recreational user – consumer of locally-caught sport from radionuclides in fish harvested from the Emory River Reach B were 1 x 10^{-7} and 3 x 10^{-8}, respectively, for bass and catfish. Radionuclide risk results are presented in Appendix B, Tables 8.61 to 8.64 of the BHHRA. Crappie and sunfish tissue samples were not analyzed for radionuclides.

The HI estimates for an adult recreational user – consumer of locally-caught sport fish exposed to chemicals in fish harvested from the Emory River Reach B were 2 for bass; 5 for catfish; 2 for crappie; and 1 for sunfish. The HI estimates for a child recreational user – consumer of locally-caught sport fish was 8 for bass; 22 for catfish; 8 for crappie; and 5 for sunfish. The HI estimates for consumption of bass, crappie, and sunfish were primarily attributable to methyl mercury. The HI estimates for consumption of catfish were primarily attributable to methyl mercury and Aroclor 1254. Aroclor 1254 is not a CCR Parameter or COPC specified by the TDEC Order.

According to Jacobs (2012), estimated cancer risks equal to or greater than 1 x 10^{-4} and noncancer HI greater than 1 were attributable to legacy contaminants already present in the River System and not associated with residual CCR material from the December 2008 release. As summarized in Section 1.4.1.2 of the BHHRA, estimated ILCR from consumption of largemouth bass and catfish from the Little

Emory River and all evaluated reaches of the Emory and Clinch rivers (including reference reaches not impacted by the December 2008 CCR material release) ranged from 7×10^{-5} for the Emory River Reference Reach to 1×10^{-4} or greater for all other reaches evaluated, including the Emory River Reach B (adjacent to the KIF Plant).

ILCR estimates greater than 1×10^{-4} presented in the BHHRA for consumption of bass and catfish from the Emory River Reach B were attributable to PCBs. PCBs were not detected in the sunfish and crappie filet samples from the Emory River Reach B used in the BHHRA and are not CCR Parameters or COPCs specified by the TDEC Order.

There were no carcinogenic CCR Parameters detected in the fish filet sample dataset from the Emory River Reach B evaluated in the BHHRA. Arsenic in fish tissue samples from the Emory River Reach B was determined to be organic arsenic, which is of low toxicity and is not a CCR material-associated COPC.

Estimated noncancer HIs greater than 1 were attributable to legacy contaminants Aroclor 1254 and methyl mercury. Estimated noncancer HIs from CCR Parameters detected in fish filet samples taken from the Emory River Reach B were less than 1.

Inorganic mercury is one of the CCR Parameters listed in Appendix III and Appendix IV of the CCR Rule. In the environment, inorganic mercury can be methylated by microorganisms to methyl mercury, which can accumulate in the tissues of organisms including fish (ATSDR 1999). Consumption of fish containing methyl mercury is one of the primary sources of non-occupational human exposure to methyl mercury. TDEC has established two fish consumption advisory levels based on total mercury (evaluated as methyl mercury) in fish tissues: (1) a “precautionary advisory” of 0.3 parts per million (ppm) (0.3 mg/kg) average concentration, which advises pregnant or nursing mothers, plus children, to avoid any consumption of fish and all other persons to limit consumption to one or two fish meals per month, and (2) a “do not consume advisory” of 1.0 ppm (1.0 mg/kg) average concentration, which advises all persons to avoid fish consumption in any amount (Denton 2007). Fish consumption advisories provide information about contaminant levels in individual types of fish from specific waterbodies and provide recommendations about how often (i.e. meals per week or per month) people can “safely” eat certain types of fish, but they are not regulatory risk assessments.

The EPCs for methyl mercury in fish tissue from Emory River Reach B (0.197 mg/kg for bass, 0.106 mg/kg for sunfish, 0.141 mg/kg for catfish, and 0.221 mg/kg for crappie; Appendix B, Tables 7.17 to 7.24 of the BHHRA) were less than TDEC's “precautionary advisory” level for methyl mercury in fish tissues. As of the date of this HHRA (2024), the Emory River Reach B adjacent to the TDEC Order CCR units at the KIF Plant is not covered by a fish consumption advisory for either mercury or PCBs (TDEC 2023). However, a precautionary advisory for mercury is in force for the Emory River upstream of the KIF Plant starting at Emory River mile 12.4, and there are fish consumption advisories for the Clinch River Arm of the Watts Bar Reservoir and the Tennessee River Arm of the Watts Bar Reservoir for PCBs.

In addition, studies conducted by TDEC to evaluate the potential bioaccumulation of metals in native game fish in Tennessee streams in coal mining regions found that mercury concentrations in fish filets were highest in fish collected from reference areas followed by fish collected downstream of inactive

coalfields (Arnwine et al. 2014). Results of these studies suggest that mercury is a regional contaminant in Tennessee related to geology, historical coal mining and other human activities.

5.3.3 Weight of Evidence

This HHRA uses a WOE approach to evaluate potential risks to human receptors from exposure to COPCs. The WOE approach is consistent with USEPA guidance for conducting risk assessments (USEPA 1989a; 2000a) and is based on the concept that a determination of health risk should go beyond solely calculating numerical risk estimates and should include both quantitative and qualitative evidence linking contaminant exposures to the likelihood of an adverse health effect. It is the combined results of multiple LOEs rather than any single result that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures.

The WOE evaluation for the KIF Plant HHRA was performed in accordance with *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A) and is based on integration of quantitative and qualitative LOEs. Quantitative LOEs include: 1) comparing concentrations of CCR Parameters measured in CCR material in the TDEC Order CCR units to medium-specific and receptor-specific human health screening levels, and 2) calculating cancer risk and noncancer HI. Qualitative LOEs include: 1) the use of published information on CCR material and CCR Parameters, and 2) narrative interpretation of findings from the environmental sampling, biological studies, and human health risk assessments conducted as part of the KRP and LTM (i.e., Jacobs 2012, Arcadis 2020) to draw conclusions about relationships between human exposures to CCR Parameters in surface stream water, seasonally exposed sediment, and consumption of sport fish and the TDEC Order CCR units at the KIF Plant.

The overall conclusions of the HHRA are that there are no unacceptable risks to onsite human receptors potentially exposed to CCR material, nor to offsite human receptors potentially exposed to CCR Parameters that could be associated with the TDEC Order CCR units in surface stream water, seasonally exposed sediment, and sport fish filet tissue from the Emory River Reach B adjacent to the KIF Plant. Cumulative ILCR and noncancer HI estimates from exposure to CCR Parameters potentially associated with the TDEC Order CCR units at the KIF Plant were less than TDEC's acceptable cancer risk criterion and hazard threshold of 1×10^{-5} and 1, respectively, for an onsite worker and for offsite recreational users of the Emory River Reach B adjacent to the KIF Plant as presented in Section 5.3.2 above.

The quantitative and qualitative LOE considered in the WOE evaluation for the KIF Plant HHRA are briefly discussed below.

Risks to onsite workers were calculated assuming no health and safety protocols were used to control or mitigate exposure. When standard health and safety protocols (e.g., wearing of protective clothing) are used during future maintenance activities, potential risks to onsite workers are expected to be even lower than estimated. Furthermore, if substantive repairs are necessary, a site-specific health and safety plan specifying procedures to protect onsite workers would be required.

Private, potable use of groundwater and springs was addressed in the water use survey for the KIF Plant in the KIF Plant EAR. The evaluation concluded that current and historical CCR management associated with the KIF Plant has not affected water supply wells or springs located downgradient of the KIF Plant.

Findings from the BHHRA (Jacobs 2012) are the major source of qualitative LOE for the offsite receptors potentially exposed to CCR Parameters in surface stream water, seasonally exposed sediment, and consumption of sport fish evaluated for the KIF Plant HHRA. Although quantitative estimates of cancer risk and noncancer hazard for offsite human receptors are presented in the BHHRA, the findings are considered qualitative LOE for the current KIF Plant HHRA for the following reasons:

- The purpose of this HHRA was to determine if there are potentially unacceptable risks to human health from exposure to CCR Parameters associated with the TDEC Order units at the KIF Plant that may require corrective measures. The BHHRA (Jacobs 2012) had a different purpose. As stated on page 1-1 of Jacobs (2012) - "*The objective of the BHHRA was to develop quantitative and qualitative estimates of potential cancer risks and noncancer hazards for human receptors exposed to environmental media impacted by ash west of Dike 2. These estimates were developed to support the evaluation of alternatives for cleanup of any residual ash as part of a Non-Time Critical Removal Action EE/CA for the river system*."

- Data for surface stream water, seasonally exposed sediment, and sport fish tissue collected from the Emory, Clinch, and Tennessee rivers during KRP investigations from 2010 through 2011 were evaluated in the BHHRA (Jacobs 2012). Although the focus of these investigations (and LTM) was to determine impacts on human and ecological receptors from residual CCR material in the River System, the sample data from the Emory River Reach B would have also represented impacts, if any, from the TDEC Order CCR units at the KIF Plant adjacent to the river. The sampling methods, data quality, and approach to the BHHRA were comparable to the protocols governing the environmental investigations and HHERA under the current TDEC Order program for TVA fossil plants, including:

    - SAPs and the data quality program developed for the KRP established the framework for EIs conducted under the current TDEC Order Program.

    - With minor exceptions (i.e. lithium), the datasets generated during the KRP and evaluated in the BHHRA (Jacobs 2012) include the same list of CCR Parameters required by the TDEC Order.

    - The CSM developed for the BHHRA (Jacobs 2012) established the template for offsite receptors currently being used for the HHRAs under the TDEC Order.

    - LOE from the BHHRA were considered qualitative because the underlying datasets used by Jacobs (2012) were not re-evaluated in the KIF Plant EAR and no new or revised quantitative risk estimates were derived.

- LOE from the BHHRA (Jacobs 2012) represent "worst case" conditions in the Emory River and are protective of human receptors. The environmental datasets used in the BHHRA were collected from late 2009 through 2011 and represented conditions in the aquatic environment

after as much CCR material as feasible had been removed from the Emory River. Studies and data collected for the LTM demonstrate that conditions have improved since the BHHRA was conducted, and it is reasonable to assume that potential risks would be lower in 2024 than in 2012.

- The KIF Plant EAR indicates there have been no documented releases of CCR material from the TDEC Order units either during the 2008 Dredge Cell failure or in the years since that event. However, impacts from the TDEC Order units (if any) not related to a physical release of CCR material would have been represented in the KRP investigation datasets for the Emory River Reach B evaluated in the BHHRA (Jacobs 2012).

- Comparison of the groundwater data summarized in the KIF Plant EAR to the datasets evaluated in the KRP provides additional qualitative LOE supporting the conclusion of no unacceptable risks to offsite human receptors from CCR Parameters that could be associated with the TDEC Order CCR units at the KIF Plant. As summarized in the KIF Plant EAR potential impacts from CCR Parameters in groundwater released to the Emory River, if any, would be limited to areas immediately downgradient of the TDEC Order CCR units bordering the Emory River and the Plant Intake Channel. The groundwater dataset analyzed in the KIF Plant EAR included samples collected between June 2009 and December 2022 (Appendix C.1). Thus, some of the groundwater data would have represented conditions associated with the TDEC Order CCR units existing during the KRP investigations.

    - Cobalt was the only CCR Rule Appendix IV constituent present at statistically significant concentrations above the GSL in groundwater. Surface stream water, sediment, and biological tissues collected during the KRP were analyzed for cobalt as well as other CCR Parameters (except lithium). Cobalt was not a risk-driver for either the BHHRA (Jacobs 2012) or the BERA (Arcadis 2012).

Although the PHA (TDH 2010) is not a major source of LOE for evaluating potential human health risks relative to the TDEC Order CCR units, it does provide context for the conditions in the Emory River Reach B and shoreline adjacent to the KIF Plant in the weeks immediately following the December 2008 CCR material release. In formulating their conclusions TDH (2010) considered a series of surface stream water samples collected by TDEC from locations in the Emory River Reach B adjacent to the KIF Plant from January through May 2009 that demonstrated decreases in concentrations of arsenic (and other CCR Parameters) over time.

LOE from the BHHRA (Jacobs 2012) support the conclusion that there are no unacceptable risks for offsite recreational users – beachcombers from potential exposures to CCR Parameters in seasonally exposed sediment along the shores of the Emory River Reach B that may be associated with the TDEC Order CCR units at the KIF Plant.

- Sediment sampling conducted for the LTM demonstrated that conditions in the Emory River have improved and that Remedial Action Objectives have been met (Arcadis 2020). It is reasonable to assume that CCR Parameters associated with residual CCR material in areas of seasonally exposed sediment within the Emory River Reach B have also attenuated over time as a result of

downstream transport and dilution from fluctuating water levels and deposition of native sediments from unimpacted locations upstream of the KIF Plant. Potential exposures and cancer risk to a recreational user – beachcomber from CCR Parameters in seasonally exposed sediment within the Emory River Reach B are reasonably expected to be lower now (2024) than in 2012 when the BHHRA was published.

- Furthermore, the CCR Parameters driving the ILCR estimates in the BHHRA (Jacobs 2012), including arsenic, radium-226 and radium-228, were related to the physical presence of CCR material from the December 2008 release event. These specific constituents were not identified as COPCs in environmental media (excluding CCR material) associated with the TDEC Order CCR units as discussed in the KIF Plant EAR.

A summary of the HHRA results is provided in Section 7.1.

5.4 UNCERTAINTY ANALYSIS

Uncertainties are inherent in the risk assessment process and arise from limitations in the available information, analysis methods, and assumptions used in the assessment. Sources of uncertainty may include chemical characterization information and limitations in the available data, assessment of potential exposures, and modeling of uptake and toxicity. To assist interpretation of the risk assessment results presented in this HHRA, the primary sources of uncertainty in each step of the HHRA are described in the following subsections.

5.4.1 Exposure Assessment

Uncertainties associated with exposure assessment include identification of COPCs, derivation of medium-specific EPCs, and calculation of exposure doses using upper bound exposure assumptions. Many of these sources of uncertainty are common in human health risk assessments. Uncertainties that are unique to this HHRA for the TDEC Order CCR units at the KIF Plant are discussed below:

- Protective methods and assumptions were used in selecting COPCs for quantitative estimates of cancer risk and noncancer hazard for onsite worker exposure to CCR material in the TDEC Order CCR units. For example, maximum CCR Parameter concentrations were compared to SSL_{HH} values based on a target cancer risk and HQ of 1×10^{-6} and 0.1, respectively, and analytical results were screened for CCR material at all sample depths. These multiple protective assumptions and methods reduce to a very low level of uncertainty that risks are underestimated by screening out CCR Parameters from the onsite worker evaluation.

- Uncertainties are associated with the availability of new toxicity criteria published by USEPA (2024) for several CCR Parameters since the development of SSL_{HH} in 2021. The approved SSL_{HH} were developed using protective assumptions (e.g., target HQ of 0.1, particulate emission factor [PEF]), and as a result, there are low uncertainties associated with these CCR Parameters and the overall conclusions of the HHRA are not expected to be impacted.

- Concentrations of CCR Parameters may vary across depths within the TDEC Order CCR units. There is low uncertainty in the COPCs identified for CCR material and quantitatively evaluated in this HHRA. The maximum detected concentration of each CCR Parameter in the collective dataset for the TDEC Order CCR units was compared to SSL_{HH} for the onsite worker. The depth of the sample with the maximum concentration of each CCR Parameter within the unit was not a factor in selecting COPCs. EPCs based on data across all sampling depths were conservatively used to calculate exposure doses where there are no distinct segregated layers within the CCR units. The type of activities envisioned for the onsite worker involve contact with CCR material at relatively shallow depths where infrastructure for closed units is typically located. This receptor is not expected to have contact with CCR material deep within the closed CCR unit. The approach used to address the uncertainties associated with selecting COPCs and EPCs in CCR material within the TDEC Order CCR units is more likely to overestimate rather than underestimate exposure and risk.

- Samples of surface stream water, seasonally exposed sediment, and fish filet tissue collected during the KRP investigations were analyzed for a wide range of chemical and radiological constituents, including but not limited to most of the CCR Parameters listed in the TDEC Order. As summarized in Section 5.1.1.3, Jacobs (2012) did not compare analytical results for surface stream water, seasonally exposed sediment, or fish filet tissue to health-based screening values to select COPCs for the BHHRA. All detected constituents that were not essential nutrients were identified as COPCs and quantitatively evaluated in the BHHRA. As a result, there is a low uncertainty associated with underestimating total cumulative risks and hazard for offsite receptors from potential exposures to CCR Parameters during the qualitative evaluation of information presented in the BHHRA.

- Lithium and fluoride were not analyzed in abiotic media or biological tissue samples collected for the KRP and as a result, they were not evaluated in the BHHRA. This source of uncertainty is not likely to be significant given that these constituents have not been identified as risk drivers in other HHRAs conducted for the TDEC Order program.

- Environmental media samples incorporated by reference in the KIF Plant EAR and evaluated in the BHHRA (Jacobs 2012) were collected in the months immediately following the December 2008 CCR material release. The fact that the analytical data used in BHHRA represented conditions in the River System, and specifically in the Emory River Reach B, more than ten years ago is a source of uncertainty for this HHRA. Given that conditions in the Emory River Reach B adjacent to the KIF Plant have demonstrably improved since 2012, qualitative interpretation of findings from the BHHRA is more likely to overestimate rather than underestimate current and future risks from CCR Parameters potentially associated with the TDEC Order CCR units at the KIF Plant.

- An individual recreational user of the Emory River Reach B may be exposed to the same CCR Parameters in different media while engaging in different recreational activities (i.e., fishing, swimming and beachcombing). ILCRs and noncancer HIs were estimated separately for each recreational user type and not summed in the BHHRA (Jacobs 2012) or the HHRAs conducted

for other TVA fossil plants covered by the TDEC Order. All relevant pathways were accounted for, and there is a low uncertainty that risks were underestimated.

- Exposure assumptions such as frequency and duration of exposure, body weight of a receptor, and amount of water, food, or soil/sediment ingested per day are highly variable for individuals and populations. Factors used in equations to derive numerical estimates of daily dose of COPCs in environmental HHRAs are frequently generic upper bound values intended to overestimate rather than underestimate exposure and dose. Exposure factors for the onsite worker evaluated in this HHRA were consistent with current USEPA recommendations. As described and documented in the BHHRA (Jacobs 2012), equations and exposure factors used to estimate daily dose of COPCs for offsite receptors were consistent with USEPA guidance at the time the evaluation was conducted. Receptor-specific assumptions for recreational receptor exposures to surface stream water and seasonally exposed sediment reflect climate-related behavior patterns in Tennessee. Although USEPA's standard default exposure variable values (USEPA 2014) have been updated since 2012 to reflect population level changes, such as a slight increase in adult average body weight, there is low uncertainty in the qualitative evaluation of risks to offsite receptors using information from the BHHRA. In addition, the conditions in the Emory River have improved since 2012 (Arcadis 2020) and constituents that are not CCR material related COPCs in this HHRA were included in the BHHRA (Jacobs 2012) evaluation, which also overestimated exposure.

- Toxicity values are generally derived from laboratory studies where readily absorbed forms of constituents are used; under site-specific environmental conditions, the chemical form of the constituent may be less bioavailable. However, the magnitude of the relative bioavailability for most COPCs is not known and is therefore a source of uncertainty in the exposure dose estimates. For quantification of onsite worker exposure to CCR material in the TDEC Order CCR units, the absorbed dose was assumed to be 100% of the exposure dose for all COPCs, except for arsenic. The oral dose of arsenic was adjusted by a relative bioavailability factor of 0.6 as recommended by USEPA (2012). For other COPCs, the assumption that 100% of the exposure dose is absorbed likely overestimates human health risks.

- The BHHRA (Jacobs 2012) was completed prior to publication of USEPA's guidance for applying a relative bioavailability factor for ingestion of arsenic from soil and soil-like media. Consequently, estimated doses from ingestion of arsenic in seasonally exposed sediment were based on 100% absorption, likely resulting in higher estimates of risk for recreational user - beachcomber receptors than would be expected if USEPA's 0.6 BAF had been applied to the estimated daily exposure dose calculations for this receptor.

5.4.2 Toxicity Assessment

Uncertainties associated with toxicity assessment are related to a lack of subchronic toxicity values for evaluating short-duration onsite worker exposures, a lack of dermal toxicity values, and assumptions used to derive cancer-based toxicity values. The uncertainties discussed below are common to human health risk assessments including the HHRA for the onsite worker and the BHHRA (Jacobs 2012) for offsite receptors:

- Noncancer hazard estimates for onsite workers exposed to CCR material were calculated using subchronic RfDs, where available. A subchronic oral RfD and subchronic inhalation RfC are not available for arsenic. As a result, the noncancer hazard estimate for arsenic was calculated using the chronic RfD and RfC (Appendix D.1, Section 2.2.2). The subchronic toxicity values used to evaluate onsite workers are higher than the corresponding chronic toxicity values. Although there is uncertainty in using a chronic toxicity value to evaluate a subchronic exposure scenario, evaluation of CCR Parameters using chronic toxicity values where subchronic values are not available results in a protective overestimate of noncancer hazard.

- Cancer risk estimates for the onsite worker presented in this HHRA were modeled using CSFs developed by the USEPA, when available. USEPA uses the linearized multistage (LMS) mathematical model to extrapolate animal toxicological data to human health toxicity values for carcinogens. The LMS model assumes that there is no dose threshold below which carcinogenic risk occurs. The uncertainty in the LMS approach is that for chemicals having a threshold, it extrapolates the dose-response curve far below the experimental dose range to where a dose carries virtually no risk (Bogdanffy et al. 2001). In addition, the LMS model also can result in conservative carcinogenic potency assumptions because: (1) any exaggerations in the extrapolation that can be produced by some high dose responses (if they occur) are generally neglected; (2) UCLs on the actual response observed in the animal study are used rather than the actual response, resulting in upper bound low dose extrapolations that can overestimate risk; and (3) non genotoxic chemicals (i.e., threshold carcinogens) are modeled in the same manner as highly genotoxic chemicals. Thus, the toxicity values (i.e., CSFs) are designed to yield conservative estimates of cancer risk, and to be protective of the overall population.

- RfDs typically have uncertainty factors of 100 to 1,000 incorporated into their development. These factors account for the potential of humans to be more sensitive to a chemical than the laboratory animal, for some humans to be more sensitive to the chemical than the general population, and for chronic exposure durations when the toxicity experiments were conducted over shorter durations, etc. Thus, toxicity values are designed to be protective of the overall population.

- Dermal toxicity criteria are not available from USEPA. Typically, a simple route to-route (oral-to-dermal) extrapolation is assumed such that the available oral toxicity criteria (RfD and CSF) are used to quantify potential effects associated with dermal exposure. However, as noted in the USEPA *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004), depending upon the COPC being evaluated, there is uncertainty and underestimation of risk and hazard to human health associated with this approach because the oral toxicity criteria are based on an administered dose and not an absorbed dose. In general, USEPA guidance recommends an adjustment of the oral toxicity criteria to convert an administered dose to an absorbed dose (USEPA 2004). The adjustment accounts for the absorption efficiency of the constituent in the "critical study" that is the basis of the oral toxicity criterion. If the oral absorption in the critical study is 100%, then the absorbed dose is equivalent to the administered dose and no adjustment is necessary. If the oral absorption of a constituent in the critical study is poor (i.e., less than 50%), then the absorbed dose is much smaller than the administered dose.

- Uncertainties are associated with the availability of new toxicity criteria published by the USEPA (2024) for several CCR Parameters since the publication of the BHHRA. Risk assessments, including the BHHRA, employ protective assumptions so that even if toxicity values change, the assessment remains protective of human health.

5.4.3 Risk Characterization

The different sources of uncertainty described above are incorporated into the risk estimate through a combination of protective assumptions. These are propagated through the exposure and risk calculations, resulting in estimated risks for an onsite worker presented in this HHRA that are most likely upper bound estimates (or overestimation) of risk. The exposure variables and assumptions used in the BHHRA (Jacobs 2012) were described by the authors as Reasonable Maximum Exposure scenarios intended to yield upper bound estimates of risk for offsite receptors from CCR Parameters in surface stream water, seasonally exposed sediment, and sport fish filet tissue.

In addition to this uncertainty analysis, the qualitative LOE presented in Section 5.3.3 provide additional context for the protective methods and assumptions used to evaluate onsite worker exposures to CCR material based on data summarized in the KIF Plant EAR, and for the evaluation of offsite receptors potentially exposed to CCR Parameters in surface stream water, seasonally exposed sediment, and consumption of sport fish from the Emory River Reach B, as presented in the BHHRA (Jacobs 2012).

As a result, the risk assessment is very unlikely to underestimate human health risk, which leads to high confidence in the HHRA conclusions.

6.0 ECOLOGICAL RISK ASSESSMENT

The ERA evaluated potential ecological risks assuming the concentrations and distribution of CCR Parameters in abiotic and biotic media (described in the KIF Plant EAR) represent current and future conditions at the KIF Plant. The ERA process was used to evaluate potential hazards to ecological receptors potentially exposed to CCR Parameters in surface stream water, sediment, or biota. Results of this ERA were used in the CARA Plan to evaluate whether corrective measures are needed for the protection of ecological receptors.

The ERA methodology described herein is based on the following USEPA guidance documents:

- Region 4 Ecological Risk Assessment Supplemental Guidance (USEPA 2018b)
- *Weight of Evidence in Ecological Assessment* (USEPA 2016)
- *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (USEPA 2001)
- *Risk Characterization* (USEPA 2000)
- *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (USEPA 1999a)
- *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Peer Review Draft* (USEPA 1999b)
- *Guidelines for Ecological Risk Assessment* (USEPA 1998)
- *Interim Final Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997)
- *Framework for Ecological Risk Assessment* (USEPA 1992c)
- *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual, Interim Final* (USEPA 1989b).

The general framework for conducting ERAs is provided in USEPA's *Framework for Ecological Risk Assessment* (USEPA 1992c). Consistent with this guidance, the ERA consists of the following primary steps:

- Problem formulation
- Exposure assessment
- Effects assessment
- Risk characterization

- Uncertainty analysis.

The methods and procedures used to perform the problem formulation, exposure assessment, effects assessment, and risk characterization steps are described in the following subsections.

6.1 PROBLEM FORMULATION

Problem formulation is a process for generating and evaluating preliminary hypotheses by developing an ecological CSM. The ecological CSM includes information on CCR Parameter sources, ecological habitats, exposure media and potential receptors, and possible exposure pathways between CCR Parameters and ecological receptors.

6.1.1 Conceptual Site Model for the Ecological Risk Assessment

The ecological CSM for the KIF Plant (Exhibit 6-1) presents the potential ecological receptors and exposure pathways through which those receptors could be exposed to CCR Parameters. The ecological CSM includes the identification of COPECs and describes the relationships between CCR Parameter sources, release mechanisms to environmental media, and routes of exposure to potential ecological receptors.

6.1.1.1 Release Mechanisms

A description of release mechanisms of CCR Parameters is provided in Section 5.1.1.1. None of the release mechanisms described in Section 5.1.1.1 are expected to result in substantial transfer of CCR Parameters to soil. Consequently, there is no pathway for potential exposure of terrestrial ecological receptors to CCR Parameters either through direct contact or dietary transfer due to ingestion of terrestrial plants. However, dissolved and soluble CCR Parameters could potentially be released to groundwater with subsequent movement to the Emory, Clinch, and Tennessee River systems, which provide habitat for riparian and aquatic wildlife.

6.1.1.2 Chemicals of Potential Ecological Concern

COPECs are those CCR Parameters that are carried through the ecological risk quantification process. The purpose of this ERA is to evaluate the risks that potential exposures to concentrations of CCR Parameters in environmental media at the KIF Plant may pose to ecological receptors. As such, the COPECs evaluated in this ERA comprise the CCR Parameters defined in Section 1.3, with the exception of the following:

- Calcium, chloride, fluoride and sulfate. These CCR Parameters were not identified as COPECs in the ERA because they are essential mineral ions and only toxic at levels considerably higher than typical environmental concentrations.
- TDS and pH. TDS and pH are general, non-specific indicators of water quality that do not provide information about the source or effects of contamination. Therefore, these CCR Parameters were not identified as COPECs in the ERA.

As such, the final list of COPECs evaluated in the ERA comprises 15 of the CCR constituents listed in Appendix III and Appendix IV of the CCR Rule (i.e., antimony, arsenic, barium, beryllium, boron, cadmium, chromium [total], cobalt, lead, lithium, mercury [inorganic], molybdenum, radium 226 & 228, selenium and thallium) and the five metals included in TDEC Appendix I that are not listed in the CCR Rule (i.e., copper, nickel, silver, vanadium, and zinc).

A summary of COPECs identified for further evaluation in the ERA is presented in Table 6-1.

6.1.1.3 Avian and Mammalian Species of Conservation Concern

As described in Section 3.2.5.3, a review of the TVA Natural Heritage Database by TVA in 2024 (TVA 2024b) indicated that of the wildlife currently or historically listed by the USFWS or TDEC as being of conservation concern, only one avian species (the osprey) with exposure to aquatic and riparian media currently occur, or are likely to occur, within a three-mile radius of the KIF Plant. The osprey, also called sea hawk, river hawk, and fish hawk, is a diurnal, fish-eating bird of prey. The osprey is piscivorous, with fish making up 99% of its diet. It is a large raptor reaching more than 60 centimeters (24 inches) in length and 180 centimeters (71 inches) across the wings. The osprey tolerates a wide variety of habitats, nesting, and breeding in any location near a body of water providing an adequate food supply. Eleven osprey nests have been reported within three miles of the TDEC Order CCR units; however, only seven of these are extant (TVA 2016). The closest record of an extant osprey nest is approximately 310 feet from the TDEC Order CCR units on a lighting structure next to the railroad tracks (TVA 2016).

6.1.1.4 Ecological Receptor Selection

For the ERA it was not necessary or feasible to individually assess each receptor that may potentially inhabit, breed, or forage at or in the vicinity of the KIF Plant. Instead, the potential for adverse effects was evaluated for a subset of receptors (i.e., surrogate species) representing the various feeding guilds and ecological communities that may be exposed to COPECs. The ecological receptors assessed in the ERA were chosen by focusing on receptors that are:

- Indigenous to the area and could potentially be exposed to COPECs
- Representative of the various feeding guilds and trophic levels present at or near the KIF Plant (e.g., aquatic carnivore, riparian herbivore, riparian insectivore)
- Representative of species classified as rare, threatened, or endangered (i.e., species of conservation concern).

As described in Section 3.2.5, areas within the KIF Plant near buildings, CCR units and settling ponds do not provide suitable terrestrial habitat for ecological receptors. As a result, the ERA focuses on aquatic/riparian receptors who utilize the habitat available in the waterbodies with COPECs (i.e., Emory River, Clinch River, and Tennessee River). These receptors may be exposed to CCR Parameters via direct contact or ingestion of surface stream water or sediment, or via food chain uptake from dietary items (e.g., aquatic plants, aquatic insects, and fish) that have accumulated CCR Parameters due to direct contact with surface stream water or sediment. The selected surrogate species for piscivorous and omnivorous aquatic and riparian-feeding birds are representative of potential exposure to the osprey. The

ecological receptor groups that were assessed in the ERA, the surrogate ecological receptors that were used to represent these various groups where applicable, and the basis for their selection, are presented in Table 6-2 and summarized below. These ecological receptors are the same as those evaluated in the BERA.

- Freshwater aquatic life:

    Benthic invertebrates – benthic invertebrate communities

    Primary producers – aquatic plant communities

    Fish – fish communities.

- Amphibians – amphibian communities
- Reptiles – reptile communities
- Aquatic and riparian-feeding birds:

    Herbivorous birds – wood duck (*Aix sponsa*)

    Omnivorous birds – mallard duck (*Anas platyrhynchos*)

    Insectivorous birds – killdeer (*Charadrius vociferus*)

    Piscivorous birds – great blue heron (*Ardea herodias*) /osprey (*Pandion haliaetus*)

- Aquatic and riparian-feeding mammals:

    Herbivorous mammals – muskrat (*Ondatra zibethicus*)

    Omnivorous mammals – raccoon (*Procyon lotor*)

    Piscivorous mammals – mink (*Neovison vison*)

- Aerial-feeding birds and mammals:

    Insectivorous birds – tree swallow (*Tachycineta bicolor*)

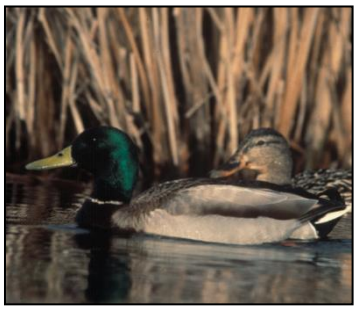
    Insectivorous mammals – gray bat (*Myotis grisescens*)

The selected ecological receptors listed above and shown in Table 6-2 are representative of other species occupying a similar position in the food web. These ecological receptors assessed in the ERA are expected to adequately represent the diversity of fauna and aquatic and riparian vegetation at or near the KIF Plant. Descriptions of the avian and mammalian ecological receptors evaluated in the ERA are provided below.

Wood Duck

The wood duck is a colorful species of waterfowl. It is common in the United States and lives near lakes and slow-moving rivers bordered by trees or other tall vegetation (California Department of Fish and Wildlife 2021). The average body weight of the wood duck is 0.658 kg (Cornell Lab of Ornithology 2021a). The foraging range of the wood duck is an estimated 612 acres. This estimate was based on the average breeding female and male home ranges (Verner et al. 1980 and Zeiner et al. 1990). Wood ducks are primarily herbivorous (Zeiner et al. 1990, Landers et al. 1977 and USDA 2021), but laying females consume a higher proportion of invertebrates. For the present assessment, the terrestrial components of the wood duck's diet (i.e., terrestrial invertebrates and terrestrial vegetation) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates and aquatic vegetation).

Mallard Duck



The mallard is the most abundant dabbling duck species in North America. It prefers areas that provide cover from predators such as grassland with tall and dense vegetation and nests near woodland lakes, streams, and marshes (USEPA 1993). The average body weight of an adult mallard is 1.17 kg (USEPA 1993). The foraging range of the mallard duck is an estimated 274 acres. This estimate was based on the average home range of laying females (USEPA 1993). Mallards feed by dabbling and filtering through sediments.

Killdeer

The killdeer is a shorebird that commonly inhabits sandbars, mudflats, and grazed fields (Cornell Lab of Ornithology 2021b). The average body weight of a killdeer is 0.102 kg (Cornell Lab of Ornithology 2021b). The foraging range of the killdeer is an estimated 10.4 acres. This estimate was based on the average home ranges of pre-nesting, nesting and post-nesting females and males (Plissner et al. 2000). They feed primarily on earthworms, snails, crayfish, grasshoppers, beetles, and aquatic insect larvae (Cornell Lab of Ornithology 2021b). For the present assessment, the diet of a killdeer is based on individuals living in North Dakota and includes terrestrial and aquatic invertebrates (Fair et al. 1995), and the terrestrial components of the killdeer's diet (i.e., terrestrial invertebrates) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates).

Great Blue Heron

The great blue heron is a large (i.e., greater than one meter tall) wading bird that feeds primarily on aquatic animals (USEPA 1993). They primarily inhabit aquatic and marine areas, spending most of their time foraging for fish in shallow waters of lakes, rivers, streams, or estuarine and sheltered coastal areas. Great blue herons tend to nest in dense colonies (heronries) close to foraging grounds (USEPA 1993). The foraging range of the great blue heron is an estimated 1.93 miles. This estimate was based on the average foraging distances of breeding adults within South Dakota rivers and streams (USEPA 1993). The average body weight of an adult great blue heron is 2.31 kg (USEPA 1993). For the present assessment, the diet of a great blue heron is based on individuals living in lower Michigan and includes aquatic invertebrates, fish, reptile/amphibians and birds/mammals.

Osprey

The osprey is a large bird of prey that feeds primarily on fish (USEPA 1993). Osprey are found primarily in marine environments in the United States, but also inhabit large inland rivers, lakes, and reservoirs. The average body weight of an adult osprey is 1.60 kg (USEPA 1993). Osprey build large stick nests in the tops of tall trees or artificial structures (USEPA 1993). The foraging range of the osprey is an estimated 2,240 acres. This estimate was based on the average foraging radius of adult males within Minnesota lakes (USEPA 1993). They are adapted for hovering over the water and dive feet-first, seizing fish with their talons (USEPA 1993).

Muskrat

The muskrat is an aquatic rodent that is common throughout most of the United States. They live along the banks of freshwater creeks, streams, lakes, marshes, and ponds (USEPA 1993). The average body weight of a muskrat is 1.17 kg (USEPA 1993). The foraging range of the muskrat is an estimated 0.330 acres. This estimate was based on the average of available home ranges (USEPA 1993). Muskrats are primarily herbivorous and feed at night on aquatic vegetation growing near their dens. They may also consume crayfish, mollusks, fish, frogs, turtles, and young birds (USEPA 1993).

Raccoon

The raccoon is the most abundant mid-sized omnivore in North America and is found throughout the United States (USEPA 1993). The average body weight of an adult raccoon is 5.84 kg (USEPA 1993). The foraging range of the raccoon is an estimated 385 acres. This estimate was based on the average home ranges of adult females and males within Michigan riparian habitats (USEPA 1993). Raccoons are found near aquatic habitat but are also common in residential areas and farmland (USEPA 1993). The raccoon is an opportunistic feeder and consumes animals, plants, garbage, and carrion. For the present assessment, the diet of raccoons is based on individuals living in Tennessee and includes terrestrial invertebrates, aquatic invertebrates, terrestrial vegetation, fish, reptile/amphibians, small mammals and birds and other/unspecified (USEPA 1993). However, the terrestrial components of the raccoon's diet (i.e., terrestrial invertebrates, terrestrial vegetation and small mammals and birds) are assumed to be composed of aquatic food items (i.e., aquatic invertebrates, aquatic vegetation and small mammals and birds).

Mink

The American mink is a member of the weasel family and is the most abundant and widely distributed carnivorous mammal in North America (USEPA 1993). Minks are active year-round and occupy aquatic habitats such as rivers, streams, lakes, ditches, swamps, marshes, and backwater areas (USEPA 1993). The average body weight of an adult mink is 1.02 kg (USEPA 1993). The foraging range of the mink is an estimated 34.8 acres. This estimate was based on the average home ranges of adult females within Montana riverine habitats (USEPA 1993). For the present assessment, the diet of minks is based on individuals living near streams and rivers in Michigan and includes aquatic invertebrates, vegetation, fish, reptile/amphibians, birds/mammals and other/unspecified. Muskrats are an important food source for minks. For the present assessment, the terrestrial components of the mink's diet (i.e., vegetation, and small mammals and birds) are assumed to be composed of aquatic food items (i.e., aquatic vegetation, and small mammals and birds).

Tree Swallow

The tree swallow is a small migratory songbird. Tree swallows breed in open habitats such as fields and wetlands throughout North America, usually adjacent to water (Cornell Lab of Ornithology 2021c). Tree swallows form large migratory and wintering flocks and often nest close together. The average body weight of adult tree swallow is 0.0205 kg (Cornell Lab of Ornithology 2021c). Although tree swallows often nest near water bodies and wetlands, their diet exhibits considerable variability with regard to the proportion of insects

consumed that are terrestrial or aquatic. A study conducted in the vicinity of the KIF Plant (Beck et al. 2013) has shown that while the tree swallow's diet of insects with an aquatic larval stage was 67% of their total diet when averaged across the study area, the percentage varied between 28 to 75% for different colonies. The study concluded these differences may be attributable to habitat characteristics and seasonal variation. The foraging range of the tree swallow is an estimated 31.1 acres. This estimate was based on the observed foraging distances of individuals from their nests (McCarty and Winkler 1999; Dunn and Hannon 1992; and Quinney and Ankey 1985). Tree swallows feed on aerial insects caught during acrobatic flight (Cornell Lab of Ornithology 2021c).

Gray Bat

The gray bat is endangered in the United States (USFWS 2022). Gray bats reside in caves located along rivers in the summer and hibernate in deep vertical caves over winter (USFWS 2022). Approximately 95% of the gray bat population hibernates in eight caves located in southeastern United States. The average body weight of a gray bat is 0.00950 kg (TNBWG 2021). The foraging range of the gray bat is an estimated 7.3 miles (LaVal et al. 1977). This estimate was based on the average distance from banding (i.e., cave and stream) of individuals. Gray bats eat a variety of flying aquatic and terrestrial insects present along rivers or lakes (USFWS 2022). Mayflies are an important food item for gray bats (TNBWG 2021). Incidental ingestion of sediment by the grey bat is assumed to be negligible.

6.1.1.5 Exposure Pathways and Routes of Exposure

Exposure pathways identified in the CSM for the KIF Plant (Exhibit 6-1) are classified as:

- Potentially complete
- Potentially complete but contribution to exposure is negligible
- Incomplete.

An exposure pathway is complete when there is potential for a receptor to be exposed to COPECs in an exposure medium through an identified exposure route. The ecological receptor groups, potential exposure media, and the classification of the potential exposure pathways for the KIF Plant ecological CSM are presented in Table 6-3. A graphical presentation of the ecological CSM is presented in Exhibit 6-1, and the complete exposure pathways are summarized below.

In general, freshwater aquatic life (i.e., benthic invertebrates, aquatic plants and fish communities) can be exposed to CCR Parameters within the environmental media that they inhabit. Direct contact and ingestion of CCR Parameters from surface stream water and sediment can occur, and some CCR Parameters in these media can bioaccumulate in aquatic life via food chain uptake. Amphibians and reptiles can also be exposed to CCR Parameters through ingestion and food chain uptake, as well as from dermal contact with, and ingestion of sediment and surface stream water. For mammals and birds, their life histories dictate the primary exposure pathways. For example, consumption of vegetation, fish,

and invertebrates makes up the primary complete exposure pathways for mammalian and avian herbivores, piscivores, and insectivores, respectively.

6.1.2 Assessment and Measurement Endpoints

Assessment and measurement endpoints define the focus of the ERA. As defined in USEPA's *Guidelines for Ecological Risk Assessment* (USEPA 1998), an assessment endpoint is an explicit expression of the environmental value that is to be protected (e.g., growth, survival, and reproduction of a specific species population). Thus, assessment endpoints focus the ERA on the guilds or communities that might be affected by exposure to COPECs.

Assessment endpoints are evaluated with measurement endpoints, which are defined as the quantitative expression of an observed or measured effect of a stressor (USEPA 1998). The assessment and measurement endpoints for this ERA are shown in Table 6-4. The assessment endpoints are population scale adverse effects to various receptors. The measurement endpoints used to evaluate these assessment endpoints are organismal-scale effects that include, but are not limited to, mortality, growth, and reproductive impairment. Ecological hazards based on organismal scale measurement endpoints are indicative of individual effects, while the population scale effect may remain uncertain.

6.2 EXPOSURE ASSESSMENT

As described in Section 2.2.2, this ERA relies on a qualitative evaluation of information reported in the BERA (Arcadis 2012) and subsequent LTM (Arcadis 2016 and 2020). The measures of exposure reported in the BERA and subsequent LTM applicable to this ERA as described in Table 6-4 include:

- Measured concentrations of COPECs in abiotic media (surface stream water and sediment)
- Measured concentrations of COPECs in biotic media (benthic invertebrates, aquatic vegetation, fish, turtles, raccoons, osprey and blue heron eggs, tree swallow eggs and nestlings)
- Calculated daily dietary dosage estimated using food chain modelling, measured COPEC concentrations in abiotic and biotic media, and modelled food-chain uptake.

Arcadis (2012) evaluated exposure of the ecological receptors identified in Section 6.1.1.4 to the COPECs identified in Section 6.1.1.2 (with the exception of lithium) in the reference reaches of the Emory, Clinch and Tennessee rivers (herein referred to as 'reference locations') as well as locations potentially affected by the 2008 CCR material release (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B; herein referred to as 'potentially impacted' locations; Exhibit 2-1). These 'potentially impacted locations' include a subset of locations that are representative of conditions adjacent to and downstream of the KIF Plant CCR units included in the TDEC Order (i.e., Emory River Reach B is adjacent to the TDEC Order CCR units at the KIF Plant, and Emory River Reach A, Clinch River Reaches A and B, and Tennessee River Reach B are all downstream from the KIF Plant). Therefore, the exposure estimates presented for 'potentially impacted locations' in the BERA include exposure estimates representative of the locations under evaluation in this ERA. As such, new quantitative estimates of exposure were not generated here. Additional qualitative exposure

information is also available for targeted COPECs and receptors based on data collected as part of the LTM program.

Quantitative estimates of exposure of ecological receptors to lithium were not provided in the BERA or LTM specifically. Because data collection for the KRP pre-dates the CCR Rule (which included the listing of CCR constituents that included lithium), quantitative estimates of exposure to lithium could not be provided in the BERA. However, the range of lithium concentrations in groundwater monitoring wells adjacent to the Emory River (Attachment E.3-A of Appendix E.3 of the KIF Plant EAR) are lower than the USEPA Region 4 (USEPA 2018b) chronic surface water screening level of 440 µg/L; therefore there is no evidence to suggest that the KIF Plant is a source of lithium to the River System. In addition, if the TDEC Order CCR units at the KIF Plant was a source of lithium to the River System, it can be inferred that the ecological receptors assessed in the BERA and LTM could potentially be exposed to lithium via the exposure pathways identified in Section 6.1.1.5. Therefore, this ERA does not provide a qualitative evaluation of exposure to lithium but rather focuses on direct measures of effect presented in the BERA and LTM (e.g., toxicity testing, community surveys, and direct measurement of various indicators of health and reproductive effects) to provide a qualitative LOE of the potential effects of exposure to lithium from the TDEC Order CCR units.

6.3 EFFECTS ASSESSMENT

The effects assessment quantifies the relationship between exposure to a stressor and the potential effects on an organism resulting from that exposure. As described in Section 2.2.2, this ERA relies on a qualitative evaluation of information reported in the BERA and subsequent LTM. The measures of effect relied on in the BERA and LTM that are applicable to this ERA, as described in Table 6-4, include:

- Comparisons of COPEC concentrations in surface stream water, sediment, and tissue to applicable benchmark values (e.g., literature-derived screening levels and critical body residue [CBR] values)
- Comparison of calculated daily doses to no observed adverse effects level (NOAEL)-based and lowest observed adverse effects level (LOAEL)-based toxicity reference values (TRVs)
- Results of toxicity tests completed using surface stream water and sediment samples collected from the Emory, Clinch, and Tennessee rivers
- Community health and reproductive health metrics measured for receptor populations from the Emory, Clinch, and Tennessee rivers.

6.4 RISK CHARACTERIZATION METHODS

Risk characterization consists of two major components: risk estimation and risk description. Risk estimation combines results of the exposure assessment and effects assessment to derive a quantitative evaluation of potential risks to potential future ecological receptors. For the risk estimation component, COPEC-specific risks are based on the HQs calculated in the BERA. No new quantitative estimates were calculated for this ERA. For the risk description component, additional information important for

interpreting the calculated risk estimates (i.e., findings of the BERA and LTM) are incorporated herein. As highlighted in Section 2.2 and provided in the document titled *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), these components were captured through a WOE approach using multiple LOEs.

6.4.1 Hazard Quotients

One of the metrics used to support risk characterization in the BERA was pathway-specific (e.g., water, sediment, dietary plant matter and/or dietary animal matter) HQs for avian and mammalian receptors, calculated using the following generic equation:

$$HQ = \frac{Dose}{TRV}$$

Where:

HQ = Hazard quotient (unitless)

Dose = Modeled exposure dose (mg/kg-day)

TRV = Toxicity reference value (mg/kg-day)

In the BERA, HQs were calculated for both NOAEL-based and LOAEL-based TRVs. When NOAEL-based HQs are above 1, there is a potential for effects to individual receptors. This is particularly relevant for species of conservation concern where effects to individuals could affect local populations. Since the LOAEL is the lowest dose at which adverse effects are observed, LOAEL-based HQs better reflect the potential risk to receptors at the population level. For example, osprey is a species of conservation concern that could be present at the site. Therefore, NOAEL-based HQs for the osprey are used to assess the risk to osprey.

HQs for community receptors were also derived in the BERA as the ratio of the EPC for each COPEC to the respective benchmark values using the following generic equation:

$$HQ = \frac{EPC}{TRV}$$

Where:

HQ = Hazard quotient (unitless)

EPC = Exposure point concentration (mg/kg or µg/L)

TRV = Benchmark value (mg/kg or µg/L)

6.4.2 Weight of Evidence Framework

This ERA uses a WOE approach to evaluate potential risks to ecological communities and receptors from exposure to COPECs. The WOE approach is consistent with USEPA guidance for conducting ERAs (USEPA 2000) and is based on the concept that a determination of ecological risk should go beyond solely calculating numerical risk estimates and should include evidence and analysis demonstrating or refuting a causal link between stressor and response (e.g., USEPA 1992c, 1997, 1998, 1999a, and 2000). It is the combined results of multiple LOEs rather than any single result that are used to determine if risk is present at a level that warrants further evaluation or consideration of corrective measures.

The WOE evaluation for the KIF Plant ERA was performed in accordance with *Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants* (Appendix A), and integrates quantitative LOEs (e.g., HQs) with qualitative LOEs (e.g., results of community health assessments). Consistent with this document, quantitative LOEs presented in the BERA and evaluated qualitatively in this ERA include:

- Comparing concentrations of COPECs to benchmark values
- Calculating HQs.

Qualitative LOEs presented in the BERA and evaluated qualitatively in this ERA include:

- Toxicity tests completed with surface stream water and sediment samples collected from upstream, adjacent, and downstream locations of the KIF Plant
- Site-specific community health and reproductive health metrics evaluated at locations upstream, adjacent, and downstream of the KIF Plant.

In the BERA, the magnitude of effects was generally classified as Negligible, Low, Moderate, or High. These classifications are defined in the BERA as qualitative and based on best professional judgement. Examples of the types of LOEs considered supportive of each of these qualitative categories are provided below.

- **Negligible:** Conservative effects values were not exceeded or site metrics were not different from those of reference (background) locations.
- **Low:** Small exceedances of conservative effects values (e.g., NOAELs), non-exceedances of less conservative effects values (e.g., LOAELs), and small differences in site metrics relative to reference locations.
- **Moderate:** Large exceedances of conservative effects values (e.g., NOAELs), small exceedances of less conservative effects values (e.g., LOAELs), and moderate differences from reference conditions.
- **High:** Large exceedances of non-conservative effects values (e.g., LOAELs) or large differences from reference conditions (e.g., > 30% reduction).

As noted above, the language in these examples is qualitative (e.g., small, moderate, large) and the final categorization was made using best professional judgement.

The quantitative/qualitative LOEs and methods of assessment that were considered in the WOE evaluation for this ERA are summarized in Table 6-5, and results of these LOEs are described in Section 6.5.

6.5 RISK ESTIMATION RESULTS AND WEIGHT OF EVIDENCE EVALUATION

6.5.1 Benthic Invertebrate Communities

The assessment endpoint for the benthic invertebrate receptor community is protection of the abundance and diversity of benthic invertebrates in the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2 and Table 6-4).

6.5.1.1 Lines of Evidence - Benthic Invertebrate Communities

The LOE from the BERA and LTM reports pertinent to the evaluation of potential impacts of site-related COPECs on benthic invertebrates in the Emory, Clinch and Tennessee rivers are summarized below:

- **Benthic invertebrate community metrics**. The BERA provides a review of benthic invertebrate community surveys conducted *in situ* in the Emory, Clinch, and Tennessee rivers in 2009 and 2010 as part of the KRP. The 2009 data were collected prior to the completion of initial dredging and the 2010 data were collected after dredging completion. Therefore, the benthic invertebrate community data collected in 2010 are more representative of the residual effects of the KIF Plant on the benthic invertebrate community and are most applicable to this ERA.

  For the benthic invertebrate community assessments reviewed in the BERA, sediment samples were collected from transects located on the Clinch, Emory and Tennessee rivers. At each sample location, physical characteristics of the location were recorded (e.g., water depth, sediment characteristics). Benthic invertebrate community metrics (e.g., number of organisms, number of taxa, diversity index and tolerance index) for each sample were subsequently measured in the laboratory. Arcadis (2012) concluded that benthic invertebrate community compositions were generally similar between reference transects and potentially impacted transects. Most benthic invertebrate community metrics for the potentially impacted transects were within the range of what was observed in reference transects. Where differences were observed, they appeared to be related to habitat differences (e.g. substrate type and water depth) rather than due to exposure to evaluated COPECs (Buys et al. 2014).

  Following the submission of the BERA, additional LTM of benthic communities in the Emory and Clinch rivers has been completed biennially. Results of the monitoring completed in 2013, 2015, and 2017 are presented in the LTM reports prepared by Arcadis (2016; 2020). These reports noted that there were no statistically significant temporal differences in benthic invertebrate community diversity between 2013 and 2017. Statistically significant decreases in chironomid and

oligochaete populations were observed between 2013 and 2017 at the potentially impacted transects; however, these temporal trends were also found for the reference sites. Therefore, Arcadis (2020) concluded that the observed temporal differences in benthic invertebrate community abundance were related to substrate characteristics and natural variability in benthic communities rather than negative impacts from evaluated COPECs.

Overall, it was concluded in the BERA that the data collected during the 2009 and 2010 community surveys were indicative of negligible risk to benthic invertebrates in the Emory, Clinch and Tennessee rivers. These findings were supported by the subsequent LTM of benthic communities presented in the LTM reports, which determined that observed changes over time in community abundance were more likely related to substrate characteristics and natural variability in benthic communities rather than negative impacts from evaluated COPECs.

- **Toxicity tests.** As part of the BERA, toxicity tests were conducted on sediment samples collected from the Clinch River and Emory River to evaluate sediment toxicity to benthic invertebrates for samples collected from reference and potentially impacted locations on the Clinch River and Emory River (Arcadis 2012). Toxicity tests were conducted using three species: *Ceriodaphnia dubia* (*C. dubia*), *Hyalella azteca* (*H. azteca*), and *Chironomus dilutus* (*C.dilutus*). For *C. dubia*, the test involved exposure to various dilutions of site sediment with river water from the test location as overlying water to permit evaluation of potential toxicity associated with the sediment-water interface. All three species were evaluated in short-term (10-day) toxicity tests; in addition, *H. azteca* and *C. dilutus* were evaluated in long-term (28-day) toxicity tests. Toxicity endpoints for *C. dubia* were effects on survival and reproduction. Toxicity endpoints for *H. azteca* and *C. dilutus* were effects on growth, biomass, survival and emergence (*C. dilutus*, only). Arcadis concluded that sediment from the Clinch River locations had minimal toxic effects to invertebrates. However, toxic effects to invertebrates were moderate for sediment collected from the Emory River. These results indicated the potential for moderate risk to benthic invertebrates in the potentially impacted areas of the Emory River as of 2010 (Stojak et al. 2014).

  Additional benthic invertebrate toxicity tests were subsequently conducted as part of the LTM program. For sediment samples collected from reference and potentially impacted locations in each of the Emory and Clinch rivers in November 2017, 10-day sediment toxicity tests to evaluate effects on survival and growth of *H. azteca* were completed. For these 2017 samples, no statistically significant reductions in *H. azteca* survival or growth were observed for the potentially impacted sediment sample locations in either the Emory or Clinch rivers relative to their applicable reference samples (Arcadis 2020). Therefore, the most recent toxicity tests indicate that there are no unacceptable risks to benthic invertebrates in the Emory or Clinch rivers.

- **COPEC concentrations in invertebrate tissues.** As part of the BERA, snail (*Pleurocera canaliculatum*) and mayfly (adults and nymphs of *Hexagenia bilineata*) tissue samples were collected in 2009 and 2010 from reference and potentially impacted locations in the Clinch River, Emory River, Little Emory River and Tennessee River, and the following three separate evaluations were conducted:

- Comparison of measured COPEC concentrations in invertebrate tissue from potentially impacted sampling locations to COPEC concentrations in invertebrate tissue collected from applicable reference locations
- Comparison of measured invertebrate tissue data to literature-derived CBR values
- Investigation of potential correlation of COPEC concentrations in measured invertebrate tissue data to COPEC concentrations in sediment.

Based on these three evaluations, the tissue concentration data were indicative of moderate risk in the Emory, Clinch and Tennessee rivers to benthic invertebrates due to exposure to arsenic and selenium.

Follow-up monitoring of COPEC concentration in invertebrate tissues in the LTM focused on collection and analysis of mayfly tissues. Additional mayfly tissue samples were collected in 2015 and 2017 from reference and site-related locations in the Clinch River and Emory River as part of LTM (Arcadis 2020). During both years, all mayfly nymph (depurated and non-depurated) and mayfly adult tissue selenium concentrations were below the LTM remedial tissue monitoring endpoints that were previously established for the site. Similarly, mayfly nymph (depurated and non-depurated) and mayfly adult tissue arsenic concentrations in 2015 and 2017 were below the LTM remedial tissue monitoring endpoints at all sampling locations. Additionally, for both selenium and arsenic, concentrations in both mayfly nymphs (depurated and non-depurated) and mayfly adults measured in 2015 and 2017 were indicative of decreasing or stable trends over time. Collectively, these data are indicative of decreased risk to benthic invertebrates in the River System over time.

- **COPEC concentrations in sediment.** The BERA provides a comparison of COPEC concentrations measured in sediment collected from potentially impacted locations in 2010 (post-dredging) to concentrations at applicable reference locations and applicable screening criteria. In the BERA, it was concluded that the observed COPEC concentrations in sediment were potentially indicative of low risks to benthic invertebrates due to exposure to arsenic (Emory River and Clinch River), copper (Clinch River), nickel (Clinch River), and mercury (Emory River).

  Additional sediment samples were collected in 2015 and 2017 as part of LTM (Arcadis 2020) from reference and potentially impacted locations in the Clinch River and Emory River and analyzed for the two COPECs most highly correlated with sediment toxicity to benthic invertebrates identified in the BERA (i.e., arsenic and selenium). All arsenic and selenium concentrations in sediment samples collected from the Clinch and Emory rivers in 2017 were below the LTM remedial monitoring endpoints that were previously established for the site and represent the most current sediment chemistry results. Therefore, this LOE is also indicative of decreasing risk to benthic invertebrates in the River System over time.

6.5.1.2 Weight of Evidence - Benthic Invertebrate Communities

Overall, Arcadis (2012) concluded in the BERA that risks to benthic invertebrates were moderate in the Emory River and low in the Clinch River based on data collected in 2009 and 2010. The COPECs associated with these risks were arsenic and selenium. As such, risk management was recommended for benthic invertebrate communities in Emory River Reaches A, B, and C. However, more recent monitoring data collected as part of the LTM program in 2015 and 2017 provide additional context to these conclusions. Specifically, as described above, the LTM program completed additional community monitoring, additional sediment toxicity tests, additional tissue monitoring, and additional sediment sampling. The more recent data collected during the LTM program provide evidence of no negative impacts from COPECs on benthic communities and no increased sediment toxicity for samples collected from potentially impacted locations compared to reference locations, indicating that sediment and tissue samples were in compliance with established LTM remedial monitoring endpoints.

Although the evidence suggests that there were some temporary risks to the benthic invertebrate community in the Emory River after the 2008 release event at the KIF Plant, it can be concluded based on the overall WOE that there are no current and ongoing unacceptable risks to benthic invertebrate communities in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs from the TDEC Order CCR units.

6.5.2 Aquatic Vegetation Communities

The assessment endpoint for the aquatic vegetation receptor community is protection of the abundance and diversity of aquatic plants in the Emory, Clinch, and Tennessee River systems by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2, Table 6-4).

6.5.2.1 Lines of Evidence – Aquatic Vegetation Communities

The LOE from the BERA pertinent to the evaluation of potential impacts of site-related COPECs on aquatic vegetation communities downstream of the KIF Plant in the Emory, Clinch and Tennessee rivers are summarized below:

- **COPEC concentrations measured in surface stream water and sediment.** Surface stream water and sediment concentrations were compared in the BERA to literature-derived toxicity data (e.g., NOAELs, LOAELs, lowest chronic values, and screening values). COPEC concentrations greater than literature-derived toxicity data (e.g., NOAELs, LOAELs, lowest chronic values, and screening values) were infrequent in these media. Where concentrations greater than applicable toxicity data were observed, additional information was presented to characterize the potential for risk (e.g., comparing to a more appropriate toxicity endpoint specific to aquatic plants rather than a generic surface water screening value protective of all aquatic receptors, or providing a spatial comparison of concentrations between reference and downstream sampling locations to indicate that elevated COPEC concentrations are not site-related). Therefore, Arcadis (2012) concluded that risks associated with exposure of aquatic plants to COPECs in surface stream water and sediment were negligible to low based on this LOE.

- **COPEC concentrations measured in aquatic vegetation tissues.** A spatial comparison of COPEC tissue concentrations in shoreline vegetation and emergent vegetation in the BERA did not indicate elevated COPEC concentrations in downstream reaches compared to upstream reference locations. For periphyton tissue concentrations, a possible trend between upstream and downstream reaches with marginal statistical significance was observed for arsenic and copper. However, an additional comparison of the measured arsenic and copper concentrations in periphyton tissue to available literature effects values indicated that these concentrations are also not expected to pose unacceptable risk to periphyton communities. Therefore, Arcadis concluded in the BERA that risks associated with exposure of aquatic plants to COPECs in surface stream water and sediment were negligible to low based on this LOE.

6.5.2.2 Weight of Evidence – Aquatic Vegetation Communities

Results of the BERA indicated that risks to aquatic vegetation communities were negligible to low in the Emory, Clinch, and Tennessee rivers. As a result, risk management recommendations for aquatic plants in the Emory, Clinch or Tennessee rivers were not provided, and no further monitoring or studies of aquatic plant communities were conducted during the LTM program. As such, it can be concluded based on the overall WOE that there are no unacceptable risks to aquatic vegetation communities in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.5.3 Fish Communities

The assessment endpoint for the fish receptor community is protection of the abundance and diversity of fish in the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2, Table 6-4).

6.5.3.1 Lines of Evidence – Fish Communities

The LOE from the BERA and LTM pertinent to the evaluation of potential impacts of site-related COPECs on fish communities downstream of the KIF Plant in the Emory, Clinch and Tennessee rivers are summarized below:

- **Fish community metrics.** There are two programs for fish community surveys that were relied on as LOEs in the BERA: a TVA annual evaluation of the spring sport fishery that has been conducted since 2002 for the Watts Bar Reservoir, and a TVA Reservoir Fish Assemblage Index (RFAI) that has monitored the condition of the fish community in the vicinity of KIF since 2001. The Watts Bar Reservoir sampling includes areas within the Emory River and Clinch River that were considered ‘near-field’ to the 2008 material release by Arcadis (2012). Data collected from these surveys regarding fish community properties were compared by Arcadis (2012) for similar locations collected before the CCR material release in December 2008 through to post-dredging conditions in 2010 and 2011. The results of this comparison indicated that the fish community in the River System had not experienced a substantive impairment due to the CCR material release.

- **Toxicity tests**. Static-renewal 7-day chronic toxicity tests with fathead minnows were completed as part of the BERA using surface stream water samples collected in 2010 from a reference

location in the Emory River, as well as Emory River Reaches A, B, and C. In these tests, there were no significant effects on fathead minnow growth or survival for any of the analyzed water samples. In addition, fish embryo-larval studies with fathead minnows were completed using bulk sediment samples collected in Emory River Reach B. These embryo-larval tests also observed no significant health effects on fathead minnow survival, hatching success, or developmental abnormalities (Rigg et al. 2014). Furthermore, long-term exposures (120 days) in which fathead minnows were in continuous contact and water-borne exposure to CCR material collected from the KIF Plant release were also indicative of low direct toxicity of CCR material in sediment to this fish species (Greeley et al. 2014).

- **Reproductive studies.** Fish were collected at the beginning of the 2009 and 2010 reproductive seasons from reference locations in the Emory and Clinch rivers, as well as from the Emory River Reaches A and B and Clinch River Reach A. In 2010, an additional reference location in the Little Emory River was also sampled. The reproductive condition of three collected fish species (bluegill sunfish, largemouth bass, and redear sunfish) was assessed in the BERA based on ovary characteristics such as ovary stage and oocyte condition. Overall, no conclusive evidence of ecologically significant effects on the reproductive condition of the three tested species in 2009 or 2010 was found (Rigg et al. 2014).

- **Tissue concentrations.** The BERA provides a comparison of measured fish tissue concentrations to CBRs for fish samples that were collected in 2010 and 2011. Fish tissue samples were collected from reference reaches in the Clinch and Emory rivers, as well as in Emory River Reaches A, B, and C and Clinch River Reaches A and B. Fish tissue concentrations of several COPECs (e.g., arsenic and selenium) were observed to be greater than the identified CBRs. However, these CBRs were considered to have limited applicability to prediction of ecological effects, and similar fish tissue concentrations were observed both at the reference locations and downstream locations. Overall, fish tissue COPEC concentrations were indicative of limited uptake/bioaccumulation of COPECs by fish, and no substantial risks to fish were predicted based on this LOE (Rigg et al. 2014). Fish tissue data are compared to CBR values in BERA Tables 3-23 through 3-29. Estimated HQs are provided in Appendix L. Interpretation of the findings and limitations of the CBR values are discussed in Section 3.2.4 of the BERA (Arcadis 2012).

- **Health Metrics.** The BERA presents the results of fish health studies carried out in the River System in 2009 and 2010. In these studies, fish were collected from reference locations in the Emory River, Clinch River, and Little Emory River, as well as in locations in Emory River Reaches A and B and Clinch River Reach A. For collected fish, a variety of fish health indicators were recorded (e.g., length, weight, external signs of injury, bioenergetic status, nutritional/ feeding level, histopathology). Overall, it was concluded based on these fish health studies that no significant health effects with respect to obvious damage or injury were present in fish collected from downstream reaches compared to reference reaches (Rigg et al. 2014).

- **Surface Stream Water Chemistry.** As described in Section 6.5.2.1**,** surface stream water samples were collected from reference locations in the Emory, Clinch and Tennessee rivers

(Emory River Reference, Clinch River Reference, and Tennessee River Reference), as well as locations potentially affected by the 2008 CCR material release (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B). COPEC concentrations in these surface stream water samples were compared to literature-derived toxicity data (e.g., NOAELs, LOAELs, lowest chronic values, and screening values). Spatial comparisons between reaches were also made. Overall, based on this LOE, it was concluded that surface stream water chemistry results indicate limited potential for exposure to COPECs in surface stream water for fish; therefore, significant risks to fish are not expected (Rigg et al. 2014).

- **Additional data collected during LTM.** Although none of the LOE from the BERA indicated the presence of unacceptable risks to the fish community, fish sampling was included in the *LTM SAP* to evaluate recovery of the ecological function and recreational use of the River System. Community health and reproductive studies for fish did not identify any visible impacts to overall fish health and reproduction. Studies conducted through 2017 indicated that fish communities continued to be present in numbers and conditions typically observed for similar water bodies (Arcadis 2020).

6.5.3.2 Weight of Evidence – Fish Communities

None of the evaluated LOE indicated the likelihood of significant risks to fish communities in the Emory, Clinch and Tennessee rivers. Therefore, the WOE associated with fish communities in the Emory, Clinch and Tennessee rivers in the BERA was that there were no unacceptable risks to fish communities in the Emory, Clinch and Tennessee rivers. As such, it can be concluded based on the overall WOE that there are no unacceptable risks to fish communities in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.5.4 Aquatic/Riparian Feeding Amphibians and Reptiles

The assessment endpoint for the aquatic/riparian feeding amphibians and reptiles receptor community is protection of the abundance and diversity of aquatic/riparian feeding amphibians and reptiles in the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2, Table 6-4).

6.5.4.1 Lines of Evidence - Amphibians and Reptiles

The LOE from the BERA pertinent to the evaluation of potential impacts of site-related COPECs on amphibians and reptiles downstream of the KIF Plant in the Emory, Clinch and Tennessee rivers are summarized below.

- **Community survey results**. The BERA provides a review of a turtle community survey that was conducted in 2009 and 2010. Turtle observations were collected throughout Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach A. Reference locations were also sampled in the Tennessee River reference reach and at a reference site independent of the River System (i.e., Timberlake Pond in Knox County). In this study, characteristics such as turtle species diversity, relative abundance, and gross pathologies were

assessed for multiple observed turtle species. It was observed that species richness and relative abundance of turtles was not impaired at locations in the Emory, Clinch and Tennessee rivers downstream of the 2008 CCR release compared to reference locations. In addition, there were no apparent differences in the qualitative observation of anomalies and diseases between reference and potentially impacted locations. Results of the turtle community surveys are summarized in Appendix AB (Trace Element Concentrations in Turtles: 2009-2010) of the BERA (Arcadis 2012).

- **Tissue concentrations**. The BERA provides a review of COPEC concentrations measured in amphibians (frogs and toads) and reptiles (turtles) in the vicinity of the KIF Plant. The frog and toad tissue samples were collected at reference locations as well as wetland habitats in the West and North Embayments that were covered with CCR material following the 2008 CCR material release. These embayments are upstream of the KIF Plant and therefore unlikely to be affected by the TDEC Order CCR units at the KIF Plant. As such, collected amphibian tissue data were not considered applicable to this ERA. However, it is noted that the evaluation of COPEC concentrations in amphibian whole body tissue concentrations for these locations were interpreted in the BERA as being indicative of negligible risk to amphibians. Turtle tissue samples were collected in Emory River Reaches A, B, and C; Clinch River Reaches A and B, and Tennessee River Reach A. Reference locations were also sampled at the Tennessee River reference reach and at a reference site independent of the River System (i.e., Timberlake Pond in Knox County). Overall, the review of COPEC concentrations in turtle tissues in the BERA indicated that turtles may have accumulated increased concentrations of COPECs (i.e., selenium and strontium) in comparison to reference locations. Despite this increase, the ecological effects of the observed tissue concentrations are not well documented. The relevance of tissue concentrations of trace element COPECs to the health of turtle populations is not well documented. Community survey observations are a stronger line of evidence that species richness and relative abundance of turtle communities in the Emory, Clinch, and Tennessee rivers downstream of the 2008 CCR release are not different from unimpacted reference locations.

- **COPEC concentrations measured in surface stream water and sediment.** As described in Section 6.5.2.1**,** surface stream water and sediment samples were collected from reference locations in the Emory, Clinch and Tennessee rivers (Emory River Reference, Clinch River Reference, and Tennessee River Reference), as well as from locations potentially affected by the 2008 CCR material release (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B). COPEC concentrations in these environmental media were compared to regulatory benchmarks that were developed to protect aquatic resources and to amphibian-specific screening values (where available). Reptile-specific screening standards were not available for comparison. Spatial comparisons between reaches were also made. Overall, based on this LOE, it was concluded that surface stream water and sediment chemistry results indicate limited potential for risks in surface stream water and sediment for amphibians and reptiles; therefore, no unacceptable risks to amphibians and reptiles are expected.

6.5.4.2 Weight of Evidence - Amphibians and Reptiles

In the LOE described above, there was some indication of the accumulation of increased concentrations of COPECs in turtle tissues sampled from potentially impacted locations compared to reference locations; however, no effects were observed on turtle species richness, relative abundance, or appearance of anomalies or disease between reference and potentially impacted locations that are relevant to this ERA. Given that the ecological effects of the observed variability of tissue concentrations are not well documented, the direct measures of ecological effects (i.e. species richness, species abundance, and the presence of observable anomalies and diseases) were assigned more weight in the BERA. As no significant differences in these direct measures of ecological effects were observed between reference and potentially impacted locations, the WOE derived in the BERA based on the LOE presented above was that there are no unacceptable risks to aquatic/riparian feeding amphibians and reptiles in the Emory, Clinch and Tennessee rivers. In addition, the review of surface water and sediment concentrations in the BERA (based on comparison to screening levels and spatial comparison) was not indicative of unacceptable risks to amphibians and reptiles. As such, it can be concluded based on the overall WOE that there are no unacceptable risks to amphibians and reptiles in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.5.5 Aquatic/Riparian Feeding Birds

The assessment endpoint for the aquatic/riparian feeding birds is protection of populations of herbivorous, omnivorous, insectivorous and piscivorous birds using the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2 and Table 6-4).

6.5.5.1 Lines of Evidence – Aquatic/Riparian Feeding Birds

The LOE from the BERA and LTM pertinent to the evaluation of potential impacts of site-related COPECs on aquatic/riparian feeding birds in the Emory, Clinch and Tennessee rivers are summarized below:

- **Dietary exposure modelling.** In the BERA, potential effects to aquatic/riparian feeding birds were evaluated through quantitative dietary exposure modelling for the following surrogate receptors in this receptor group:
    - Wood duck – surrogate for herbivorous birds
    - Mallard duck – surrogate for omnivorous birds
    - Killdeer – surrogate for insectivorous birds
    - Great blue heron – surrogate for piscivorous birds
    - Osprey – surrogate for piscivorous birds.

  For each receptor, dietary exposure modelling was completed for each potentially impacted reach of the Emory, Clinch, and Tennessee rivers (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B), as well as the reference reaches for each

river. This permitted a comparison of HQs between potentially impacted reaches and their applicable reference reaches. On the basis of these evaluations, Arcadis (2012) concluded that this LOE was indicative of negligible risk to piscivorous birds (heron and osprey) and herbivorous birds (wood duck), and low risk to insectivorous birds (killdeer) and omnivorous birds (mallard). Based on this LOE alone, it was concluded in the BERA that the COPECs associated with low risk were aluminum, arsenic and selenium for insectivorous birds and selenium only for omnivorous birds. These low risks were related to consumption of benthic invertebrates.

- **Site-specific biological monitoring data.** The BERA also summarized the findings of additional site-specific biological monitoring data pertinent to aquatic/riparian feeding birds (i.e., egg health metrics and COPEC concentrations in eggs for heron and osprey) (Meyer et al. 2014).

  There were no statistically significant differences between potentially impacted and reference locations for egg health metrics (clutch size and egg biometrics) for heron, which provided evidence of negligible effects on heron populations. For osprey, some significant differences in egg health metrics were noted between locations, but they were not considered to provide "substantive evidence of impacts on osprey populations" (Arcadis 2012).

  The comparisons of COPEC concentrations in heron and osprey eggs between reference and potentially impacted locations identified some significant ($p \leq 0.05$) or almost significant ($0.05 \leq p \leq 0.1$) increases in selenium, copper, and mercury concentrations for heron eggs from potentially impacted locations compared to reference locations. However, these concentration differences were determined to be small and not biologically meaningful, which was supported by the absence of observed differences in clutch size and egg biometrics, as noted above. For osprey eggs, none of the evaluated COPECs had concentrations that were higher for potentially impacted locations compared to reference locations.

- **Additional data collected during LTM.** Although none of the LOE from the BERA indicated the presence of unacceptable risks to aquatic/riparian feeding birds, risk management was recommended in the BERA for killdeer in the Emory River Reaches A and B, and Clinch River Reaches A and B due to their consumption of benthic invertebrates, which were determined to be at low to moderate risk due to exposure to arsenic and selenium in these river reaches as described above. As described above in Section 6.5.1, additional mayfly tissue samples were collected in 2015 and 2017 from reference and potentially impacted locations in the Clinch River and Emory River as part of LTM (Arcadis 2020). These more recent samples were below the LTM remedial tissue monitoring endpoints that were previously established for the site for selenium and arsenic and were generally indicative of decreasing or stable trends in arsenic and selenium concentrations in mayfly tissue over time. Therefore, the additional data from LTM are supportive of a conclusion that risks to killdeer have also decreased or remained stable since the completion of the BERA. This also applies to the low risks predicted in the dietary exposure modelling for omnivorous birds (mallard) due to exposure to selenium in benthic invertebrates. The killdeer was considered in the BERA to be more sensitive to exposure to selenium in benthic invertebrates than the mallard due to additional vegetation in the mallard diet.

6.5.5.2 Weight of Evidence – Aquatic/Riparian Feeding Birds

Of the LOE summarized above, the dietary exposure modelling indicated negligible risks for the evaluated COPECs for piscivores and herbivores and low risks for insectivores and omnivores while the site-specific biological monitoring data indicated no substantive evidence of impacts on the monitored bird species. However, risk management was recommended in the BERA for killdeer in the Emory River Reaches A and B, and Clinch River Reaches A and B due to their consumption of benthic invertebrates, which were determined to be at low to moderate risk in these river reaches as described above. Additional monitoring of tissue concentrations of dietary items for killdeer and mallard (i.e., benthic invertebrates) as part of the LTM program supported the conclusion that the low risks identified for these receptors via dietary exposure modelling are stable or decreasing over time. As such, it can be concluded based on the overall WOE that there are no unacceptable risks to aquatic/riparian feeding birds in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.5.6 Aquatic/Riparian Feeding Mammals

The assessment endpoint for the aquatic/riparian feeding mammals is protection of populations of herbivorous, omnivorous, and piscivorous mammals in the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2 and Table 6-4).

6.5.6.1 Lines of Evidence – Aquatic/Riparian Feeding Mammals

The LOE from the BERA pertinent to the evaluation of potential impacts of site-related COPECs on aquatic/riparian feeding mammals downstream of the KIF Plant in the Emory, Clinch and Tennessee rivers are summarized below:

- **Dietary exposure modelling.** In the BERA, potential effects to aquatic/riparian feeding mammals were evaluated through quantitative dietary exposure modelling for the following surrogate receptors in this receptor group:
    - Muskrat – surrogate for herbivorous mammals
    - Raccoon – surrogate for omnivorous mammals
    - Mink – surrogate for piscivorous mammals.

  For each receptor, dietary exposure modelling was completed for each potentially impacted reach of the Emory, Clinch, and Tennessee rivers (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B), as well as the reference reaches for each river. This permitted a comparison of HQs between potentially impacted reaches and their applicable reference reaches.

  On the basis of these evaluations, Arcadis (2012) concluded that this LOE indicated that risks were negligible to all evaluated receptors for the evaluated COPECs. The BERA also identified potential low risks to omnivores (raccoon), piscivores (mink), and herbivores (muskrat) due to exposure to aluminum (all three receptors) and iron (piscivores only); however, exposure to these

parameters was not determined to be site-related and neither aluminum nor iron were identified as COPECs in this ERA. Therefore, risks associated with exposure to aluminum or iron are not discussed further herein.

- **Site-specific biological monitoring data.** The BERA also summarized the findings of additional site-specific biological monitoring data pertinent to aquatic/riparian feeding mammals (i.e., raccoon tissue data, and raccoon health metrics). Tissues collected included raccoon hair, brain, gonad, kidney, liver, muscle, and blood. The raccoon health metrics that were evaluated included blood count, plasma biochemistry, and histopathology of liver, kidney, lungs, brain, gonad, and adrenal glands (Meyer et al. 2014).

  With respect to raccoon tissue concentrations of COPECs, concentrations were higher at potentially impacted locations compared to reference locations for arsenic, chromium, and selenium in hair; mercury and iron in muscle; and zinc and barium in the brain. However, it was concluded that these concentrations are unlikely to lead to toxic effects in the raccoon population at the site based on comparison to 'thresholds of concern' representing benchmarks for background levels or adverse effect levels for omnivorous mammals (10% effect concentration [EC10] or LOAEL), where available. For example, reported arsenic and chromium concentrations in raccoon hair were comparable to or less than reported background concentrations of arsenic and chromium in human hair and reported selenium concentrations in raccoon hair measured in support of the BERA were less than concentrations of selenium in raccoon hair from a previously measured selenium-contaminated site. This conclusion is also supported by raccoon health metrics collected in the potentially impacted areas that were observed to be within a normal range. Additionally, it was noted that "no clinically significant differences were observed in prevalence of lesions, blood counts, or plasma biochemistry" for raccoons that were present in the potentially impacted areas (Arcadis 2012).

6.5.6.2 Weight of Evidence – Aquatic/Riparian Feeding Mammals

Of the LOE summarized above, the dietary exposure modelling indicated negligible risks for the evaluated site-related COPECs for omnivores, piscivores, and herbivores while the site-specific biological monitoring data indicated no substantive evidence of impacts on the monitored omnivorous mammal species (i.e., raccoon). As such, it can be concluded based on the overall WOE that there are no unacceptable risks to aquatic/riparian feeding mammals in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.5.7 Aerial Feeding Birds and Mammals

The assessment endpoint for the aerial feeding birds and mammals receptor group is protection of populations of aerial-feeding insectivorous birds and mammals using the Emory, Clinch and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs (Section 6.1.2 and Table 6-4).

6.5.7.1 Lines of Evidence – Aerial Feeding Birds and Mammals

The LOE from the BERA and LTM pertinent to the evaluation of potential impacts of site-related COPECs on aerial-feeding birds and mammals in the Emory, Clinch and Tennessee rivers are summarized below:

- **Dietary exposure modelling.** In the BERA, potential effects to aerial feeding birds and mammals were evaluated through quantitative dietary exposure modelling for the following species, representative of trophic levels applicable to the site:
    - Tree swallow – surrogate for aerial-feeding insectivorous birds
    - Gray bat – surrogate for aerial-feeding insectivorous mammals, including the southeastern bat, tri-colored bat, and northern long-eared bat.

  For each receptor, dietary exposure modelling was completed for each potentially impacted reach of the Emory, Clinch, and Tennessee rivers (i.e., Emory River Reaches A, B, and C; Clinch River Reaches A and B; and Tennessee River Reach B), as well as the reference reaches for each river. This permitted a comparison of HQs between potentially impacted reaches and their applicable reference reaches. On the basis of these evaluations, Arcadis (2012) concluded that this LOE indicated the presence of low risks to tree swallows and negligible-to-low risks to gray bats associated with exposure to selenium (tree swallow and gray bat) and copper (tree swallow only). However, given that the HQs for copper for tree swallows were not significantly different from reference HQs, the numeric risks predicted from copper for the tree swallow were not considered to require further evaluation in the BERA.

- **Tree swallow reproductive data and tissue concentrations.** In 2009 and 2010 (prior to completion of dredging), tree swallow boxes were monitored in potentially impacted and reference locations in the vicinities of the Emory River, Clinch River, and Tennessee River and at three embayments surrounding the KIF Plant (East Embayment, West Embayment and North Embayment). Eggs and fledglings were collected from accessible nests and analyzed for COPEC concentrations in egg contents, eggshells, and whole-body nestling tissue. Tree swallow nests were also monitored for reproductive success biometrics (i.e., clutch size, hatching success, fledgling survival, and number of female fledglings per nesting female) (Meyer et al. 2014). The BERA review of the collected data consisted of the following evaluations:
    - Statistical comparison between potentially impacted and reference locations for COPEC concentrations in tree swallow egg, eggshell, and whole-body nestling tissue
    - Statistical comparison between potentially impacted and reference locations for egg and nestling health metrics and reproductive measures
    - Evaluation of statistical correlation between estimated COPEC daily dose calculated during dietary exposure modelling and reproductive measures
    - Comparison of measured tree swallow tissue COPEC concentrations to literature-derived CBR values.

In the BERA, these data were interpreted to be indicative of low risk to tree swallows based on exposure to selenium, strontium, and manganese. Of these three parameters, Arcadis (2012) considered the evidence associated with risk due to exposure to selenium to be the strongest. This evidence included (a) the observation that selenium concentrations in a small fraction (1.7%) of tree swallow eggs in the impacted reaches were greater than the identified adverse effect level for selenium in eggs and (b) a negative correlation between calculated selenium dose in the dietary exposure modeling and tree swallow reproductive success. The evidence suggesting potential adverse effects to tree swallows due to exposure to strontium and manganese was considered weak given that applicable CBR values were not available for these parameters for the evaluated tissues. Therefore, these parameters were not identified as sources of potential risk based on the dietary exposure modelling summarized above. In addition, neither strontium nor manganese were identified as COPECs in this ERA. Therefore, risks associated with exposure to strontium and manganese are not discussed further herein.

- **Additional sediment and benthic macroinvertebrate COPEC concentrations collected during LTM.** Although none of the LOE from the BERA indicated the presence of unacceptable risks to aerial feeding birds or mammals, risk management was recommended in the BERA for tree swallows in Emory River Reaches A and B and Clinch River Reaches A and B due to their consumption of benthic invertebrates, which were determined to be at low to moderate risk due to exposure to arsenic and selenium in these river reaches as described above. As described above in Section 6.5.1, additional mayfly tissue samples were collected in 2015 and 2017 from reference and potentially impacted locations in the Clinch River and Emory River as part of LTM (Arcadis 2020). These more recent samples were below the LTM remedial tissue monitoring endpoints that were previously established for the site for selenium and arsenic and were generally indicative of decreasing or stable trends in arsenic and selenium concentrations in mayfly tissue over time. Therefore, the additional data from LTM are supportive of a conclusion that risks to tree swallows have also decreased or remained stable since the completion of the BERA. These evaluations also support a finding of decreasing or stable risks to the gray bat, which were also assumed to consume benthic invertebrates in the dietary exposure modelling.

- **Additional tree swallow reproductive and tissue monitoring conducted during LTM.** Based on the risk management recommendations identified for tree swallows in the BERA in Emory River Reaches A and B and Clinch River Reaches A and B, the LTM program has also included additional tree swallow reproductive and tissue monitoring. The LTM results for these monitoring programs as reported to date are summarized below. Additional information about these results is also available in supporting reports and published literature (see Arcadis 2016; Walls et al. 2014).

    - In 2015, there were no significant differences observed in tree swallow clutch size, hatching success, fledgling success, fecundity or morphological measures in Emory River Reach B compared to the reference location. For Emory River Reach A, a statistically lower hatching success was observed in comparison to the reference location, but there were no statistically significant differences in fledgling success or fecundity over time. Arcadis (2016) concluded that impacts to the overall reproductive success of tree swallows at Emory River Reach A are unlikely to occur as a result of

the 2008 CCR material release. The USEPA agreed that tree swallow reproduction and bioaccumulation studies were not needed for the next five-year monitoring event.

- Selenium concentrations measured in tree swallow egg tissue collected in 2015 indicated that selenium concentrations for eggs collected in Emory River Reaches A and B were comparable to their applicable reference locations. In addition, concentrations were lower than literature derived threshold effects (EC10) concentrations for selenium in various species of avian eggs.

- Correlation analyses between reproductive metrics and selenium egg tissue concentrations were conducted using available data collected from 2011 through 2015. These evaluations identified a weak statistically significant negative relationship between selenium concentrations and fledgling success at Emory River Reach A; however, no relationship was identified between selenium concentrations and overall fecundity. Consequently, the correlation between selenium and fledgling success was not strong enough to adversely impact the overall reproduction of the tree swallow population near the ash release (Arcadis 2016).

- The above results suggest that risks to tree swallow populations in the vicinity of the KIF Plant (1) were only slightly elevated following the 2008 CCR material release, (2) were attributable to the 2008 CCR material release rather than potential contaminant releases from the TDEC Order CCR units, and (3) are decreasing over time.

6.5.7.2 Weight of Evidence – Aerial Feeding Birds and Mammals

Overall, the BERA concluded that risks to aerial-feeding birds and mammals were low to negligible in the Emory, Clinch, and Tennessee rivers for the evaluated COPECs. However, risk management was recommended in the BERA for tree swallows in the Emory River Reaches A and B, and Clinch River Reaches A and B due to their consumption of benthic invertebrates, which were determined to be at low to moderate risk in these river reaches as described above. Additional monitoring of tissue concentrations of dietary items for tree swallow and the gray bat (i.e., benthic invertebrates) and tree swallow reproductive and tissue monitoring as part of the LTM program has supported the conclusion that the low risks identified for these receptors via dietary exposure modelling are stable or decreasing over time. Therefore, it can be concluded based on the more recent available data that there are no current and ongoing unacceptable risks to aerial feeding birds and mammals in the Emory, Clinch and Tennessee rivers from exposure to site-related COPECs.

6.6 INTERPRETATION OF RISK

This ERA included multiple LOEs in a WOE evaluation (Section 6.5) of potential ecological risks to community receptors and avian and mammalian receptor populations from exposure to CCR Parameters measured in environmental media samples collected from the Emory, Clinch and Tennessee rivers. Based on the WOE presented in Section 6.5 and summarized above, the overall interpretation is that there are no unacceptable risks to abundance and diversity in community receptors and populations of avian and mammalian receptors inhabiting or using the Emory, Clinch and Tennessee rivers associated

with the TDEC Order CCR units at the KIF Plant. Given that the LOEs evaluated include direct measurements of biological effects in locations that are downstream from the TDEC Order CCR units at the KIF Plant, the conclusions of this risk assessment apply to all of the COPECs identified in Section 6.1.1.2, including lithium, even though lithium exposure was not directly evaluated in the BERA.

6.7 UNCERTAINTY ANALYSIS

Uncertainties are inherent in the risk assessment process and arise from limitations in the available information, analysis methods, and assumptions used in the assessment. Sources of uncertainty may include chemical characterization information and limitations in the available data, assessment of potential exposures, and modeling of uptake and toxicity. To assist interpretation of the risk assessment results presented in this ERA, the primary sources of uncertainty in each step of the ERA are described in the following subsections.

6.7.1 Problem Formulation Uncertainties

Uncertainties associated with the problem formulation include identification of COPECs and selection of ecological receptors, as described below:

- Selection of ecological receptors (and surrogate species) for risk evaluation may be a source of uncertainty. Ecological receptors were chosen by focusing on organisms indigenous to the area and representative of different feeding guilds, as well as species of conservation concern. Ecological receptors evaluated in this ERA are the same as those identified in the BERA. A review of these receptors and comparison to habitat characteristics in the vicinity of the KIF Plant indicates that these receptors are representative of organisms indigenous to the area (including species of conservation concern) and include feeding guilds that have potential to be exposed to COPECs present in surface stream water or sediment. Using these criteria, the ecological receptors assessed in the ERA should provide an adequate representation of the diversity of the fauna and aquatic and riparian vegetation at and near the KIF Plant. Consequentially, uncertainty related to the selection of ecological receptors at the KIF Plant is likely to be low.

6.7.2 Exposure Assessment Uncertainties

This ERA did not include new quantitative estimates of exposure. Rather, evaluation of exposure was completed qualitatively based on the quantitative exposure estimates presented in the BERA (and in some cases, the LTM reports). These exposure estimates are applicable to this ERA given that the locations sampled in the KRP and evaluated in the BERA include a subset of exposure locations that are adjacent to and downstream from the TDEC Order CCR units under evaluation in the ERA. One area of uncertainty is the absence of direct measures of exposure for lithium in the BERA. However, the direct measures of effects included in this ERA (e.g., sediment toxicity tests, aquatic toxicity testing, reproductive and health metrics on fish populations, biomonitoring of osprey and heron for egg health metrics, reproductive monitoring in tree swallows, and community survey metrics for benthic invertebrates, fish, and turtles) were sufficiently robust to determine that adverse effects resulting from exposures to lithium (if present) in the Emory, Clinch and Tennessee rivers are not expected.

Another source of uncertainty is that the majority of exposure information relied on in the BERA is based on samples collected in 2009 or 2010, shortly after the 2008 CCR material release at the KIF Plant. Additional LTM completed after that time has generally indicated that COPEC concentrations have been stable or decreasing over time due to ongoing natural attenuation that has occurred post-dredging. Therefore, these measures of exposure likely overestimate exposure.

Additional details regarding uncertainties associated with the exposure assessment are provided in the BERA report (Arcadis 2012).

6.7.3 Effects Assessment Uncertainties

This ERA did not identify new quantitative measures of effect. Rather, evaluation of effect was completed qualitatively based on the quantitative measures of effect presented in the BERA (and in some cases LTM reports). These measures of effect are applicable to this ERA given that the locations sampled in the KRP and evaluated in the BERA include a subset of locations that are adjacent to and downstream from the TDEC Order CCR units under evaluation in the ERA.

One source of uncertainty associated with the measured biological indicators of effect relied on in this ERA is that the majority of exposure information relied on in the BERA is based on data collected in 2009 or 2010, shortly after the 2008 CCR material release at the KIF Plant. Additional LTM completed after that time has generally indicated that COPEC concentrations have been stable or decreasing over time due to ongoing natural attenuation that has occurred post-dredging. Therefore, the measures of effect based upon the data reported from assessments conducted in 2009-2010 likely overestimate current and future impacts to ecological receptors in the Emory, Clinch and Tennessee rivers.

Additional details regarding uncertainties associated with the effects assessment are provided in the BERA report (Arcadis 2012).

6.7.4 Risk Characterization Uncertainties

The different sources of uncertainty described above were incorporated into the ERA. Because the majority of these uncertainties err on the conservative side (i.e., environmentally protective), the estimated risks presented in this ERA most likely represent upper bound estimates of risk. As a result, when estimated risks indicate there are no unacceptable risks, the probability of there actually being unacceptable risk is low.

7.0 SUMMARY

The findings of the HHRA and ERA for the KIF Plant are summarized in Sections 7.1 and Section 7.2 below, respectively. Confidence in the findings of the HHERA is supported by the use of multiple LOEs in a WOE approach and by incorporation of protective assumptions for and approaches to important uncertainties in the assessments.

7.1 HUMAN HEALTH RISK ASSESSMENT

The HHRA process was used to evaluate potential carcinogenic risks and noncarcinogenic hazards to onsite human receptors potentially exposed to CCR material, and to offsite human receptors potentially exposed to CCR Parameters in groundwater, surface stream water, sediment, and fish tissue. The findings of the water use survey in the KIF Plant EAR determined that offsite residential potable use of groundwater wells and springs is not a complete pathway of exposure for this HHRA. Potable use of groundwater at the KIF Plant is not a complete pathway of exposure under current and reasonably anticipated future land use. If land use changes in the future, the HHRA would be re-evaluated.

The human receptors identified in the HHRA (and the primary exposure media for each) are as follows:

- Onsite worker (exposed to CCR material)
- Recreational user – swimmer (exposed to surface stream water)
- Recreational user – beachcomber (exposed to seasonally exposed sediment)
- Recreational user – consumer of locally-caught sport fish (exposed to fish tissue)
- Offsite resident (use of surface stream water for domestic water supply).

Based on quantitative and qualitative LOE, the overall WOE interpretation of the HHRA is that there are no unacceptable risks to onsite or offsite human receptors from exposure to CCR Parameters associated with the TDEC Order CCR units at the KIF Plant.

- Cumulative ILCR and noncancer hazard estimates were below TDEC's acceptable cancer risk criterion and hazard threshold of 1 x 10^{-5} and 1, respectively, for an onsite worker exposed to COPCs in CCR material within the TDEC Order CCR units at the KIF Plant.
- Qualitative interpretation of findings from the BHHRA (Jacobs 2012) support the conclusion that there are no unacceptable risks to offsite human receptors that use the Emory River Reach B adjacent to the KIF Plant as a domestic water source or for recreational activities and that are potentially exposed to CCR Parameters that could be associated with the TDEC Order CCR units at the KIF Plant.

7.2 ECOLOGICAL RISK ASSESSMENT

The ERA process was used to evaluate potential hazards to aquatic ecological community receptors and to populations of avian and mammalian receptors from exposure to CCR Parameters measured in environmental media samples collected from the Emory, Clinch, and Tennessee rivers.

The general assessment endpoint for this ERA is protection of the abundance and diversity of community receptors and populations of avian and mammalian receptors in the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs. Specific assessment endpoints were identified and evaluated for these ecological community receptors (i.e., benthic invertebrate, aquatic vegetation, fish, and aquatic/riparian feeding amphibian and reptile communities); and populations of aquatic/riparian feeding birds, aquatic/riparian feeding mammals, and aerial-feeding birds and mammals.

Based on the LOE and summary above, the overall WOE interpretation is that there are no unacceptable risks to abundance and diversity in community receptors or populations of avian and mammalian receptors inhabiting or using the Emory, Clinch, and Tennessee rivers related to the TDEC Order CCR units at the KIF Plant.

7.3 NEXT STEPS

In accordance with the TDEC Order, TVA is submitting the HHERA with the CARA Plan. TVA has further evaluated the risk assessment findings in the CARA Plan to assess whether corrective measures are needed. If needed, the CARA Plan specifies the actions TVA plans to take at the TDEC Order CCR units, the basis of those actions, and incorporates any other operational changes planned or in progress by TVA.

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TABLES

TABLE 4-1 – CCR Material Data Summary and Comparisons to Human Health Screening Levels
Kingston Fossil Plant

	Data Summary [a]								Screening	
CCR Parameters	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects	Maximum Reporting Limit for Non-Detects	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Screening Level [b]	Maximum Detected Concentration > Screening Level
			%	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	mg/kg or pCi/g	
Antimony	53	53	100	n/a	n/a	0.225	2.01	0.713	13	No
Arsenic	53	53	100	n/a	n/a	15.9	119	46.5	5.9	**Yes**
Barium	53	53	100	n/a	n/a	79.7	1,520	317	2,200	No
Beryllium	53	53	100	n/a	n/a	0.321	5.49	1.87	12	No
Boron	53	53	100	n/a	n/a	3.92	211	40.2	4,500	No
Cadmium	53	53	100	n/a	n/a	0.0520	0.879	0.261	5.4	No
Calcium	53	53	100	n/a	n/a	770	51,100	8,170	-	n/a
Chloride	53	26	49.1	3.79	10.2	4.36	104	11.9	-	n/a
Chromium	53	53	100	n/a	n/a	8.73	41.0	21.8	3,100	No
Cobalt	53	53	100	n/a	n/a	3.15	35.6	9.45	12	**Yes**
Copper	53	53	100	n/a	n/a	12.3	79.3	30.6	1,400	No
Fluoride	53	27	50.9	0.756	1.37	1.07	6.13	2.35	1,200	No
Lead	53	53	100	n/a	n/a	2.82	27.4	12.0	130	No
Lithium	53	53	100	n/a	n/a	5.75	38.8	18.3	68	No
Mercury	53	51	96.2	0.0148	0.0305	0.0307	1.22	0.139	50	No
Molybdenum	53	53	100	n/a	n/a	0.990	16.0	4.00	800	No
Nickel	53	53	100	n/a	n/a	10.2	40.0	21.1	110	No
Radium-226	53	53	100	n/a	n/a	1.57	5.00	3.61	6.5	No
Radium-228	53	52	98.1	1.33	1.33	1.37	3.97	2.59	6.5	No
Selenium	53	53	100	n/a	n/a	1.00	13.5	3.34	170	No
Silver	53	37	69.8	0.0324	0.333	0.0202	0.355	0.0741	170	No
Sulfate	53	53	100	n/a	n/a	31.9	16,400	863	-	n/a
Thallium	53	53	100	n/a	n/a	0.353	7.31	1.15	1.4	**Yes**
Vanadium	53	53	100	n/a	n/a	11.1	121	45.8	55	**Yes**
Zinc	53	53	100	n/a	n/a	5.43	61.5	26.3	10,000	No

Notes:

Bold	maximum detected concentration > screening level for detected CCR Parameter
-	not available
%	percent
>	greater than
CCR	coal combustion residuals
mg/kg	milligrams per kilogram
n/a	not applicable
pCi/g	picocuries per gram (radium-226 and radium-228 only)
SSL_{HH}	receptor-specific screening levels for human health

[a] Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a CCR Parameter is less than 100%.

[b] Screening levels are equal to the soil SSL_{HH} for an onsite worker based on a target carcinogenic risk and hazard quotient of $1x10^{-6}$ and 0.1, respectively (Appendix B.1).

TABLE 5-1 – COPCs Identified for the HHRA
Kingston Fossil Plant

CCR Parameter [a]	CCR Material: Onsite Worker
Antimony	
Arsenic	✓
Barium	
Beryllium	
Boron	
Cadmium	
Calcium	--
Chloride	--
Chromium	
Cobalt	✓
Copper	
Fluoride	
Lead	
Lithium	
Mercury	
Molybdenum	
Nickel	
Radium-226	
Radium-228	
Selenium	
Silver	
Sulfate	--
Thallium	✓
Vanadium	✓
Zinc	

Notes:

Groundwater exposure pathways associated with onsite and offsite use of groundwater and springs as a drinking water source were not considered complete, and therefore, there are no COPCs for groundwater.

	not detected or was detected below respective screening levels
--	detected but not selected as a COPC because it is naturally occurring and has a low risk potential (refer to Section 5.1.1.3)
✓	denotes a COPC
CCR	coal combustion residuals
COPC	constituent of potential concern
HHRA	human health risk assessment

[a] A CCR Parameter detected above its respective screening level is identified as a COPC unless otherwise noted.

TABLE 5-2 - Exposure Assumptions Used in the Human Health Risk Assessment
Kingston Fossil Plant

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
CCR Material	Onsite Worker	Adult	Ingestion	IR_{CCR}	Ingestion Rate of CCR Material	mg/day	330	n/a	n/a	Soil ingestion rate for a construction worker (USEPA 2002)
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				CF	Conversion Factor	kg/mg	1E-06	n/a	n/a	n/a
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	n/a	n/a	Default (USEPA 2012)
				BW_w	Body Weight	kg	80	n/a	n/a	Adult worker body weight (USEPA 2014)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	n/a	n/a	n/a
				AF_w	Adherence factor of CCR Material to skin	mg/cm^2-event	0.3	n/a	n/a	Default adherence factors for a construction worker (USEPA 2002)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	n/a	n/a	USEPA 2004
				SA_w	Skin surface area available for contact	cm^2	3,527	n/a	n/a	Worker skin surface area (USEPA 2014).
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				BW_w	Body Weight	kg	80	n/a	n/a	Adult worker body weight (USEPA 2014)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)
			Inhalation	CF	Conversion Factor	mg/µg	1E-03	n/a	n/a	n/a
				ET_w	Exposure Time	hours/day	8	n/a	n/a	Worker air exposure time (USEPA 2014)
				PEF	Particulate Emission Factor	m^3/kg	1.36E+09	n/a	n/a	Default outdoor worker PEF (USEPA 2002)
				EF_w	Exposure Frequency	days/year	20	n/a	n/a	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	years	1	n/a	n/a	Exposure duration for a construction worker (USEPA 2002)
				AT_{NCw}	Averaging Time (noncancer)	days	28	n/a	n/a	7 days/week for 4 weeks
				AT_C	Averaging Time (cancer)	days	25,550	n/a	n/a	Lifetime (70 years) x 365 days/year (USEPA 1989a)

Notes:

cm^2	square centimeters
kg	kilograms
kg/mg	kilograms per milligram
m^3/kg	cubic meters per kilogram
mg/cm^2	milligrams per square centimeters
mg/cm^2-event	milligrams per square centimeters per event
mg/day	milligrams per day
mg/µg	milligrams per microgram
n/a	not applicable

TABLE 5-3 - Toxicity Values Used in the Human Health Risk Assessment
Kingston Fossil Plant

COPC	Cancer Slope Factor				IUR		Chronic RfD				Subchronic RfD [a]				Subchronic Inhalation		ABS_{GI} [c]	Target Organ/System Effect [d]
	Oral		Dermal [b]				Oral		Dermal [b]		Oral		Dermal [b]		RfC [a]			
	$(mg/kg\text{-}day)^{-1}$		$(mg/kg\text{-}day)^{-1}$		$(\mu g/m^3)^{-1}$		mg/kg-day		mg/kg-day		mg/kg-day		mg/kg-day		mg/m^3		%	
Arsenic	1.5E+00	I	1.5E+00	R	4.3E-03	I	3.0E-04	I	3.0E-04	R	3.0E-04	cr	3.0E-04	R	1.5E-05	cr	100%	Skin, Blood, Developmental, Neurological, Respiratory
Cobalt	-	-	-	-	9.0E-03	P	3.0E-04	P	3.0E-04	R	3.0E-03	P	3.0E-03	R	2.0E-05	P	100%	Thyroid, Respiratory
Thallium	-	-	-	-	-	-	1.0E-05	X	1.0E-05	R	4.0E-05	X	4.0E-05	R	-	-	100%	Skin
Vanadium	-	-	-	-	-	-	5.0E-03	G	1.3E-04	R	1.0E-02	A	2.6E-04	R	1.0E-04	A	2.6%	Chronic: Skin, Respiratory; Subchronic: Blood, Respiratory

Notes:

-	not available	mg/m^3	milligrams per cubic meter
%	percent	$\mu g/m^3$	micrograms per cubic meter
ABS_{GI}	oral absorption efficiency	n/a	not applicable
COPC	constituent of potential concern	PRG	preliminary remediation goal
CSF	cancer slope factor	RfD	reference dose
USEPA	United States Environmental Protection Agency	RfC	reference concentration
IUR	inhalation unit risk	RSL	Regional Screening Levels
mg/kg-day	milligrams per kilogram per day		

Sources Key: A = Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels; C = California Environmental Protection Agency (CalEPA) Toxicity Values; cr = chronic value; G = RSL User's Guide; I = Integrated Risk Information System (IRIS) Database; P = Provisional Peer Reviewed Toxicity Values (PPRTVs); R = route extrapolation; X = Screening values in chemical-specific PPRTV Appendices. All sources and toxicity values as cited in the USEPA RSL Tables (USEPA 2024).

[a] Subchronic RfDs and RfCs obtained from USEPA's RSL Tables (USEPA 2024) were used unless otherwise noted in text.

[b] The following equations are used as recommended by the USEPA (2004) to estimate dermal CSFs and RfDs from the ingestion toxicity values when ABS_{GI} is less than 50 percent:

Dermal RfD = Oral RfD x ABS_{GI} and Dermal CSF = Oral CSF/ABS_{GI}.

When ABS_{GI} is greater than 50 percent, the dermal CSF and/or RfD is assumed to be equal to the oral CSF and/or RfD (USEPA 2004).

[c] Values are from USEPA Risk Assessment Guidance for Superfund (RAGS) Part E. Where no specific ABS_{GI} is available, the ABS_{GI} is assumed to be 100 percent (USEPA 2004).

[d] Target organs are for noncancer effects and based on data from the online Risk Assessment Information System (RAIS) chemical toxicity metadata accessed in June 2024 (RAIS 2024b). Where the source of an inhalation RfC or oral RfD is CalEPA, target organs are also based on information from the California Office of Environmental Health Hazard Assessment (OEHHA) chemical database metadata accessed in June 2024 (OEHHA 2024).

TABLE 5-4 - Summary of Human Health Risk Estimates for Chemical COPCs
Kingston Fossil Plant

Receptor/Media/Exposure Unit [a]	Cumulative ILCR	Risk Driver [b]	HI	Hazard Driver [b]
Onsite Worker				
CCR Material				
Interim Ash Staging Area	2E-07	n/a	0.5	n/a
Sluice Trench and Area East of Sluice Trench	2E-07	n/a	0.5	n/a
Stilling Pond	3E-07	n/a	0.7	n/a
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:	1E-05		1	

Notes:

CCR	coal combustion residuals
COPC	constituent of potential concern
HI	hazard index
ILCR	incremental lifetime cancer risk
n/a	not applicable

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk or noncancer threshold.

[a] Only those media where COPCs were selected and the applicable receptors for those media are presented herein.

[b] "Risk drivers" are those COPCs with an ILCR that is greater than the State of Tennessee acceptable cancer risk of 1E-05. "Hazard drivers" are those constituents with an HI that is greater than the noncancer threshold of 1.

TABLE 5-5 - Summary of Risk Estimates for Onsite Workers Exposed to Chemical COPCs in CCR Material
Kingston Fossil Plant

Medium/CCR Unit/COPC	EPC[a]	Onsite Worker		
		ILCR	Hazard Quotient	Target Organ for Subchronic Exposure
	mg/kg	unitless	unitless	
CCR Material				
Interim Ash Staging Area				
Arsenic	5.62E+01	1.9E-07	0.39	Skin, Blood, Developmental, Neurological, Respiratory
Cobalt	1.07E+01	1.8E-11	0.011	Thyroid, Respiratory
Thallium	1.48E+00	n/a	0.11	Skin
Vanadium	4.73E+01	n/a	0.014	Skin, Respiratory
	Cumulative ILCR/HI:	2E-07	0.5	
Sluice Trench and Area East of Sluice Trench				
Arsenic	4.90E+01	1.7E-07	0.34	Skin, Blood, Developmental, Neurological, Respiratory
Cobalt	1.35E+01	2.3E-11	0.013	Thyroid, Respiratory
Thallium	1.18E+00	n/a	0.087	Skin
Vanadium	7.06E+01	n/a	0.021	Skin, Respiratory
	Cumulative ILCR/HI:	2E-07	0.5	
Stilling Pond				
Arsenic	8.08E+01	2.7E-07	0.55	Skin, Blood, Developmental, Neurological, Respiratory
Thallium	1.51E+00	n/a	0.11	Skin
	Cumulative ILCR/HI:	3E-07	0.7	
State of Tennessee Acceptable Cancer Risk and Noncancer Threshold:		1E-05	1	

Notes:

%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
ILCR	incremental lifetime cancer risk
mg/kg	milligrams per kilogram
n/a	not applicable
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk or noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

TABLE 6-1 – COPECs Identified for the ERA
Kingston Fossil Plant

	CCR Parameter Identified as COPEC by Location [a]		
CCR Parameter	**Emory River**	**Clinch River**	**Tennessee River**
Antimony	✓	✓	✓
Arsenic	✓	✓	✓
Barium	✓	✓	✓
Beryllium	✓	✓	✓
Boron	✓	✓	✓
Cadmium	✓	✓	✓
Calcium	--	--	--
Chloride	--	--	--
Chromium	✓	✓	✓
Cobalt	✓	✓	✓
Copper	✓	✓	✓
Fluoride	--	--	--
Lead	✓	✓	✓
Lithium	✓	✓	✓
Mercury	✓	✓	✓
Molybdenum	✓	✓	✓
Nickel	✓	✓	✓
Radium-226	✓	✓	✓
Radium-228	✓	✓	✓
Selenium	✓	✓	✓
Silver	✓	✓	✓
Sulfate	--	--	--
Thallium	✓	✓	✓
Vanadium	✓	✓	✓
Zinc	✓	✓	✓

Notes:

✓	denotes a COPEC
--	not selected as a COPEC because it is naturally occurring and has a low risk potential (refer to Section 6.1.1.2)
CCR	coal combustion residuals
COPEC	constituent of potential ecological concern
ERA	ecological risk assessment
[a]	all CCR parameters identified as COPECs in this ERA unless otherwise specified

Table 6-2 – Selected Ecological Receptors for the ERA
Kingston Fossil Plant

	Receptor Group	Receptor Type	Basis	Surrogate Receptors
Freshwater Aquatic Life	Benthic Invertebrate	Epifauna	Benthic invertebrates in the Emory, Clinch and Tennessee Rivers could be directly exposed to CCR-related COPECs in impacted media.	Benthic invertebrate communities
		Infauna		
	Primary Producer	Phytoplankton	Aquatic/riparian plants in the Emory, Clinch and Tennessee Rivers could be directly exposed to CCR-related COPECs in impacted media.	Aquatic plant communities
		Periphyton		
		Macrophyte		
	Fish	Benthivorous	Fish in the Emory, Clinch and Tennessee Rivers could be directly exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Fish communities
		Planktivorous		
		Piscivorous		
	Amphibian	Omnivorous	Amphibians utilizing the Emory, Clinch and Tennessee Rivers could be directly exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Amphibian communities
	Reptile	Omnivorous	Reptiles utilizing the Emory, Clinch and Tennessee Rivers could be directly exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Reptile communities
	Aquatic and Riparian-Feeding Birds	Herbivorous	Herbivorous birds utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Wood duck
		Omnivorous	Omnivorous birds utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Mallard duck
		Insectivorous	Insectivorous birds utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Killdeer
		Piscivorous	Piscivorous birds utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Great blue heron/Osprey

Table 6-2 – Selected Ecological Receptors for the ERA
Kingston Fossil Plant

Receptor Group	Receptor Type	Basis	Surrogate Receptors
Aquatic and Riparian-Feeding Mammals	Herbivorous	Herbivorous mammals utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Muskrat
	Omnivorous	Omnivorous mammals utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Raccoon
	Piscivorous	Piscivorous mammals utilizing the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Mink
Aerial-feeding Birds and Mammals	Insectivorous	Aerial-feeding insectivorous birds feeding over the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Tree swallow
	Insectivorous	Aerial-feeding insectivorous mammals feeding over the Emory, Clinch and Tennessee Rivers could be exposed to CCR-related COPECs in impacted media and indirectly via the food web.	Gray bat

Notes:

CCR	coal combustion residuals
COPEC	constituent of potential ecological concern
ERA	ecological risk assessment

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Kingston Fossil Plant

Receptor Group		Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Freshwater Aquatic Life	Benthic Invertebrate Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for benthic invertebrate communities. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, benthic invertebrate communities are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, benthic invertebrate communities are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, benthic invertebrate communities are not exposed to seep water.
		Surface stream water	Direct contact	Yes	Benthic invertebrates could be exposed to CCR Parameters in surface stream water through direct contact, ingestion of surface water and ingestion of algae and bacteria within surface water.
			Ingestion	Yes	
			Food chain uptake	Yes	
		Sediment	Direct contact	Yes	Benthic invertebrates live in sediments for most of their lifespan. Therefore, benthic invertebrates could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of algae and bacteria within sediment.
			Incidental ingestion	Yes	
			Food chain uptake	Yes	
		Groundwater and Springs	Direct contact and ingestion	No	Benthic invertebrate communities are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
	Aquatic Plant Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for aquatic plant communities. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, aquatic plant communities are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, aquatic plant communities are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, aquatic plant communities are not exposed to seep water.
		Surface stream water	Direct contact	Yes	Aquatic plant communities could be exposed to CCR Parameters in surface water via root uptake. Ingestion and food chain uptakes are not applicable to plants.
			Ingestion	No	
			Food chain uptake	No	
		Sediment	Direct contact	Yes	Many aquatic plants live in or are associated with sediments for most of their lifespan. Therefore, aquatic plant communities could be exposed to CCR Parameters in sediment via direct contact with sediment. Ingestion and food chain uptakes are not applicable to plants.
			Incidental ingestion	No	
			Food chain uptake	No	
		Groundwater and Springs	Direct contact and ingestion	No	Aquatic plant communities are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
	Fish Communities	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for fish. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, fish are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, fish are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, fish are not exposed to seep water.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Kingston Fossil Plant

Receptor Group		Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Freshwater Aquatic Life	Fish Communities	Surface stream water	Direct contact	Yes	Surface water provides habitat for fish communities. Therefore, fish could be exposed to CCR Parameters in surface water through direct contact, ingestion of surface stream water, and ingestion of plants or invertebrates exposed to surface stream water.
			Ingestion	Yes	
			Food chain uptake	Yes	
		Sediment	Direct contact	Yes	Sediment provides habitat for fish communities. Therefore, fish could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of plants or invertebrates exposed to sediment.
			Incidental ingestion	Yes	
			Food chain uptake	Yes	
		Groundwater and Springs	Direct contact and ingestion	No	Fish are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Amphibians		CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for amphibians. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, amphibians are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, amphibians are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, amphibians are not exposed to seep water.
		Surface stream water	Direct contact	Yes	Amphibians could be exposed to CCR Parameters in surface water through direct contact, ingestion of surface stream water, and ingestion of food items exposed to surface stream water.
			Ingestion	Yes	
			Food chain uptake	Yes	
		Sediment	Direct contact	Yes	Amphibians could be exposed to CCR Parameters in sediment through direct contact, incidental ingestion of sediment, and ingestion of plants or invertebrates exposed to sediment.
			Incidental ingestion	Yes	
			Food chain uptake	Yes	
		Groundwater and Springs	Direct contact and ingestion	No	Amphibians are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Reptiles		CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for reptiles. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, reptiles are not exposed to CCR material.
		Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, reptiles are not exposed to seep soil.
		Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, reptiles are not exposed to seep water.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Kingston Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Reptiles	Surface stream water	Direct contact	Negligible	Exposure via direct contact with surface stream water is assumed to be a minor exposure pathway for reptiles relative to ingestion of surface stream water and ingestion of food items exposed to surface stream water.
		Ingestion	Yes	Reptiles could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water.
		Food chain uptake	Yes	Reptiles could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface water.
	Sediment	Direct contact	Negligible	Exposure via direct contact with sediment is assumed to be a minor exposure pathway for reptiles relative to ingestion of sediment and ingestion of foods items exposed to sediment.
		Incidental ingestion	Yes	Reptiles could be exposed to CCR Parameters in sediment through incidental ingestion of sediment.
		Food chain uptake	Yes	The diets of reptiles include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake.
	Groundwater and Springs	Direct contact and ingestion	No	Reptiles are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Mammals	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for mammals. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, mammals are not exposed to CCR material.
	Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, mammals are not exposed to seep soil.
	Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, mammals are not exposed to seep water.
	Surface stream water	Direct contact	Negligible (No for aerial-feeding mammals)	Exposure to CCR Parameters in surface stream water via direct contact with surface stream water is assumed to be a minor exposure pathway for mammals relative to ingestion of water and ingestion of food items (e.g., fish) from the aquatic environment. Aerial-feeding mammals are not expected to be dermally exposed to surface water.
		Ingestion	Yes	Mammals could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water.
		Food chain uptake	Yes	Mammals could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface water.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Kingston Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale
Mammals	Sediment	Direct contact	Negligible (No for aerial-feeding mammals)	Exposure to CCR Parameters in sediment via direct contact with sediment is assumed to be a minor exposure pathway for mammals relative to incidental ingestion of sediment and ingestion of food items (e.g., fish) exposed to sediment. Aerial-feeding mammals are not expected to be dermally exposed to sediment.
		Incidental ingestion	Yes (No for aerial-feeding mammals)	Mammals could be exposed to CCR Parameters in sediment through incidental ingestion of sediment. Activities such as grooming and constructing dens (e.g., muskrat) could also result in incidental sediment ingestion. Aerial-feeding mammals are not expected to ingest sediment.
		Food chain uptake	Yes	The diets of some mammals include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake.
	Groundwater and Springs	Direct contact and ingestion	No	Mammals are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.
Birds	CCR Material	Inhalation, direct contact, incidental ingestion and food chain uptake	No	CCR units do not provide suitable habitat for birds. Also, once a geosynthetic cover system has been installed there will be no exposure to CCR material. Therefore, birds are not exposed to CCR material.
	Potential seep soil	Inhalation, direct contact, incidental ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, birds are not exposed to seep soil.
	Potential seep water	Direct contact, ingestion and food chain uptake	No	There are no known active seeps present at the KIF Plant. Therefore, birds are not exposed to seep water.
	Surface stream water	Direct contact	Negligible (No for aerial-feeding birds)	Exposure to CCR Parameters in surface stream water through direct contact with surface stream water is assumed to be a minor exposure pathway for birds relative to ingestion of water and ingestion of food items (e.g., fish) exposed to surface stream water. Aerial-feeding birds are not expected to be dermally exposed to surface stream water.
		Ingestion	Yes	Birds could be exposed to CCR Parameters in surface stream water through ingestion of surface stream water.
		Food chain uptake	Yes	Birds could be exposed to CCR Parameters in surface stream water through ingestion of food items exposed to surface stream water.
	Sediment	Direct contact	Negligible (No for aerial-feeding birds)	Exposure to CCR Parameters in sediment through direct contact with sediment is assumed to be a minor exposure pathway for birds relative to ingestion of sediment and ingestion of foods items (e.g., fish) exposed to sediment. Aerial-feeding birds are not expected to be dermally exposed to sediment.
		Incidental ingestion	Yes (No for aerial-feeding birds)	Birds could be exposed through incidental ingestion of sediment. Activities such as grooming and constructing nests could also result in incidental sediment ingestion. Aerial-feeding birds are not expected to ingest sediment.
		Food chain uptake	Yes	The diets of some birds include a proportion of benthic invertebrates and aquatic plants. As such, they could be exposed to CCR Parameters in sediment through food chain uptake.
	Groundwater and Springs	Direct contact and ingestion	No	Birds are not exposed to groundwater onsite because no springs are present and groundwater is inaccessible.

TABLE 6-3 – Summary of Ecological Exposure Pathways and Routes of Exposure
Kingston Fossil Plant

Receptor Group	Exposure Media	Exposure Pathway	Potentially Complete? (Yes/No/Negligible)	Rationale

Notes:

Negligible	exposure pathway is potentially complete but contribution to exposure is negligible
No	exposure pathway is incomplete
Yes	exposure pathway is potentially complete
CCR	coal combustion residuals

TABLE 6-4 – Summary of Assessment and Measurement Endpoints

Kingston Fossil Plant

Assessment Endpoint	Receptor	Measures of	
		Exposure	Effect
Protect the abundance and diversity of benthic invertebrates in the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Benthic invertebrate communities	• Measured concentrations of COPECs in invertebrate tissue and sediment	• Compared COPEC concentrations in invertebrate tissues and sediments with critical body residues and sediment benchmarks • Benthic invertebrate community metrics • Laboratory toxicity tests with invertebrates and site sediments
Protect the abundance and diversity of aquatic plants in the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Aquatic plant communities	• Measured concentrations of COPECs in surface stream water, sediment, and aquatic vegetation tissue	• Compared COPEC concentrations in surface stream water, sediment, and aquatic plant tissue with aquatic plant benchmarks
Protect the abundance and diversity of fish in the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Fish communities	• Measured concentrations of COPECs in fish tissue, surface stream water and sediment	• Compared COPEC concentrations in fish tissue and surface stream water with critical body residues and surface water benchmarks • Fish reproductive studies • Fish toxicity tests • Fish community health metrics
Protect the abundance and diversity of amphibians utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Amphibian communities	• Measured concentrations of COPECs in surface stream water and sediment	• Compared COPEC concentrations in surface stream water and sediment with applicable benchmarks
Protect the abundance and diversity of reptiles utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Reptile communities	• Measured concentrations of COPECs in reptile tissue, surface stream water and sediment	• Compared COPEC concentrations in surface stream water and sediment with benchmarks • Reptile community survey data
Protect populations of herbivorous mammals utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Muskrat	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake	• Compared calculated dose to NOAEL and LOAEL TRVs for mammalian receptors

TABLE 6-4 – Summary of Assessment and Measurement Endpoints

Kingston Fossil Plant

Assessment Endpoint	Receptor	Measures of	
		Exposure	Effect
Protect populations of omnivorous mammals utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Raccoon	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake • Measured concentrations of COPECs in raccoon tissue	• Compared calculated dose to NOAEL and LOAEL TRVs for mammalian receptors • Comparison of measured COPEC tissue concentrations to benchmarks for toxic effects to mammals • Site-specific biological monitoring data
Protect populations of piscivorous mammals utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Mink	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake	• Compared calculated dose to NOAEL and LOAEL TRVs for mammalian receptors
Protect populations of aerial-feeding insectivorous mammals feeding over the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Gray bat	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake	• Compared calculated dose to NOAEL and LOAEL TRVs for mammalian receptors
Protect populations of herbivorous birds utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Wood duck	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake.	• Compared calculated dose to NOAEL and LOAEL TRVs for avian receptors.
Protect populations of omnivorous birds utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Mallard duck	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake	• Compared calculated dose to NOAEL and LOAEL TRVs for avian receptors
Protect populations of invertivorous birds utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Killdeer	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake	• Compared calculated dose to NOAEL and LOAEL TRVs for avian receptors

TABLE 6-4 – Summary of Assessment and Measurement Endpoints

Kingston Fossil Plant

Assessment Endpoint	Receptor	Measures of	
		Exposure	Effect
Protect populations of piscivorous birds utilizing the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Great blue heron/Osprey	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake • COPEC concentrations in osprey and blue heron eggs	• Compared calculated dose to NOAEL and LOAEL TRVs for avian receptors • Compared measured COPEC concentrations in eggs to applicable EC10 or LOAEL TRVs • Egg health metrics
Protect populations of aerial-feeding insectivorous birds feeding over the Emory, Clinch, and Tennessee rivers by limiting acute and chronic effects from exposure to site-related COPECs.	Tree swallow	• Calculated daily dosage using exposure models, measured COPEC concentrations in abiotic and biotic media, and food-chain uptake • COPEC concentrations in tree swallow eggs, eggshells, and nestlings	• Compared calculated dose to NOAEL and LOAEL TRVs for avian receptors • Compared COPEC concentrations in tree swallow eggs, eggshells, and nestings to applicable EC10 or LOAEL TRVs • Tree swallow egg and nestling health metrics • Tree swallow productivity metrics

Notes:

COPEC	constituent of potential ecological concern
EC10	Concentration resulting in measured effect for 10% of test organisms
NOAEL	no-observed-adverse-effect level
LOAEL	lowest-observed-adverse-effect level
TRV	toxicity reference value

Table 6-5 – Lines of Evidence and Methods of Assessment To Be Used in the Ecological Risk Assessment Kingston Fossil Plant

Receptor	Lines of Evidence	Method of Assessment
Benthic Invertebrate Communities	1. Benthic invertebrate community metrics	1. Compare metrics for upstream, adjacent, and downstream locations at the KIF Plant
	2. Toxicity tests	1. Compare results for toxicity tests completed using sediment samples collected upstream, adjacent, and downstream locations at the KIF Plant
	3. COPEC concentrations in invertebrate tissues	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream) 2. Compare measured COPEC concentrations to critical body residues 3. Correlation analysis between measured COPEC concentrations in tissue and measured COPEC concentrations in sediment
	4. COPEC concentrations in sediment	1. Compare sediment data to chronic and acute sediment benchmarks 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
Aquatic Plant Communities	1. COPEC concentrations in surface stream water and sediment	1. Compare surface stream water and sediment data to applicable benchmarks 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
	2. COPEC concentrations in aquatic vegetation tissues	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream) 2. Compare tissue concentration data to applicable literature effects values
Fish Communities	1. Fish community metrics	1. Compare metrics for upstream, adjacent, and downstream locations at the KIF Plant over time
	2. Toxicity tests	1. Compare results for toxicity tests completed using surface water samples collected upstream, adjacent, and downstream locations at the KIF Plant
	3. Reproductive studies	1. Compare results of evaluation of fish reproductive condition *in situ* for upstream, adjacent, and downstream locations at the KIF Plant
	4. COPEC concentrations in fish tissues	1. Compare fish tissue data to critical body residues 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
	5. Fish health metrics	1. Compare results of evaluation of fish health *in situ* for upstream, adjacent, and downstream locations at the KIF Plant
	6. COPEC concentrations in surface stream water and sediment	1. Compare surface stream water data to chronic and acute surface water benchmarks 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
Amphibian Communities	1. COPEC concentrations in surface stream water and sediment	1. Compare surface stream water and sediment data to applicable benchmarks 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)

Table 6-5 – Lines of Evidence and Methods of Assessment To Be Used in the Ecological Risk Assessment Kingston Fossil Plant

Receptor	Lines of Evidence	Method of Assessment
Reptile Communities	1. Reptile community metrics	1. Compare metrics for upstream, adjacent, and downstream locations at the KIF Plant
	2. COPEC concentrations in reptile tissues	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
	3. COPEC concentrations in surface stream water and sediment	1. Compare surface stream water and sediment data to chronic and acute surface water benchmarks 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
Herbivorous Mammals and birds	1. Dietary exposure modelling	1. Food chain model. Compare estimated exposure dose of COPEC to literature-derived NOAEL and LOAEL TRV 2. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
Omnivorous Mammals and Birds	1. Dietary exposure modelling	1. Food chain model. Compare estimated exposure dose of COPEC to literature-derived NOAEL and LOAEL TRV
	2. Raccoon tissue data and raccoon health metrics	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream) 2. Compare tissue data to benchmarks for toxic effects to mammals
Carnivorous/Piscivorous Mammals and Birds	1. Dietary exposure modelling	1. Food chain model. Compare estimated exposure dose of COPEC to literature-derived NOAEL and LOAEL TRV
	2. Osprey and blue heron egg tissue data and egg health metrics	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream)
		2. Compared measured COPEC concentrations in eggs to applicable EC10 or LOAEL TRVs
Aerial Insectivorous Mammals & Birds	1. Dietary exposure modelling	1. Food chain model. Compare estimated exposure dose of COPEC to literature-derived NOAEL and LOAEL TRV
	2. Tree swallow reproductive data and tissue concentrations	1. Spatial analysis (e.g., location and frequency of detections, concentrations upstream, adjacent and downstream) 2. Correlation analysis between tissue concentrations and modelled food chain exposure estimates 3. Compare tissue data to critical body residues

Notes:

COPEC	constituent of potential ecological concern
KIF Plant	Kingston Fossil Plant
EC10	Concentration resulting in measured effect for 10% of test organisms
LOAEL	lowest-observed-adverse-effect level
NOAEL	no-observed-adverse-effect level
TRV	toxicity reference value

EXHIBITS

Exhibit No.

1-1

Title

KIF Plant Overview

Client/Project

Tennessee Valley Authority
Kingston Fossil (KIF) Plant TDEC Order

Project Location

Roane County, Tennessee

175668043
Prepared by MB on 2024-07-23
Technical Review by EM on 2024-07-23

0 500 1,000 1,500 2,000 Feet

1:6,000 (At original document size of 22x34)

Legend

- Limit of Existing Cover System for TDEC Order CCR Units (Approximate – 2024)
- Subsurface Wall (Approximate)
- TDEC Order CCR Unit Area (Approximate)
- Engineered Wetlands (Approximate)
- Polishing Pond (Approximate)
- CCR Unit Area (Approximate) Not Included in TDEC Order

Perimeter Wall Stabilization (As Shown in Inset)

- Inboard/Outboard Wall
- Shear Wall

CCR = Coal Combustion Residuals

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery provided by TVA (2023)
3. The KRP Ash Landfill and Peninsula Disposal Area are not included in the TDEC Order; the units are regulated in accordance with TDEC Rule 0400-11-01-.04 Division of Solid Waste Management (DSWM).

Stantec TVA

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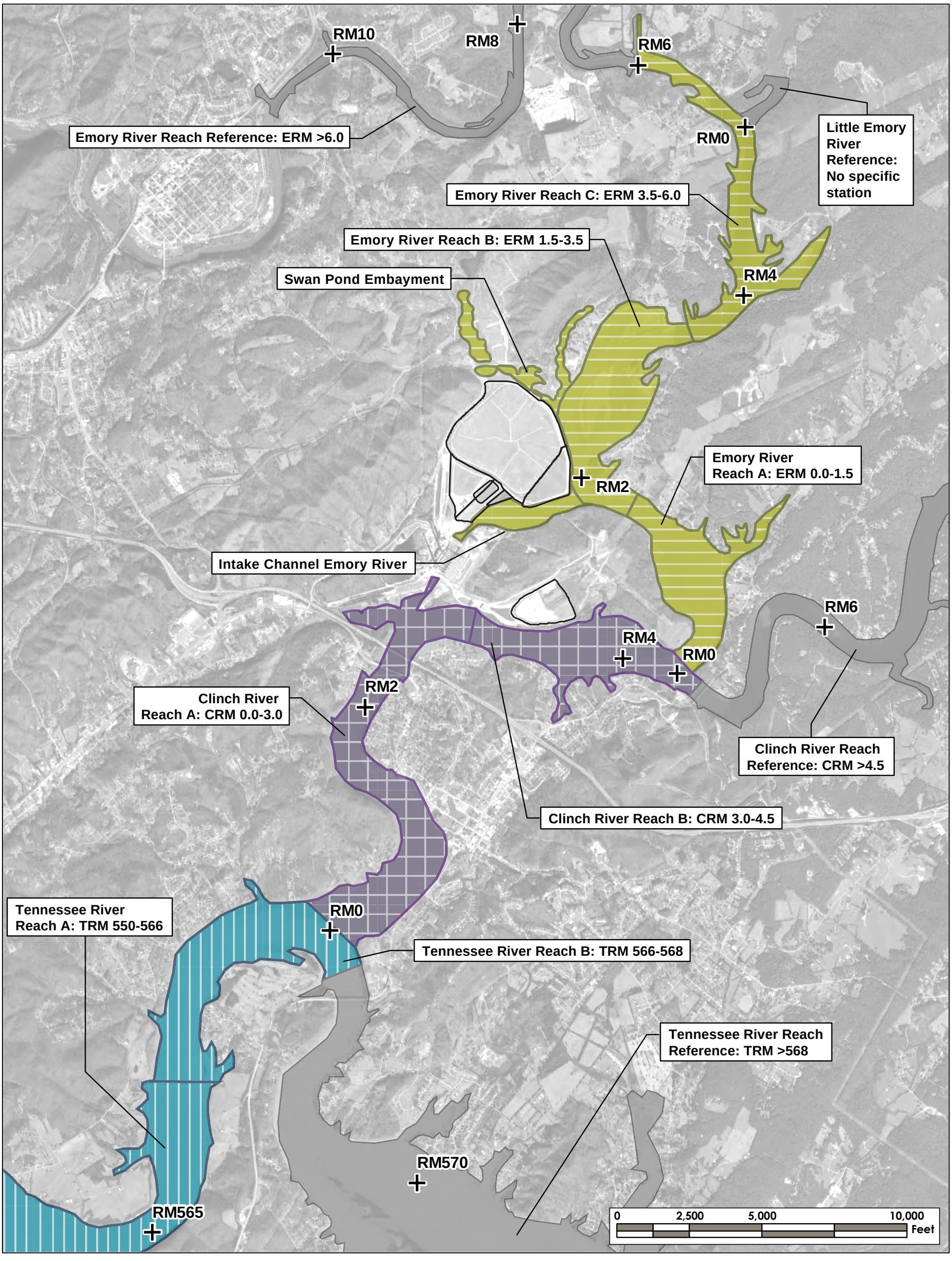
J:\TVA-EIP\175668043_KF_Phase2\gis\mxd\CARA\Ex1_PlantOverview\KIF_Ex1_PlantOverview.aprx 1-1 KIF_PlantOverview Revised: 2024-07-23 By: mbough



Legend

- RM River Mile
- TDEC Order Study Area CCR Units (Approximate)
  - CCR = Coal Combustion Residuals

Surface Stream, Sediment, and Ecology Sampling Reach Location

- Clinch River
- Tennessee River
- Emory River, Plant Intake Channel and Embayments
- Reference

The Watts Bar Reservoir extends from the Watts Bar Dam to Fort Loudoun Dam along the Tennessee River and includes parts of the Clinch River and Emory and Little Emory Rivers.

Imagery provided by ESRI.

Exhibit No.
2-1

Title
KIF Plant River Reaches

Client/Project
Tennessee Valley Authority
Kingston Fossil (KIF) Plant TDEC Order

Project Location
Roane County, Tennessee

175668043
Prepared by KB on 2024-02-29

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Exhibit No.
4-1

Title

KIF Plant CCR Units

Client/Project

Tennessee Valley Authority
Kingston Fossil (KIF) Plant TDEC Order

Project Location
Roane County, Tennessee

175668043
Prepared by DMB on 2024-07-23
Technical Review by VC on 2024-07-23

0 300 600 900 1,200 Feet

1:3,600 (At original document size of 22x34)

Legend

- Geotechnical Boring
- Temporary Well (Screened Interval)
- Limit of Existing Cover System for TDEC Order CCR Units (Approximate – 2024)
- TDEC Order CCR Unit Area (Approximate)
- Engineered Wetlands (Approximate)
- Polishing Pond (Approximate)

CCR = Coal combustion residuals

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery provided by TVA (2023)
3. The KRP Ash Landfill is not included in the TDEC Order; the unit is regulated in accordance with TDEC Rule 0400-11-01-.04 Division of Solid Waste Management (DSWM).
4. KIF-TW03a and KIF-TW03b were attempted at the KIF-TW03 location referenced in EIP Rev. 4. However, the temporary well could not be installed at this location.
5. KIF-TW03 was drilled at the KIF-TW03Alt location referenced in EIP Rev. 4.
6. Boring locations for KIF-TW01, KIF-TW02, KIF-TW03, KIF-TW04, KIF-TW05 surveyed by the R.L.S. Group on May 2, 2019. Boring locations for KIF-TW03a and KIF-TW03b based on handheld GPS coordinates at the time of drilling.
7. Borings locations for KIF-B01a, KIF-B01b, KIF-B02a, KIF-B02b, KIF-B03a, KIF-B03b, and KIF-B04a surveyed by TVA on January 9, 2020.

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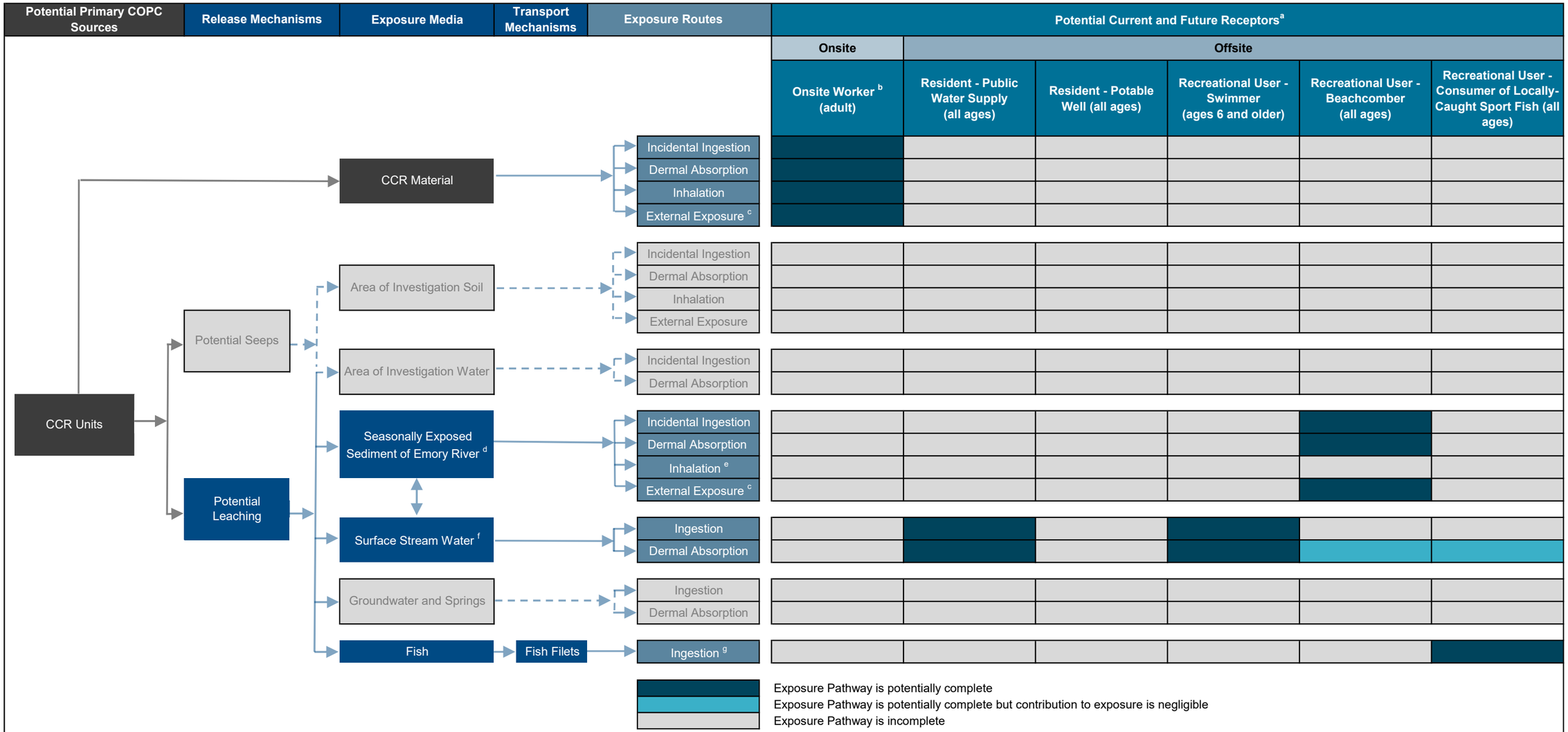
J:\TVA-EIP\175668043_KIF_Phase2\gis\mxd\CARA\HHERA\KIF_HHERA_ExhVSF_HHERA_Exh.aprx 4-1_KIF_Plant_CCR_Units Revised: 2024-07-23 By: mbaugh

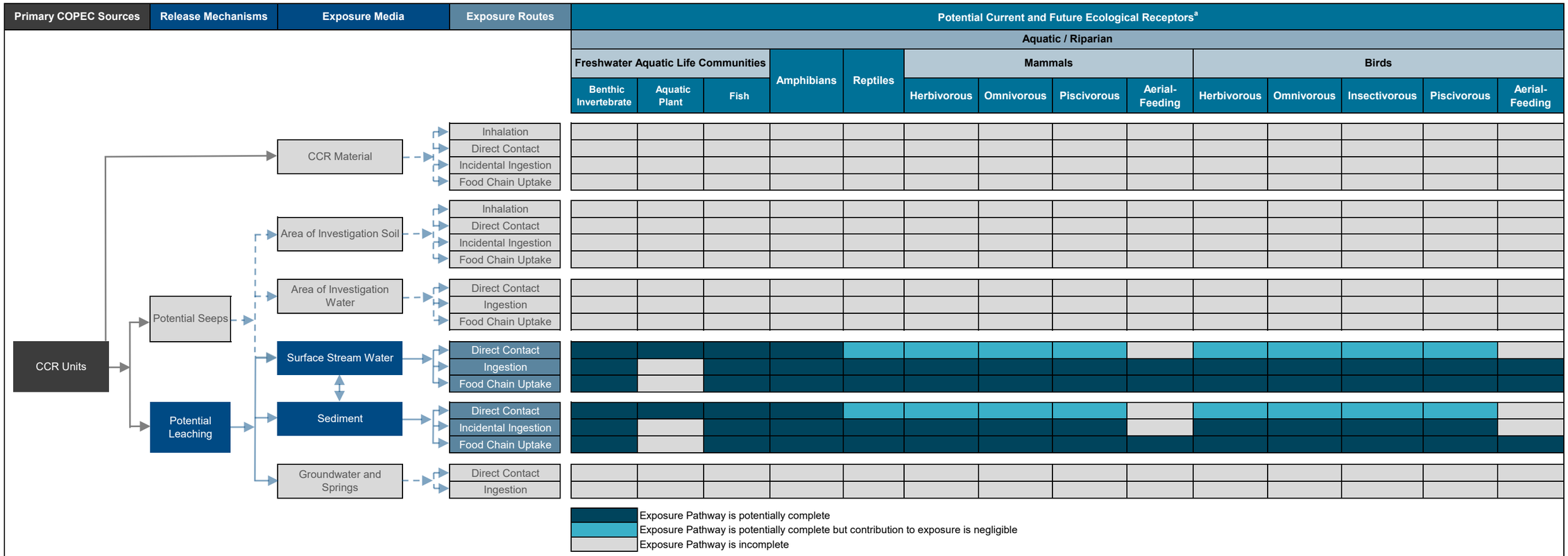
EXHIBIT 5-1
Human Health Risk Assessment Conceptual Site Model
Kingston Fossil Plant



Notes:
CCR - Coal combustion residuals
COPC - Constituent of potential concern

[a] The Kingston Fossil Plant is expected to continue industrial operations into the future. Rationale for why exposure pathways are incomplete or potentially complete are noted in Section 5.1.1 of the text.
[b] Onsite workers making minor repairs to the CCR units or on dikes that may include limited digging.
[c] External exposure to radiation emanating from radionuclides (radium) in CCR material and seasonally exposed sediment.
[d] Sediment on the banks of the Emory River that is above water during low pool conditions. Submerged sediment is not a complete pathway of exposure for human receptors (USEPA 2018).
[e] Seasonally exposed sediment is damp. Windborne dust is unlikely to occur.
[f] Surface stream water in the Emory River.
[g] Offsite residential potable use of groundwater and springs was determined to be an incomplete exposure pathway based on the findings of the water use survey.
[h] Consumption of locally-harvested aquatic and riparian biota (e.g., fish, crayfish) is represented by sport fish. Submerged sediment is not a complete pathway of exposure for human receptors (USEPA 2018).

EXHIBIT 6-1
Ecological Risk Assessment Conceptual Site Model
Kingston Fossil Plant



Notes:
CCR coal combustion residuals
COPEC constituent of potential ecological concern

[a] Rationale for why exposure pathways are incomplete or potentially complete are noted in Table 6-3.

PHOTOGRAPHS

Stantec

Photographic Log

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 1

Photo Location:
Cooling Water Intake

Direction:
Northwest

Survey Date:
10/23/2019

Comments:
Looking northwest at the Cooling Water Intake. Located southwest of the Sluice Trench and Area East of Sluice Trench.

Photograph ID: 2

Photo Location:
Emory River

Direction:
Southwest

Survey Date:
10/23/2019

Comments:
Looking southwest at the Emory River from the Stilling Pond.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 3

Photo Location:
Emory River

Direction:
East

Survey Date:
10/23/2019

Comments:
Looking east at the Emory River from the Stilling Pond.

Photograph ID: 4

Photo Location:
Engineered Wetland

Direction:
Northeast

Survey Date:
10/23/2019

Comments:
Vegetation in engineered wetland. View from perimeter access road along north side of cooling water Intake Channel.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 5

Photo Location:
Plant Intake Channel

Direction:
Southwest

Survey Date:
10/23/2019

Comments:
Looking southwest at the Kingston Fossil Plant from the Plant Intake Channel.

Photograph ID: 6

Photo Location:
Plant Intake Channel

Direction:
Southeast

Survey Date:
10/23/2019

Comments:
Looking southeast towards Emory River from the Plant Intake Channel.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 7

Photo Location:
Interim Ash Staging Area

Direction:
Southeast

Survey Date:
10/23/2019

Comments:
Looking southeast at the Interim Ash Staging Area. Located southwest of the KRP Ash Landfill.

Photograph ID: 8

Photo Location:
Kingston Fossil Plant

Direction:
Southwest

Survey Date:
10/23/2019

Comments:
Looking southwest at the Kingston Fossil Plant from the KRP Ash Landfill.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 9

Photo Location:
Kingston Fossil Plant

Direction:
Southwest

Survey Date:
10/23/2019

Comments:
Looking southwest at the Kingston Fossil Plant from dock at Lakeshore Park.

Photograph ID: 10

Photo Location:
Polishing Pond

Direction:
Southwest

Survey Date:
10/23/2019

Comments:
Looking southwest at the Polishing Pond with power plant towers in the background.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 11

Photo Location:
Restored Swan Pond Embayment

Direction:
North

Survey Date:
10/23/2019

Comments:
Restored Swan Pond Embayment nature area opposite KRP Ash Landfill.

Photograph ID: 12

Photo Location:
Restored Swan Pond Embayment

Direction:
Northeast

Survey Date:
10/23/2019

Comments:
Looking northeast at road across Restored Swan Pond Embayment from the KRP Ash Landfill.

Client:	**TVA**	**Project:**	**HHERA**
Site Name:	**KIF Plant**	**Site Location:**	**Harriman, Tennessee**

Photograph ID: 13

Photo Location:
Restored Swan Pond Embayment

Direction:
Northwest

Survey Date:
10/23/2019

Comments:
Looking Northwest at the Restored Swan Pond Embayment from the KRP Ash Landfill.

Photograph ID: 14

Photo Location:
Lakeshore Park Boardwalk

Direction:
North

Survey Date:
10/23/2019

Comments:
Looking North at the Lakeshore Park Boardwalk from dock at Lakeshore Park.

APPENDIX A –
MULTIPLE LINES OF EVIDENCE FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FOR TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION ORDER PLANTS

Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments for Tennessee Department of Environment and Conservation Order Plants

October 22, 2021

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Record

Revision	Description	Date
0	Submittal to TDEC	July 23, 2021
1	Addresses August 26, 2021 TDEC Review Comments and Issued for TDEC Review	September 24, 2021
2	Addresses October 12, 2021 TDEC Review Comments and Issued for TDEC Review	October 22, 2021

Sign-off Sheet

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Executive Summary

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. One of the purposes of the TDEC Order is to establish a transparent comprehensive process for the investigation, assessment, and remediation of unacceptable risks resulting from the management and disposal of CCR at seven coal-fired power plants subject to the TDEC Order (TDEC Order plants). Stantec Consulting Services Inc. (Stantec) will be preparing human health and ecological risk assessment (HHERA) reports for six of these TDEC Order plants.

The United States Environmental Protection Agency encourages the use of multiple lines of evidence (LOE) when conducting HHERAs such that a weight of evidence approach is used to characterize risk. The LOE to be used in the HHERA for the TDEC Order plants are quantitative and qualitative in nature. Quantitative LOE will include 1) comparing concentrations of CCR chemical constituents (referred to as Parameters) measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) results of Environmental Investigations (EIs) conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project).

The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented. For example, the KRP was based on approximately 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses; toxicity testing of both water and sediments (including partial life-cycle tests); field and laboratory studies conducted by TVA staff, consultants, government research agencies, and universities; all of which culminated in approximately 50 papers published in peer-reviewed journals. As such, the KRP has influenced the scope of the EIs, the pathways and receptors to be considered in the TDEC Order HHERAs, and provides information that support a LOE evaluation. Indeed, findings and recommendations stemming from the HHERAs conducted as part of the KRP supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring, and influenced the data collection activities for the TDEC Order plant EIs.

The objective of this report is to outline the multiple quantitative and qualitative LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risk based on the combined results of LOE rather than any single LOE alone.

Abbreviations

BERA	Baseline Ecological Risk Assessment
CCR	coal combustion residuals
CCR constituents	constituents serving to form, compose or make up the whole of CCR material
CCR Parameters	constituents listed In Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
COPC	constituents of potential concern
COPEC	constituents of potential ecological concern
EI	environmental investigation
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
HHERA	human health and ecological risk assessment
HHRA	human health risk assessment
HQ	hazard quotient
KIF	Kingston Fossil Plant
KRP	Kingston Recovery Project
LOE	lines of evidence
SLERA	screening level ecological risk assessment
SSL_{HH}	human health screening levels
TDEC	Tennessee Department of Environment and Conservation
TDEC Order	(TDEC) Commissioner's Order No. OGC15-0177
TDEC Order plants	TVA coal-fired power plants subject to the TDEC Order
TDH	Tennessee Department of Health
TVA	Tennessee Valley Authority

1.0 INTRODUCTION

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. The TDEC Order has two purposes. First, the TDEC Order is intended to establish a transparent comprehensive process for the investigation, assessment, and remediation of unacceptable risks resulting from the management and disposal of CCR at seven coal-fired power plants subject to the TDEC Order, namely the Allen Fossil Plant, Bull Run Fossil Plant, Cumberland Fossil Plant, John Sevier Fossil Plant, Johnsonville Fossil Plant, Kingston Fossil Plant, and Watts Bar Fossil Plant (collectively, the TDEC Order plants). Second, the TDEC Order is intended to establish the process whereby TDEC will oversee TVA's implementation of the 2015 United States Environmental Protection Agency Final CCR Rule to insure coordination and compliance with Tennessee laws and regulations that govern the management and disposal of CCR (TDEC 2015).

As stipulated in the TDEC Order, the Corrective Action/Risk Assessment Plan specifies the actions (i.e., corrective measures) TVA plans to take at each of the TDEC Order plants and the basis for those actions. In addition to other regulatory criteria, the need for, and extent of, corrective measures will be informed by whether the presence of CCR consitiutents in environmental media at the TDEC Order plants presents unacceptable risks to human health and the environment.

1.1 OBJECTIVE

Stantec Consulting Services Inc. (Stantec) will be preparing human health and ecological risk assessment (HHERA) reports for six of the TDEC Order plants (not for the Allen Fossil Plant). The objective of the HHERAs is to provide quantitative and qualitative statements of potential risks to human and ecological receptors from exposures to CCR Parameters in environmental media at the TDEC Order plants to inform future CCR management decisions. When conducting risk assessment, the United States Environmental Protection Agency (EPA) encourages the use of multiple lines of evidence (LOE) such that a weight of evidence approach can be used to characterize risk (e.g., EPA 2000a). In their guidance, EPA also makes clear that determining unacceptable risk should go beyond solely calculating numerical risk estimates and should include evidence and analysis demonstrating or refuting a causal link between stressor and response (e.g., EPA 1992, 1997, 1998, 1999 and 2000b). It is the combined results of these LOE rather than any single line of evidence that are used to determine if risk is present at a level that warrants further evaluation or consideration of remedial options.

Accordingly, the objective of this report is to outline the multiple LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risk based on the combined results of LOE rather than any single LOE alone.

1.2 QUANTITATIVE AND QUALITATIVE LINES OF EVIDENCE

The LOE to be used in the HHERA for the TDEC Order plants are both quantitative and qualitative in nature. Quantitative LOE will include 1) comparing concentrations of CCR Parameters measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) results of Environmental Investigations (EIs) conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the Kingston Recovery Project (KRP, also known as the Kingston Ash Recovery Project).

In brief, the KRP took place after the 2008 structural failure at TVA's Kingston Fossil (KIF) Plant that resulted in the release of approximately 5.4 million cubic yards (cy) of sluiced ash (CCR material) into the adjacent Swan Pond Embayment with transport into the Emory, Clinch, and Tennessee River system. The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented. For example, the KRP was based on approximately 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses; toxicity testing of both water and sediments (including partial life-cycle tests); field and laboratory studies conducted by TVA staff, consultants, government research agencies, and universities; all of which culminated in approximately 50 papers published in peer-reviewed journals. As such, the KRP has influenced the scope of the EIs, the pathways and receptors to be considered in the TDEC Order HHERAs, and provides information that support a LOE evaluation. Indeed, findings and recommendations stemming from the HHERAs conducted as part of the KRP supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring, and influenced the data collection activities for the TDEC Order plant EIs.

1.3 REPORT ORGANIZATION

This report is organized into the following sections:

- **Section 2 - Human Health and Ecological Risk Assessment for the TDEC Order Plants:** A summary of available TDEC Order Plant datasets and receptor-exposure pathway interactions
- **Section 3 - Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments:** A description of the quantitative and qualitative LOE to be used in the HHERAs for the TDEC Order plants
- **Section 4 - Conclusions:** A summary of the report
- **Section 5 - References:** Lists the reference documents cited in this report
- **Appendices:** Provides published information on primary CCR constituents

2.0 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT FOR THE TDEC ORDER PLANTS

2.1 DATASETS

Analytical results from the EIs conducted at the TDEC Order plants are the primary datasets for evaluating potential human and ecological exposures and risks. Quantitative estimates of exposures and risks will be based on the concentrations for the following CCR constituents listed in Appendices III and IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- Antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids

and five metals included in Appendix 1 of TN Rule 0400-11-01-04 that are not listed in 40 CFR 257:

- Copper, nickel, silver, vanadium, and zinc.

The term “CCR Parameters” is used for these specific constituents for the purpose of the EI and HHERA conducted under the TDEC Order.

As part of the EI, these CCR Parameters were analyzed in CCR material, soils from areas of interest (collected as part of seep investigations), surface stream water, sediment, mayfly tissue, and fish tissues. Onsite groundwater is not a source of potable water or other human contact uses for the TDEC Order plants; therefore, on-site groundwater data will not be used to estimate human exposure risks (with the possible exception of the Allen Fossil Plant in Memphis, Tennessee). Details of the investigations can be found in the Environmental Investigation Plans for each TDEC Order plant and can be found on-line at https://www.tva.com/environment/environmental-stewardship/tdec-order-on-coal-combustion-residuals.

While offsite groundwater data were not collected as part of the EI, domestic use of offsite groundwater is still a potentially complete exposure pathway. Domestic use includes, but is not limited to human consumption. Based on the outcome of water use surveys, samples of groundwater from private wells and springs that could act as a domestic source will be analyzed for CCR Parameters. Analytical results from private domestic sources may be supplemented with modeled data, which will be used as a line of evidence to assess the potential of CCR Parameter movement from onsite to offsite locations of domestic water use.

2.2 HUMAN HEALTH AND ECOLOGICAL RECEPTORS AND EXPOSURE PATHWAYS

The seven coal-fired power plants subject to the TDEC Order are similar in several ways. They were constructed during an approximately 20-year period between the early 1950s and mid-1970s. The environmental settings are similar across the fleet and all are located on large rivers that are sources of

public drinking water supplies and widely used for boating and water sports, fishing, and shoreline activities. CCR Parameters potentially released from the CCR management units could be transported to nearby surface streams and rivers where human and ecological exposure might occur.

Given the commonalities among the TDEC Order plants and their adjacent land uses, for the purposes of the HHRA, human receptors have been grouped as onsite and offsite receptors – people who may be present on or near the CCR management units, and people who may be present on surrounding properties or who use adjacent water bodies for recreation, respectively. Consistent with the approach taken in the KRP, these receptors will be grouped by their primary activities to assess risk, specifically:

- Onsite Workers – Workers who may have contact with CCR material, or CCR Parameters in seep soils and seep water while engaged in short-term excavation projects
- Offsite Residential Users of Surface Stream Water – Local residents whose drinking water is supplied by public drinking water utilities using surface streams downstream from these power plants as their source water
- Offsite Residential Users of Groundwater – Nearby residents who use private wells and springs for drinking water
- Offsite Recreational Users – Swimmers who may be in direct contact with CCR Parameters in surface stream water
- Offsite Recreational Users – Beachcombers who may be in direct contact with CCR Parameters in seasonally exposed sediment
- Offsite Recreational Users – Consumers who may be exposed to CCR Parameters through ingestion of locally-caught fish.

For the purposes of the ERA and consistent with the approach in the KRP, risks to the following groups of ecological receptors from exposure to CCR Parameters will be assessed:

- Benthic Invertebrate Communities – In contact with surface stream sediments and pore water
- Aquatic Plant Communities – In contact with surface stream sediments, pore water, and surface water
- Fish Communities – In contact with surface stream water and sediments (demersal fish only)
- Amphibians and Reptiles – In contact with surface stream water and bank sediments
- Aquatic and Riparian Mammals and Birds – In contact with surface stream water and bank sediments and consume benthic invertebrates, aquatic plants, and forage fish.

3.0 LINES OF EVIDENCE TO BE USED IN THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

As noted above, the EPA encourages the use of LOE in HHERA such that a weight of evidence approach can be used to characterize risk (e.g., EPA 2000a). The multiple LOE to be used in the HHERA for the TDEC Order plants are quantitative and qualitative in nature.

- Quantitative LOE will include 1) comparing concentrations of CCR Parameters measured at the TDEC Order plants to medium-specific and receptor-specific human health/ecological screening levels and 2) calculating carcinogenic risk and non-cancer hazard index (for the human health assessment) and hazard quotients (for the ecological assessment). Details of these LOE are provided in **Section 3.1.**

- Qualitative LOE will include 1) the use of published information on CCR and CCR Parameters, 2) findings from EIs conducted at each of the TDEC Order plants, and 3) findings from the environmental sampling, biological studies, and human health and ecological risk assessments conducted as part of the KRP. Details of these LOE are provided in **Section 3.2.**

A summary of the key studies conducted for the KRP, their major findings, the LOE used in those studies, and a discussion of the application of the findings and LOE to the TDEC Order HHERAs are provided in **Table 1**. The information available from the KRP is especially useful because it is directly applicable to the TDEC Order plants (e.g., based on similar stressors, receptors, exposure pathways) and well documented.

3.1 QUANTITATIVE LINES OF EVIDENCE

3.1.1 Screening Levels

3.1.1.1 Human Health Screening Levels

Concentrations of CCR Parameters measured in CCR material, soil, sediment and fish tissue will be compared to medium-specific and receptor-specific human health screening levels (SSL_{HH}). The methods used to derive SSL_{HH} for CCR material, soil, sediment and fish tissue are described in *Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})* (Stantec 2021). Offsite surface stream water is also evaluated as a potential medium of concern for the HHRA because surface stream waters are used as sources of public drinking water supplies and for recreational activities (e.g., swimming). State of Tennessee and EPA water quality criteria and standards for domestic water supply are available and will be used to screen CCR Parameters in surface stream water used for both domestic water supply and human recreational activities (Stantec 2021). CCR Parameters with media concentrations higher than SSL_{HH} for CCR material, soil, sediment or fish tissue, or generic human health screening levels for surface stream water will be identified as constituents of potential concern (COPCs) for further evaluation in the HHRA.

Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments

The potential movement of CCR Parameters in onsite groundwater to offsite locations where there may be private domestic wells or springs will be addressed by water use surveys and offsite water analysis. Should the use survey indicate that groundwater is used for human consumption, the intent is to sample water from wells/taps and analyze for CCR Parameters. The measured concentrations will then be screened against EPA drinking water standards and Tennessee Groundwater Protection Standards consistent with the Federal CCR Rule. Groundwater modeling may also be used as a line of evidence to assess the potential of CCR Parameter movement from onsite to offsite locations of domestic water use (i.e., modeled data will be compared to measured data).

3.1.1.2 Ecological Screening Criteria

Concentrations of CCR Parameters in abiotic media (i.e., stream surface water and sediment) will be compared to media-based ecological screening criteria in the ERA. CCR Parameters with media concentrations higher than ecological screening criteria will be identified as constituents of potential ecological concern (COPECs) for further evaluation in the ERA. Because media-based ecological screening criteria (e.g., sediment screening benchmarks) are generally based on the potential for impacts to lower trophic level receptors (e.g., benthic macroinvertebrates), they may not be adequately protective of higher trophic level receptors (e.g., birds or mammals). This is particularly relevant for bioaccumulating constituents that may increase in concentration through successive stages of the food chain. Therefore, to be protective of aquatic-dependent birds and mammals, COPEC selection will be based on multiple media-based ecological screening criteria. Concentrations of CCR Parameters in surface stream water and sediment will be compared to ecological screening criteria for each of these media; a given CCR Parameter with concentrations that are higher than an abiotic screening criterion will be identified as a COPEC for further evaluation in the ERA. In addition, CCR Parameters that are known to bioaccumulate (i.e., mercury and selenium) will be identified as COPEC for higher trophic levels if present in sediment or surface water.

Food chain modeling based on an oral dose approach will be used to estimate exposures to COPECs in surface stream water, sediment and biological (i.e., mayfly and fish) tissues for avian and mammalian receptors. Exposure doses calculated for each COPEC and ingestion exposure pathway (i.e., ingestion of food, water and sediment) will be compared to effects-related endpoints to estimate potential hazards. COPEC concentrations in biological (mayfly and fish) tissues will be evaluated in the ERA for potential risks to benthic macroinvertebrate and fish communities, respectively, through comparison to critical body residues. For CCR Parameters that are known to bioaccumulate, fish tissue concentrations from multiple species and trophic levels in the food web (i.e., bluegill, channel catfish, redear sunfish, gizzard shad and largemouth bass), will be compared to critical body residue values.

3.1.2 Hazard Thresholds, Hazard Index and Hazard Quotients

CCR Parameters identified during the screening process as COPCs and COPECs will be further quantitatively evaluated by calculating hazard thresholds, hazard indices or hazard quotients as applicable. The EPA considers a carcinogenic risk between 1×10^{-6} and 1×10^{-4} and a non-cancer hazard index of one as the points of departure for risk management decisions about potential human health

concerns at a contaminated site (EPA 1991). However, the upper boundary of the risk management range is not a discrete line at 1 x 10^{-4}, although the EPA generally uses 1 x 10^{-4} in risk management decisions. A specific risk estimate slightly higher than 1x10^{-4} may be considered acceptable if justified based on site-specific conditions (EPA 1991). The State of Tennessee (TDEC 2016) refers to the EPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and Risk Assessment Guidance for Superfund. The regulatory target for acceptable excess lifetime cancer risk in Tennessee is 1 x 10^{-5} (TDEC 2019). Since the Tennessee risk assessment process is consistent with CERCLA, the risk assessments being evaluated as part of the TDEC Order will assume that regulatory program targets for acceptable excess lifetime cancer risk and non-cancer hazard index for protection of human health are 1x10^{-5} and 1.0, respectively.

Hazard quotients (HQs) for birds and mammals will be calculated based on no observed adverse effect levels and lowest observed effects levels. The EPA considers that when HQ calculated based on no observed adverse effect levels are less than or equal to one, adverse effects on representative ecological receptors are not likely (EPA 1997). When ecological HQs are greater than one, adverse effects on representative ecological receptors are possible, but interpretation of HQs greater than one should include a weight of evidence evaluation including, but not limited to, consideration of the potentially affected receptor(s), the nature of the stressor(s), ecological effects information, toxicological relevance to population effects and the likelihood and duration of exposure.

3.2 QUALITATIVE LINES OF EVIDENCE

3.2.1 Published Information on Primary CCR Parameters in Fish

Consumption of locally-caught fish is an important pathway of exposure to contaminants for human and ecological receptors. Fish take up naturally-occurring metals/metalloids from their environment and incorporate some of them into their tissues. The toxicities of metals depend on their chemical forms and valence states, important characteristics that may not be represented by the toxicity factors used to estimate cancer risk and non-cancer hazard from total metals concentrations in environmental or biological media. Section 4.3.1 of the USEPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000b) provides a discussion of metals in edible portions of fish. Of the CCR Parameters, EPA listed inorganic arsenic, cadmium, selenium, and methyl mercury as priority target analytes for fish tissue sampling programs.

In the KRP Baseline Ecological Risk Assessment (BERA; Arcadis 2012), arsenic and selenium in stream sediment were identified as the primary hazard drivers for ecological receptors (benthic macroinvertebrates). The KRP Baseline HHRA determined that arsenic in edible fish tissue was primarily organic arsenic, which has very low toxicity. Thus arsenic in fish tissue was not a risk driver for human health. Information on these CCR Parameters that is relevant to interpreting fish tissue analytical results collected during the TDEC Order EIs is summarized in **Appendix A**.

3.2.2 Ecological Sources of Information and Assessment Methods

The following sources of information and methods of assessment will be used to evaluate potential ecological exposures and hazards.

Benthic Invertebrate Communities: Concentrations of COPECs measured in samples of sediment and surface stream water from locations upstream, adjacent, and downstream of the TDEC Order plants will be compared to published ecological screening values, literature-derived toxicity values, and concentrations used in toxicity tests in the KRP studies. Concentrations of COPECs measured in the tissues of mayfly nymphs and adults will be compared spatially (upstream, adjacent, and downstream) by sample transects in nearby surface water bodies, and to critical body residues derived from the literature. TVA's benthic community indices will be compared spatially (upstream, adjacent, and downstream) and to historical benthic community indices derived as part of TVA's reservoir vital signs monitoring program.

Aquatic Plant Communities: Effects of potential releases of CCR constituents on aquatic plants in water bodies in close proximity to the TDEC Order plants will be inferred by comparing concentrations of COPECs in surface stream water and sediment to literature-derived screening levels and by evaluating possible spatial differences among upstream, adjacent, and downstream locations.

Fish Communities: Concentrations of COPECs measured in samples of sediment and surface stream water from locations upstream, adjacent, and downstream of the TDEC Order plants will be compared to published ecological screening values, literature-derived toxicity values, and concentrations observed in toxicity test samples from the KRP studies. Concentrations of COPECs measured in tissues of fish collected from sampling transects upstream, adjacent, and downstream will be compared to critical body residues derived from the literature and to findings from the KRP studies. In addition, TVA fish community assessments conducted at each plant over extended periods of time will constitute another line of evidence for assessing risks to fish communities from plant operations.

Amphibians and Reptiles: Effects of potential releases of CCR Parameters on amphibians and reptiles in the riparian habitat adjacent to the TDEC Order plants will be inferred by comparing COPEC concentrations in sediment and surface stream water to literature-derived screening levels and results of KRP biological investigations.

Mammals and Birds: There are three general classifications of mammals and birds based on feeding habits: herbivores, omnivores, and carnivores/piscivores. Food chain modeling based on an oral dose approach will be used to estimate exposures of these receptors to COPECs in surface stream water, sediment and biological (i.e., mayfly and fish) tissues. Exposure doses calculated for each COPEC and ingestion exposure pathway (i.e., ingestion of food, water and sediment) will be compared to literature-derived toxicity reference values to estimate potential hazards (refer to **Section 3.1.2**).

3.2.3 Environmental Investigations and Assessments Conducted for the Kingston Recovery Project

Following the CCR release from the KIF Plant in December 2008, TVA in partnership with federal and state agencies conducted numerous environmental sampling investigations, biological studies, and HHERAs to evaluate potential effects of the release on human and ecological receptors. Investigations were conducted immediately following the release as part of the Time-Critical Action to remove CCR material from the river system and adjacent properties, and additional sampling and assessment studies were conducted as part of the Non-Time-Critical Action after dredging of CCR material from the Emory River. The Baseline HHRA (Jacobs 2012) and BERA (Arcadis 2012) were conducted as part of the Non-Time Critical Removal Action for the River System, and represent conditions and potential risks to receptors from residual CCR that could not be removed or otherwise was not removed from the river sediments.The extensive information generated during the KRP between 2009 and 2014, were summarized by EPA in the Project Completion Fact Sheet (EPA 2014) and included results reported from each of the following:

- Approximately, 20,000 samples of air, water, sediment, CCR material, and biota resulting in more than 500,000 chemical analyses
- Toxicity testing conducted on water and sediments, including partial life-cycle tests of a duration as long as 60 days
- Field and laboratory studies of possible effects on fish and community health and reproduction
- Field biological studies on birds and other wildlife species conducted by TVA staff, consultants, government research agencies, and universities
- Site-specific HHERAs to evaluate potential impacts of the ash release and emergency response/cleanup activities on the surrounding human and ecological communities
- Approximately 50 papers published in peer-reviewed journals.

The KRP serves as a blueprint for the HHRAs and ERAs to be prepared under the TDEC Order. For instance, the HHERAs prepared for the KIF Plant following the December 2008 CCR release were based on multiple LOE, and many of these are also applicable to the TDEC Order HHERAs. The environmental settings adjacent to TDEC Order plants in Tennessee are similar to the settings assessed for the KRP. Regardless of how CCR Parameters have been or may be released into the surrounding environment from the CCR management units at a given plant, nearby surface streams and rivers are the primary locations where human and ecological receptors might be exposed. The major rivers adjacent to the TDEC Order plants are sources of public drinking water supplies and are widely used for boating, water sports, fishing, and shoreline activities. In addition, concentrations of CCR Parameters in samples of environmental media collected as part of the TDEC Order EIs can be compared to the analytical data generated during the KRP to infer risks to human and ecological receptors as LOE in the TDEC Order

HHERAs. Similarly, quantitative estimates of risk and results of biological studies conducted during the KRP may inform as to risks and biological effects that may occur at the TDEC Order plants.

3.2.3.1 Environmental Sampling Investigations

Following the 2008 CCR release at the KIF Plant, TVA conducted sampling of abiotic media and biota in the rivers and coves adjacent to the plant from 2009 to the present. Environmental sampling activities were associated with the dredging period (2009), post-dredging residual CCR period (2010–2011), and long-term monitoring (2013–present). Dredging period sampling was conducted to: (1) assess potential effects from dredging and ash dewatering activities on water column biota and benthic biota; and (2) characterize the toxicity of ash deposits in the KIF Plant river system on benthic biota. Post-dredging sampling was conducted to assess potential toxicity of the CCR remaining in the Clinch and Emory Rivers to benthic biota, fish, and aquatic-dependent ecological receptors (i.e., reptiles, birds, and mammals) after dredging operations ceased. Long-term monitoring of sediments, benthic biota, fish, and aquatic-dependent ecological receptors is continuing to assess the progress of the monitored natural recovery program. Information from reports of these investigations will be used to make inferences about risks at the TDEC Order plants (**Table 1**).

3.2.3.2 Biological Studies

Numerous toxicological and biological studies were conducted during the KRP to evaluate potential impacts of the 2008 CCR release on ecological communities using or inhabiting the rivers and coves adjacent to the KIF Plant. Toxicological evaluations conducted during the KRP included field and laboratory studies on water column and benthic invertebrates during dredging activities and field and laboratory studies on benthic invertebrates and fish during post-dredging and long-term monitoring activities (Sherard et al. 2015). Biological studies conducted during the KRP included field and laboratory assessments of benthic invertebrate communities, aquatic plant communities, fish communities, amphibians and reptiles, and mammals and birds inhabiting the KIF Plant river system. The biological studies included collecting tissue samples from benthic invertebrates, plants, amphibians, reptiles, birds, and mammals for analysis of CCR Parameters to evaluate bioaccumulation potential. In addition, reproductive health and community metrics were evaluated in fish and avian communities. Information from these reports will be used to make inferences about risks at the TDEC Order plants (**Table 1**).

3.2.3.3 Human Health and Ecological Risk Assessments

The Tennessee Department of Health (TDH) Environmental Epidemiology Program, in collaboration with the Agency for Toxic Substances and Disease Registry, evaluated the potential impacts of the December 2008 ash release and emergency response/cleanup activities on the health of the surrounding community (TDH 2010). The TDH used data reported from environmental samples collected and analyzed by the TVA, EPA, and TDEC in the health assessment. TVA's main KRP contractor, Jacobs Engineering, Inc., performed a baseline HHRA for the Non-Time-Critical Removal Actions for the Swan Pond Embayment/Dredge Cell Engineering Evaluation/Cost Analysis (EE/CA) (Jacobs 2010). It evaluated potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by ash west of Dike 2 in the Swan Pond Embayment.

Lines of Evidence to Be Used in the Human Health and Ecological Risk Assessments

A second baseline HHRA, the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Human Health Risk Assessment* (Jacobs 2012), evaluated potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by residual ash in the river system (Clinch, Emory, and Tennessee rivers). The HHRA represented conditions in the river system following removal of as much ash as practical and was based on analytical data collected in 2010 and 2011 from surface water, seasonally exposed sediment, and fish tissue (fillet) samples.

Jacobs also performed a screening level ecological risk assessment (SLERA) for the *Non-Time-Critical Removal Actions Swan Pond Embayment/Dredge Cell Engineering Evaluation/Cost Analysis (EE/CA)* (Jacobs 2010) that evaluated the possibility of adverse effects to terrestrial and aquatic receptors from direct contact with ash in the Dredge Cell and Swan Pond Embayment. Results of the SLERA indicated that a more detailed BERA was warranted for the river system to assess ecological risks following completion of the cleanup. The subsequent River System BERA (Arcadis 2012) evaluated potential adverse effects of CCR and CCR Parameters on 17 ecological receptors in the Clinch, Emory, and Tennessee rivers. The BERA assessed maintenance and reproduction of communities or populations of both lower trophic level and upper trophic level aquatic and riparian receptors. Information from these reports will be used to make inferences about risks at the TDEC Order plants (**Table 1**).

4.0 CONCLUSIONS

Due to the protective nature of the methods, exposure assumptions, and toxicity values that are used in HHERAs, the resulting quantitative risk estimates often overestimate risks to human and ecological receptors. The EPA encourages the use of multiple LOE such that a weight of evidence approach can be used to characterize risk. The objective of this report is to outline the multiple quantitative and qualitative LOE to be used in the HHERAs such that future CCR management decisions at the TDEC Order plants are informed by an assessment of risks based on the combined results of LOE rather than any single LOE alone. These include quantitative LOE for human and ecological risk (i.e., the calculation of carcinogenic risk, non-cancer hazard index and ecological hazard quotients), and qualitative LOE (e.g., published information on CCR and CCR constituents, findings from EIs conducted at each of the TDEC Order plants, and findings from the environmental sampling, biological studies, and HHERA conducted as part of the KRP). By using a multiple LOE approach, future CCR management decisions at the TDEC Order plants can be informed by an assessment of risk based on the combined results of LOE rather than any single LOE.

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TABLE

Table 1: Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order

Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Human Health Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order HHRA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Human Health Risk Assessment. Jacobs Engineering Group, July 11, 2012. EPA-AO-052. This baseline HHRA evaluated potential cancer risks and noncancer hazards for human receptors exposed to environmental media impacted by residual ash in the river system (Clinch, Emory, and Tennessee Rivers) based on analytical data collected in 2010 and 2011 from surface water, seasonally exposed sediment, and fish tissue (fillet) samples. Abiotic environmental media and fish tissue samples were collected from locations in the Clinch, Emory, and Tennessee Rivers impacted by the 2009 ash release, as well as unimpacted upstream reference (background) segments of the Clinch, Emory, and Little Emory Rivers. Samples of sediment, surface water, and fish tissue collected from each of the river reaches were analyzed for CCR constituents, as well as legacy constituents present in the river system from sources other than coal ash. Arsenic and selenium found in fish tissue were speciated to determine the chemical form. The HHRA evaluated the following receptor exposure scenarios: a resident using surface water for domestic supply, a recreational swimmer, a recreational beachcomber, and a recreational fisher.	Health risks for CCR constituents and legacy constituents did not exceed EPA acceptable risk ranges for residential domestic use of river water or recreational contact (swimmer) with river water. Health risks for CCR constituents and legacy constituents in seasonally exposed sediment did not exceed EPA acceptable risk ranges for recreational contact. Non-ash related legacy constituents PCBs and mercury were the primary contributors to cancer risk and non-cancer hazard for consumption of recreationally caught fish. Arsenic in fish filet was in the organic form (with one exception) and not evaluated (per EPA guidance). Major conclusion - no unacceptable risks to human receptors from concentrations of ash-related constituents remaining in the river system. EPA determined that no further actions were required to protect human health.	Concentrations of CCR constituents in surface water, seasonally exposed sediment, and fish fillet samples collected from reaches of the Emory and Clinch Rivers impacted by ash did not exceed EPA acceptable risk ranges for potentially exposed human receptors (i.e., domestic use of river water, recreational swimmer, beachcomber, and consumers of locally-caught fish).	Concentrations of CCR Parameters in surface stream water, seasonally-exposed sediment, and fish fillets in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP HHRA. If concentrations at the TDEC Order plant are within the range considered in this KRP HHRA, then risk and hazard for the recreational swimmer, beachcomber, and consumer of locally caught fish are expected to be similar (but not identical) to those reported in the KRP HHRA. Because none of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies, the post-removal conditions in the KRP river system and associated risks to human receptors documented in the KRP HHRA will be used as a "worst case" benchmark for comparing concentrations of CCR Parameters in surface water, seasonally-exposed sediments, and edible fish tissue collected for the TDEC Order plants.
		Arsenic in edible portions of fish was determined to be in the organic form (e.g. arsenobetaine). Organic arsenic is the most common form in fish and is much less toxic than inorganic arsenic.	The text will be revised as follows: "The assumption that most of the arsenic present in fish fillet tissue is in the organic form is based on EPA guidance (EPA 2000); research conducted by EPA (EPA 1997); state regulatory agencies (e.g., Idaho DEQ 2010; Oregon DEQ 2011); peer-reviewed publications (e.g., Schoof and Yager 2007; Rosemond et al., 2008); and speciation of fish fillet samples collected to support the Baseline Human Health Risk Assessment for the KRP (Jacobs 2012). Arsenic was determined to be in the organic form for most, but not all fillet samples from bluegill, largemouth bass, and channel catfish analyzed for the baseline HHRA. The same types of fish were collected for the TDEC Order investigations from streams with conditions similar to the Clinch, Emory, and Tennessee Rivers associated with the Kingston Fossil Plant. It is therefore reasonable to assume that the types of arsenic in fish fillet tissue collected for the TDEC order would be comparable to the KRP results. Rather than completely excluding arsenic in fish fillet from the TDEC Order human health risk assessments, it will be assumed that inorganic forms of arsenic comprise 10% of the total reported arsenic for quantification of risks to consumers of sport-caught fish. The assumption that, on average, 10% or less of the total arsenic in fish fillet tissue is in the inorganic form is supported by Schoof and Yager (2007), Idaho DEQ (2010), Rosemond et al. (2008), Oregon DEQ (2011), and references provided in Schoof (2014). References: - Idaho Department of Environmental Quality (DEQ). 2010. *Arsenic, Mercury and Selenium in Fish Tissue from Idaho Lakes and Reservoirs* , November 2010. - Oregon Department of Environmental Quality (DEQ). 2011. *Water Quality Standards and Recommendations-Arsenic* . Debra Sturdevant author. Draft April 4, 2011. - Rosemond S., Q. Xie, K. Liber. 2008. *Arsenic concentration and speciation in five freshwater fish species from Back Bay near Yellowknife, NT. Canada* . Environmental Monitoring and Assessment. 147:199-210. - Schoof R.A., and J.W. Yager. 2007. *Variation of total and speciated arsenic in commonly consumed fish and seafood* . Human and Ecological Risk Assessment, 13:946-965. - Schoof R.A. 2014. *Elk Valley Water Quality Plan Annex L.1. Human Health Evaluation of Current Baseline Conditions* , Prepared for Teck Coal Limited, Sparwood, BC by ENVIRON International Corporation, July 2014. - United States Environmental Protection Agency (EPA). 1997a. *Arsenic and Fish Consumption*. EPA-823-R-
		Mercury in fish tissues was not related to the CCR released into the river system.	Mercury in fish tissue may be related to natural and anthropogenic sources. Potential sources will be evaluated on a site-specific basis, including but not limited to: 1) mercury concentrations in fish collected adjacent to the plant will be compared to concentrations in fish collected from sampling reaches downstream of the plant and upstream of the plant; 2) spatial distribution of mercury concentrations in sediments adjacent to the plant compared to upstream and downstream; 3) local/regional geology; 4) existing fish consumption advisories for mercury that encompass river miles starting upstream of the plant and continuing downstream of the plant; and 5) documented (industrial) sources of mercury upstream of the plant.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA). Arcadis, August 3, 2012. EPA-AO-050 The BERA is a comprehensive evaluation of multiple receptors and pathways representing the aquatic/riparian foodweb in the Clinch, Emory, and Tennessee Rivers surrounding the Kingston Fossil Plant, incorporating the results of environmental samples (river water, sediment, sediment pore water, biological tissues), toxicity studies, fish and benthic macroinvertebrate community metrics, and dietary foodweb models. The extensive data collection provided multiple lines of evidence for most receptors evaluated in the BERA.	Weight of evidence risk characterization by receptor indicated: - negligible risks for fish, heron, osprey, and wood duck - low risks for aquatic vegetation, mammals (mink, raccoon, muskrat, gray bat), amphibians (toads and frogs), reptiles (turtles), killdeer, mallard, and tree swallow - moderate risks for benthic macroinvertebrates directly exposed to ash, arsenic and selenium in surface sediments for the most heavily impacted reaches of the Emory River, and low or negligiblefor all other areas of the Emory, Clinch, and Tennessee Rivers. The BERA identified benthic macroinvertebrate exposure to ash, arsenic, and selenium in sediment and potential dietary exposure to insectivorous birds that feed on benthic macroinvertebrates (killdeer and tree swallow) as the critical receptors and pathways requiring actions to manage risks. These findings supported the decision to implement a monitored natural recovery program, which was confirmed through long term monitoring.	The studies conducted during the KRP represent the conditions in the Clinch, Emory, and Tennessee Rivers in the vicinity of the Kingston Fossil Plant after as much ash as practical had been removed. The studies provide LOE for relationships between concentrations of ash and CCR constituents in sediment and surface water in the river system, concentrations in the tissues of ecological receptors, and potential adverse effects to individual organisms, populations, and communities.	None of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies. The post-removal conditions in the river system and associated risks to ecological receptors documented in the BERA will be used as a "worst case" benchmark for comparing concentrations of ash and CCR Parameters in environmental media and biota collected for the TDEC Order plants.
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Fish* - Weight of evidence risk characterization concluded that ash and ash-related constituents posed a negligible risk to fish communities in the Clinch, Emory, and Tennessee Riversbased on fish community surveys, fish toxicity tests, and fish reproduction studies.	Two programs for fish community surveys were used to characterize fish abundance and diversity through direct measurement. The survey results indicated no substantive impairment to the fish community related to ash or CCR constituents.	The types of fish collected during the EIs for the TDEC Order plants are comparable to the types of fish analyzed for the KRP BERA. Concentrations of CCR Parameters in surface stream water, sediment, and fish tissues in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP ERA to inform the characterization of risk to fish communities.
		The surface water toxicity testing program used fish as a test species, and fish toxicity tests were also conducted using ash-impacted sediment. These direct measures of potential toxicity found no significant health effects (i.e., no direct observations of reducted survivial, hatching succes, or developmental abnormalities).	
		Fish reproductive studies conducted to evaluate the bioaccumulation of metals of reproductive concern (such as selenium) in fish. No conclusive evidence of ecologically significant effects were observed from the fish reproductive studies.	Concentrations of CCR Parameters in fish tissues in streams adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP HHRA to infer the characterization of risk to fish communities.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Benthic Invertebrates* - Weight of evidence characterization concluded moderate risks for benthic invertebrates directly exposed to ash, arsenic and selenium in surface sediments for the most heavily impacted reaches of the Emory River, and low or negligiblefor all other areas of the Emory, Clinch, and Tennessee Rivers. Benthic community metrics were given the greatest weight because they are a direct measurement of community health. Three other lines of evidence (sediment toxicity tests, benthic invertebrate tissue concentrations, and sediment porewater concentrations) were consistent but contrary to the benthic invertebrate community survey results, indicating the potential for low risk to benthic invertbrates.	Benthic invertebrate community surveys suggested that differences in benthic community metrics were largely explained by variability in sediment substrate. Statistical analysis indicated that ash and arsenic were the most closely associated with adverse effects.	Consistent with the weight of evidence hierarchy in the BERA, benthic community metrics will be the primary LOE for the TDEC Order ERAs.
		Statistical analysis indicated that ash and arsenic were the most closely associated with adverse effects. Selenium was shown to bioaccumulate in benthic invertebrates. However, tissue concentrations alone were not considered reliable predictors of toxicity to benthic communities in the river system (outside of laboratory conditions). Literature-derived effects values were considered the least relevant LOE.	Concentrations of CCR Parameters in sediment and mayfly tissue collected during the environmental investigations for the TDEC Order will be compared to comparable data from the KRP. Relative concentrations in sediment (especially % ash, arsenic, and selenium) from surface streams adjacent to a TDEC Order plant will be used to infer the characterization of risk to benthic invertebrate communities.
	Aquatic Vegetation - Risk to aquatic plants were characterized based on constituent concentrations in abiotic media (surface stream water, sediment, sediment pore water) and biotic media (periphyton and aquatic vegetation). Evidence based on comparison of abiotic media to literature values was given a low weight.	Concentrations of ash-related constituents in vegetation did not indicate that concentrations are higher in vegetation growing within downstream reaches (relative to reference areas).	Concentrations of CCR Parameters in sediment and surface stream water collected during the environmental investigations for the TDEC Order will be compared to comparable data from the KRP. Relative concentrations will be used to infer the characterization of risk to aquatic vegetation.
	Aquatic- and Riparian-Feeding Birds - Risk to piscivores (Heron and Osprey) is based on multiple LOEs - egg health metrics, egg concentrations, and dietary exposure models. The multiple lines of evidence consistently indicated a negligible risk to piscivore birds.	Eggs were collected from heron and osprey nests in impacted and reference locations. Eggs were measured for weight, volume, length, width, and clutch size to evaluate whether CCR constituents were impacting egg development, and egg tissue was analyzed for CCR constituents. Authors concluded the magnitudes of differences were small and not likely biologically meaningful to population viability.	The findings of dietary models used to evaluate risk to piscivorous birds to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to piscivore birds.
	Aerial-Feeding Brids and Mammals - Risk to aerial feeding birds is based on multiple LOEs for the Tree swallow - reproductive data, egg tissue concentrations, nestling tissue concentrations, and dietary exposure models. The weight of evidence supported a conclusion of low risk to aerial-feeding birds. Risk to aerial feeding mammals (bats) was based on dietary exposure models. The evidence suggests that ash-related COPECs pose, at most, low risks to aerial-feeding insectivorous mammals that forage over the river system. however, due to the use of probabilistic modeling, confidence in this conclusion was low.	The Tree swallow study included the construction of over 500 nest boxes. Tree swallow egg, eggshell, and nestling concentrations, egg and nestling health metrics, and reproductive measures were statistically compared between impacted and reference locations. The findings suggested a small, but uncertain reduction in female fledglings per swallow nest initially hypothesized to be associated with selenium bioaccumulation. There was no evidence for adverse effects of selenium on bats at the concentrations occurring in emergent insects, though laboratory studies do show reduced growth in young at such concentrations.	The findings of dietary models used to evaluate risk to aerial-feeding birds to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to aerial-feeding birds. The findings of dietary models used to evaluate risk to aerial-feeding mammals to be evaluated in the ERAs for the TDEC Order plants will be compared to the findings of dietary models used in the KRP BERA to infer the characterization of risk to aerial-feeding mammals.
	Amphibians - Weight of evidence characterization concluded a low risk to amphibian populations based on whole body frog and toad tissue data and evaluation of surface water and sediment chemistry data.	American toads, spring peepers, and upland chorus frogs were collected from two impacted locations, two unimpacted locations (north of the ash spill), and a reference location. Whole body tissue samples were analysed for CCR constituents. The authors concluded that selenium was the CCR constituent with the clearest trend between sites and year; however, when compared with literature-derived whole-body amphibian concentrations, the concentrations measured in impacted areas appeared to reflect natural variability of amphibians.	Concentrations of CCR Parameters in surface stream water adjacent to TDEC Order plants can be compared to concentrations evaluated in this KRP ERA to infer the characterization of risk to amphibians.

Table 1. Multiple Lines of Evidence for the Human Health and Ecological Risk Assessments Under the TDEC Order (cont'd)
Summary of Key Studies Conducted for the Kingston Recovery Project

Lines of Evidence for the Ecological Risk Assessment

Study Title and Description	Major Findings	Key Lines of Evidence	Application to TDEC Order ERA
Kingston Ash Recovery Project, Non-Time Critical Removal Action, River System. Baseline Ecological Risk Assessment (BERA) (cont'd)	*Reptiles* - Weight of evidence characterization concluded a low risk to reptile populations based on turtle community surveys and chemical concentrations in turtle blood tissue, surface stream water, and sediment.	Turtle community surveys did not indicate alterations in community structure or obvious signs of illness in individual turtles. Concentrations of selenium and strontium in the blood of turtles from areas impacted by the ash release were higher than concentrations ins turtles from reference areas. These findings suggest increased exposure to turtles, but no adverse effects correlated with the blood concentrations of selenium and strontium could be found in the literature.	Concentrations of CCR Parameters in surface stream water and sediment adjacent to TDEC Order plants can be compared to concentrations evaluated in the KRP BERA to inform the characterization of risk to reptiles.
Updated Analysis and Temporal Trend Evaluations in Biota - Benthic Invertebrates (Arcadis 2015, 2020) Benthic invertebrate and fish community investigations were conducted in 2014 and 2017, as part of the Long-Term Monitoring Sampling and Analysis Plan (Jacobs 2013). The 2014 and 2017 studies assess benthic invertebrate tissue concentrations and potential impacts to benthic invertebrate community metrics across multiple impacted locations relative to reference locations in the Emory and Clinch Rivers and include toxicity testing in the laboratory. The 2014 and 2017 studies also included evaluation of fish reproductive health, bioaccumulation, physiological health, and community structure	Based on results of toxicity testing, sediment is not likely to impact benthic invertebrates in the Emory and Clinch Rivers.	Sediment samples from impacted sites at dilutions of 100%, 80%, 60%, 40%, and 20% impacted sediment showed no statistically significant reduction in survival or growth relative to sediment samples from reference locations.	Concentrations of CCR Parameters in sediment adjacent to TDEC Order plants can be compared to concentrations evaluated in this test to infer the characterization of risk to benthic invertebrates
	The 2014 benthic invertebrate community metrics were consistent with results from previous years. While some differences in community metrics were identified among impacted locations or between impacted locations compared to reference locations in 2017, these differences appear to be a reflection of substrate characteristics and natural variability in benthic communities, rather than negative impacts from residual ash.	Long-term monitoring supports conclusions of KRP BERA, which suggested that differences in benthic community metrics were largely explained by variability in sediment substrate.	This LOE increases the confidence of conclusions reached using benthic invertebrate community surveys, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Fish community health, as indicated by fish community health data and sportfish surveys, indicate no apparent relation to the ash spill.	Long-term monitoring of fish community health are consistent with fish community surveys reviewed as part of the KRP BERA, which concluded no substantive impairment to the fish community related to ash or ash-related constituents.	This LOE increases the confidence of conclusions reached in the KRP BERA, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Reproductive health for sentinel fish species (redear sunfish, bluegill sunfish, and largemouth bass) was evaluated between 2009 and 2017. The data indicate that there are no patterns to increases and decreases in the measures of reproductive health that were evaluated, and changes in condition measured at ash-impacted sites tend to be similar within each study year to those at reference sites.	Long-term monitoring of fish reproductive health is consistent with KRP BERA, which concluded no conclusive evidence of ecologically significant effects to fish reproductive health.	This LOE increases the confidence of conclusions reached in the KRP BERA, and provides additional support for monitored natural recovery as a potential remedial strategy.
	Fish tissue samples from sentinal species (redear sunfish, bluegill sunfish, and largemouth bass) were analyzed for arsenic, mercury and selenium. Selenium concentrations in fillets of these three species were higher in fish from impacted sites than from reference sites, consistent with previous years.	Selenium concentrations in fish fillets from impacted areas are higher than from reference sites	None of the other TDEC Order plants have released similar volumes of residual CCR material (ash) to adjacent surface water bodies. The potential effects from impacted areas will be used as a "worst case" benchmark for comparing results based on concentrations of ash and CCR Parameters in environmental media and biota collected for the TDEC Order plants.
	The health metrics for physiological and energetic responses were evaluated in sentinel fish (bluegill sunfish, redear sunfish, and largemouth bass).	Several health metrics that may be indicative of kidney or liver dysfunction were statistically different between impacted and reference sites.	

Notes:

CCR constituents are constituents serving to form, compose or make up the whole of CCR material

CCR Parameters are constituents listed In Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04

Appendix A
PUBLISHED INFORMATION ON PRIMARY CCR PARAMETERS IN FISH

PUBLISHED INFORMATION ON PRIMARY CCR PARAMETERS IN FISH

The Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order No. OGC15-0177 (TDEC Order) established the process whereby TDEC will oversee the Tennessee Valley Authority's implementation of the 2015 United States Environmental Protection Agency (EPA) Final Coal Combustion Residuals (CCR) Rule to ensure coordination and compliance with Tennessee laws and regulations that govern the management and disposal of CCR (TDEC 2015). As per the TDEC Order, samples of environmental media are analyzed for the following CCR Parameters listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- Antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH, radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids.

Samples of environmental media are also analyzed for five inorganic constituents listed in Appendix 1 of Tennessee Rule 0400-11-01-.04 that are not listed in 40 CFR 257:

- Copper, nickel, silver, vanadium, and zinc.

Consumption of locally-caught fish is an important pathway of exposure to contaminants for human and ecological receptors. Fish take up naturally-occurring metals/metalloids from their environment and incorporate some of them into tissue. The toxicity of metals depends on the chemical form and valence state, an important nuance that may not be represented by the toxicity factors used to estimate cancer risk and non-cancer hazard from total metals concentrations in environmental or biological media. Section 4.3.1 of the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000) provides a discussion of metals in edible portions of fish. Of the CCR Parameters, the EPA listed inorganic arsenic, cadmium, methyl mercury, and selenium as priority target analytes for fish tissue sampling programs.

In the Kingston Recovery Project (KRP) baseline ecological risk assessment, inorganic arsenic and selenium associated with ash in river sediments were identified as primary CCR-associated ecological risk drivers. Arsenic was not a significant risk driver for human consumption of locally-caught fish because analytical speciation indicated organic arsenic was the predominant chemical form in fish fillet. Organic arsenic is relatively non-toxic. Fish tissue samples collected during the environmental investigations for the TDEC Order plants were analyzed for total metals. As pointed out by the KRP human health risk assessment, the chemical form of a metal in biota (fish) consumed by human receptors is an important line of evidence for understanding potential risk. Information relevant to interpreting the fish tissue analytical results from the TDEC Order Environmental Investigations is summarized below.

COAL COMBUSTION RESIDUALS

The majority of the information available in the literature focuses on the impacts of fly and bottom ashes; other coal combustion wastes have received limited study. CCR disposal in landfills and settling ponds can influence adjacent aquatic ecosystems directly, through CCR management unit effluent and surface runoff, and indirectly, through seepage and groundwater contamination. Major impacts are generally associated with changes in water chemistry, including changes in pH and concentrations of potentially toxic elements (Carlson and Adriano 1993).

Sediment samples containing a broad range of ash content collected during the KRP from the Emory and Clinch rivers post-CCR release were used in a tiered toxicity testing program that included a combination of 10-day acute sediment toxicity tests and longer-term partial life cycle “definitive” tests. Two species (*Hyalella azteca* and *Chironomus dilutus*) were used in these tests to evaluate potential effects of the CCR release on the benthic community. Arsenic (and to a much lesser extent, selenium) in the ash was identified as the likely toxicant(s) causing observed effects in the laboratory toxicity tests. Sites in the Emory and Clinch Rivers with the greatest statistical and biologically relevant effects had arsenic concentrations in sediments twice the probable effects concentration of 33 milligram per kilogram. These sites contained greater than 50% ash. Sites with less than approximately 50% ash in sediments exhibited fewer toxic responses relative to the reference sediment in the laboratory (Stojak et al. 2014).

Parallel laboratory studies were performed on river sediment porewater samples collected throughout the KRP by investigators using various collection and porewater extraction methods to better understand the relationships between ash content and dissolved metals/metalloids concentrations. These studies show a general pattern of porewater arsenic concentrations that support the above-described toxicity test results. That is, relatively low and stable arsenic concentrations occurred at less than approximately 40% to 50% ash content in sediments, followed by a roughly linear relationship between porewater arsenic and ash content above that point (Sherrard et al. 2015).

Saying this, as part of the HHERA the CCR parameters listed above (not just arsenic, mercury and selenium) and measured in soil, sediment and fish tissue will be compared to medium-specific and receptor-specific human health screening levels and media-based ecological screening criteria and Critical Body Residues (refer to **Section 3.1.1.1** and **3.1.1.2** above). Concentrations of CCR Parameters lower than their respective screening levels are an indication that risks to human and ecological receptors are acceptable; if concentrations are greater than the screening levels, other lines of evidence will be used in the risk characterization.

ARSENIC

Arsenic is a non-metallic element (metalloid) that occurs naturally and is widely distributed in the environment. The toxicity of arsenicals depends on the nature of the compounds, and particularly the valence state of the arsenic atom (EPA 2000). Typically, compounds containing trivalent (+3) arsenic are much more toxic than those containing pentavalent (+5) arsenic. The valence of the arsenic is a more important factor in determining toxicity than the organic or inorganic nature of the arsenic-containing

compound (EPA 2000), although organic forms of arsenic are generally less toxic than inorganic forms (see below). With respect to inorganic arsenic compounds, pentavalent forms of arsenic (arsenates) are less toxic than trivalent forms (arsenites) (EPA 2000).

Section 4.3.1 of the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1. Fish Sampling and Analysis* (EPA 2000) provides a discussion of metals in edible portions of fish including the chemical forms of arsenic most frequently found in fish and seafood. Seafood is a major source of trace amounts of arsenic in the human diet. However, arsenic in the edible parts of fish and shellfish is predominantly present as the arsenic-containing organic compound arsenobetaine, which has been shown to be metabolically stable and nontoxic in a number of studies (EPA 2000). The assumption that most of the arsenic present in fish fillet tissue is in the organic form is based on EPA guidance (EPA 2000); research conducted by EPA (EPA 1997); state regulatory agencies (Idaho DEQ 2010; Oregon DEQ 2011); peer-reviewed publications (Schoof and Yager 2007; Rosemond et al. 2008); and speciation of fish fillet samples collected to support the Baseline Human Health Risk Assessment for the KRP (Jacobs 2012). Arsenic was determined to be in the organic form for most, but not all fillet samples from bluegill, largemouth bass, and channel catfish analyzed for the baseline HHRA. The same types of fish were collected for the TDEC Order investigations from streams with conditions similar to the Clinch, Emory, and Tennessee Rivers associated with the Kingston Fossil Plant. It is therefore reasonable to assume that the types of arsenic in fish fillet tissue collected for the TDEC order would be comparable to the KRP results. Rather than completely excluding arsenic in fish fillet from the TDEC Order human health risk assessments, it will be assumed that inorganic forms of arsenic comprise 10% of the total reported arsenic for quantification of risks to consumers of sport-caught fish. The assumption that, on average, 10% or less of the total arsenic in fish fillet tissue is in the inorganic form is supported by Schoof and Yager (2007), Idaho DEQ (2010), Rosemond et al. (2008), Oregon DEQ (2011), and references provided in Schoof (2014). Inorganic arsenic may be present in fish tissue but is generally a minor component of the total arsenic content compared to arsenobetaine. If present, inorganic arsenic may be a concern for human consumers of fish and seafood. Consequently, it is critical to determine the chemical forms of arsenic present in fish tissue consumed by people.

The chemical species of arsenic detected in fish fillet samples from the Emory and Clinch Rivers is important information for interpreting the results for fish fillet samples collected from the Tennessee Valley Authority coal-fired power plants subject to the TDEC Order (TDEC Order plants). The predominant chemical form of arsenic present in fish fillet samples from the Emory and Clinch Rivers was organic arsenic. The same types of fish analyzed during the KRP (i.e., largemouth bass, crappie, sunfish, and catfish) are common sportfish throughout the Tennessee Valley. It is reasonable to assume that arsenic in the fillet of the same types of fish collected from other locations is also predominantly in the organic form.

MERCURY

Mercury is a metallic element that occurs naturally in the environment. Metallic or elemental mercury (Hg^0) is the main form of mercury released into the air by natural processes. Mercury bound to other chemicals may have valence states of either +1 (Hg^{1+}) or +2 (Hg^{2+}). Mercury with a valence state of +1 is

referred to as mercurous mercury, and mercury with a valence state of +2 (divalent) is referred to as mercuric mercury. Many inorganic and organic compounds of mercury can be formed from the mercuric cation (ATSDR 1999).

In the environment, inorganic mercury can be methylated by microorganisms to methylmercury. Methylmercury can accumulate in the tissues of organisms. The animals at the top of the food chain tend to accumulate the most methylmercury in their bodies. A source of mercury release to the environment may, therefore, lead to increased levels of methylmercury in tissues of large fish and mammals (ATSDR 1999).

The general population is most commonly exposed to mercury primarily from two sources: (1) eating fish and marine mammals that may contain some methylmercury in their tissues; or (2) from the release of elemental mercury from the dental amalgam used in fillings (ATSDR 1999). Dietary intake is the most important source of non-occupational exposure to mercury, with fish and other seafood products being the dominant source of mercury in the diet. Most of the mercury consumed in fish or other seafood is the highly absorbable methylmercury form.

It should be noted that the majority of the mercury measured in environmental samples collected from the Kingston Fossil Plant were the result of regional legacy contamination issues and not from the 2008 CCR release (Arcadis 2020). Arnwine et al. (2014) conducted a study to evaluate the potential bioaccumulation of metals in native game fish in streams draining four land-use categories (i.e., active coal mines, abandoned/reclaimed coal mines, non-coal mining activities, and reference areas) in Tennessee and found that mercury concentrations in fish fillets were highest in fish collected from reference areas followed by fish collected downstream of inactive coalfields. The results of this study suggest that mercury is a naturally-occurring regional contaminant in Tennessee and also is related to historical coal mining and other activities. Thus, mercury concentrations measured during some of the TDEC Order Environmental Investigations may have a regional ambient contribution that should be considered during the interpretation of human health and ecological risk assessment results for those facilities.

SELENIUM

Selenium is a non-metallic element (metalloid) that occurs naturally in the environment. It is distributed widely in nature and is found in most rocks and soils at concentrations between 0.1 and 2.0 milligram per kilogram (Fishbein 1983 as cited in ATSDR 2003). Selenium is ubiquitous in the environment, being released from both natural and anthropogenic sources. The principal releases of selenium into the environment as a consequence of human activities result from the combustion of coal (ATSDR 2003).

The primary factor determining the fate of selenium in the environment is its oxidation state. Selenium is stable in four valence states (-2, 0, +4, and +6) and forms chemical compounds similar to those of sulfur (ATSDR 2003). The heavy metal selenides (-2) are insoluble in water, as is elemental selenium; the inorganic alkali selenites (+4) and selenates (+6) are soluble in water (Weast 1988 as cited in ATSDR 2003) and are, therefore, more bioavailable.

Selenium in an aquatic environment can be bioaccumulated by aquatic organisms (Chau and Riley 1965, Ohlendorf et al. 1986a, Rudd and Turner 1983a, and Saiki and Lowe 1987 as cited in ATSDR 2003). Soluble forms of selenium can be accumulated by plants. Although both selenite ($Se^{4+)}$ and selenate (Se^{6+}) are soluble forms of selenium, selenate was found to be the preferred form of selenium taken up by plants (Bañuelos and Meek 1990 as cited in ATSDR 2003). Terrestrial plants taking up soluble selenate and selenite can biosynthesize organic selenium compounds, predominantly selenomethionine and, to a lesser extent, selenocysteine; these compounds can be released to the soils once the plants die and decay (ATSDR 2003).

The primary sources of selenium in the human diet are meat products, and wheat bread and flour. Organ meats and seafood contain the highest concentrations of selenium (ATSDR 2003). However, it should be noted that selenium is an essential nutrient, and many individuals routinely ingest selenium as a dietary supplement.

Selenium in the tissues of fish and mayflies may be related to natural and anthropogenic sources. The potential for increased bioaccumulation of selenium in aquatic/riparian receptors from the management of CCR material will be evaluated using multiple lines of evidence, including but not limited to: 1) selenium concentrations in fish and mayfly tissues collected adjacent to the plant will be compared to concentrations in fish and mayfly tissues collected from sampling reaches downstream of the plant and upstream of the plant; 2) the spatial distribution of selenium concentrations in sediments adjacent to the plant compared to upstream and downstream; 3) local/regional geology; 4) concentrations of selenium in fish tissues (whole body, fillet, and ovaries) for protection of aquatic life (EPA 2016); 5) comparison of selenium concentrations in sediment, fish and mayfly tissues for the TDEC Order sites to concentrations in the same media collected for the KRP and Long Term Monitoring from reference and ash impacted reaches of the Clinch, Emory, and Tennessee Rivers; 6) KRP studies evaluating selenium concentrations in eggs and reproductive success of tree swallows (aerial feeding insectivores) from reference and ash impacted reaches of the Clinch, Emory and Tennessee Rivers; and 7) review of published reports of the relationships between selenium concentrations in environmental media (sediment and surface water) and uptake by aquatic organisms (benthic macroinvertebrates).

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APPENDIX B – SCREENING LEVELS USED IN THE HUMAN HEALTH RISK ASSESSMENT

APPENDIX B.1

PROPOSED RECEPTOR-SPECIFIC SCREENING LEVELS FOR HUMAN HEALTH

Stantec

Memo

To:	**TVA Core Team** **Tennessee Valley Authority**	**From:**	**Stantec**
File:	**Proposed Receptor-Specific Screening Levels for Human Health**	**Date:**	**June 25, 2021**

Reference: Proposed Receptor-Specific Screening Levels for Human Health (SSL_{HH})

INTRODUCTION AND REGULATORY CONTEXT

The purpose of this memorandum is to describe the derivation of receptor-specific screening levels (SSL_{HH}) for the human health risk assessment (HHRA) to be conducted within the regulatory context of the Tennessee Department of Environment and Conservation (TDEC) Commissioner's Order No. OGC15-0177, issued on August 6, 2015 and herein referred to as the TDEC Order. The Preamble to the TDEC Order states that one of the purposes of the Order is "*to establish a transparent, comprehensive process for the investigation, assessment, and remediation of unacceptable risks, resulting from the management and disposal of coal combustion residuals (CCR) at the Tennessee Valley Authority's (TVA) coal-fired power plants in Tennessee".*

As part of the TDEC Order, TVA is implementing Environmental Investigation Plans (EIPs) at the following seven TDEC Order plants in Tennessee:

- Allen Fossil (ALF) Plant
- Bull Run Fossil (BRF) Plant
- Cumberland Fossil (CUF) Plant
- Johnsonville Fossil (JOF) Plant
- John Sevier Fossil (JSF) Plant
- Kingston Fossil (KIF) Plant
- Watts Bar Fossil (WBF) Plant.

The EIP for each TDEC Order plant describes the investigation to be conducted. Multiple environmental media are being sampled at each TDEC Order plant for a common group of individual constituents, collectively called "CCR Parameters" (i.e., measurable representatives of components of CCR constituents), namely:

- antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH (standard unit), radium 226 and 228 (radium 226+228), selenium, sulfate, thallium, and total dissolved solids (specified by TDEC and

found listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257)

- copper, nickel, silver, vanadium, and zinc (the five inorganic constituents listed in Appendix I of TN Rule 0400-11-01-.04 (i.e., TDEC regulations) that are not listed in 40 CFR 257).

Environmental samples were analyzed for up to 26 individual CCR Parameters (listed above), as applicable to the media.

As per the TDEC Order, the findings of the environmental investigations described in the EIPs will be provided in TDEC Order plant-specific Environmental Assessment Reports (EARs). Environmental sampling is complete, or nearing completion, and development of the EARs has begun. Corrective Action/Risk Assessment (CARA) Plans will follow the EARs, and as stipulated in the TDEC Order, the CARA Plans will specify the actions (i.e., corrective measures) TVA plans to take at the TDEC Order plants and the basis for those actions. Corrective measures may include remediation, risk assessment and institutional controls, or no further action.

APPLICATION OF HUMAN HEALTH SCREENING LEVELS IN THE EAR AND THE CARA

For the EARs, concentrations of CCR Parameters in surface stream water, surface stream sediments, groundwater, and biological tissues collected from fish and benthic macroinvertebrates (mayflies) are being compared to conservative generic screening levels (not specific to an individual human or ecological receptor) and protective of human health and the environment. Generic screening levels used in the EAR are criteria or standards published by the State of Tennessee and the U.S. Environmental Protection Agency (EPA), other regulatory entities, or results from applicable studies conducted during the Kingston Recovery Project. These generic screening levels are described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in Environmental Assessment Report (EAR)* (**Attachment A**).

Except for surface stream water used as domestic water supply, the generic screening levels used in the EAR are not applicable to human health exposure assessment. As such, the SSL_{HH} described in this Technical Memorandum will be used in the HHRA to evaluate CCR Parameters in exposure pathways (e.g., sediment, fish tissue) for which there are no generic human health screening levels. For the CARA, concentrations of CCR Parameters reported in a media data set are compared to SSL_{HH}, which allows the CARA to focus on the subset of CCR Parameters that may contribute to risk. CCR Parameters above the SSL_{HH} will be further evaluated in the HHRA as part of the CARA. The methods used to derive SSL_{HH} for potential human exposure to CCR Parameters in environmental media near the TDEC Order plants are described in detail in the following sections of this Technical Memorandum. If CCR Parameter concentrations are lower than the SSL_{HH}, these CCR parameters will not be further evaluated in the HHRA. CCR Parameters with concentrations higher than the SSL_{HH} will be further evaluated in the HHRA but should not be interpreted as evidence of unacceptable risk to human health.

POTENTIAL HUMAN RECEPTORS AND PATHWAYS

The TDEC Order plants covered by the TDEC Order are similar. They were constructed during an approximately 20-year period between the early 1950s and mid-1970s. The environmental settings are similar across the fleet. The TDEC Order plants are located on large rivers that are sources of public drinking water supplies and are widely used for boating and water sports, fishing, and shoreline activities. CCR Parameters potentially released from the CCR management units could be transported to nearby surface streams and rivers where human exposure might occur. Possible movement of CCR Parameters in groundwater beneath CCR management units to offsite potable wells and springs is another potential exposure pathway being considered in the HHRA.

Based on current knowledge of the TDEC Order plants and adjacent land use, human health risks for one onsite and four offsite human receptors are being assessed. These receptors and exposure pathways are described below.

POTENTIAL ONSITE RECEPTORS

TVA still actively manages CCR at the BRF Plant, CUF Plant, and KIF Plant but each of these also has previously closed CCR units. The BRF Plant is phasing out coal-fired power generation. Coal-fired power generation has ceased at the JOF Plant and the facility is in the process of being decommissioned. The JSF Plant and WBF Plant have been decommissioned. The ALF Plant is in the process of closing its CCR management units by removal to a lined landfill.

Trespasser

Casual unauthorized visitors (trespassers) might access closed CCR units in locations where there are no physical barriers (e.g., fencing or barricades), but the opportunity for direct contact with CCR Parameters in environmental media are extremely limited for this potential receptor. In addition, compared to the onsite trespasser the onsite worker described below is the more highly exposed receptor and the SSL_{HH} developed for that worker would be protective of the potential trespasser. Therefore, no SSL_{HH} were developed for the trespasser.

Onsite Worker

Under current and reasonable future land uses, onsite workers are expected to have only limited direct contact with CCR or environmental media impacted by CCR once a final cover has been installed. Direct contact to CCR material would be limited to an onsite worker engaged in minor repairs to the infrastructure (e.g., piping, surface water management, etc.), or replacing rip-rap on exterior retention dikes in locations where seeps may have occurred prior to closure. Such occasional maintenance projects may occur, but would be of short duration (i.e., exposure frequency of 20 days or less). Consequently, an onsite worker who is not engaged in large-scale construction projects or daily CCR management is the most applicable onsite receptor.

Groundwater beneath the TVA facilities is not a source of potable water and is unlikely to be a future source of potable water under reasonably anticipated future land use. The onsite worker would have, at most, minor incidental contact with surface stream water or stream sediments. The SSL_{HH} for the onsite worker assumes the following routes of exposure to CCR parameters in CCR material or soil (Soil SSL_{HH}):

- Incidental ingestion of soil or CCR material
- Dermal exposure to soil or CCR material
- Inhalation of particulates released from soil or CCR material
- External exposure to ionizing radiation (radium-226+228) from soil or CCR material.

POTENTIAL OFFSITE RECEPTORS

Four potential future offsite human receptor scenarios have been identified that are considered common to most TDEC Order plants under current and reasonable future land use.

- Residential use of surface stream water for domestic water supply
- Private residential use of groundwater and springs for potable supply
- Recreational use of rivers and streams
- Consumption of fish taken from rivers and streams near the TDEC Order plants.

These receptor scenarios are described in more detail below.

Residential Use of Surface Stream Water for Domestic Water Supply

Except for the ALF Plant (located on McKellar Lake Harbor in the Port of Memphis), there are public water utilities with intakes on the rivers where TDEC Order plants are located. State of Tennessee and EPA water quality criteria and standards are the human health screening levels for domestic water supply and surface stream water used in the EAR and are sufficient and appropriate for assessing human health risk for residential use of surface stream water as a source for domestic water supply. Consequently, no SSL_{HH} were developed for this receptor. These screening levels are described in the Technical Memorandum*, Proposed Screening Levels for Data Analysis in Environmental Assessment Report (EAR)* **(Attachment A)**.

Residential Use of Groundwater and Springs for Private Potable Supply

The potential migration of CCR Parameters in onsite groundwater to offsite locations where there may be private potable wells or springs will be addressed by water use surveys and groundwater modeling. EPA drinking water standards and Tennessee Groundwater Protection Standards consistent with the Federal CCR Rule are the human health screening levels for CCR Parameters in groundwater and are sufficient and appropriate for assessing human health risk for residential potable use of groundwater and springs. Consequently, no SSL_{HH} were developed for this receptor. These screening levels are described in the

Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report (EAR)* (**Attachment A**).

Recreational Receptors

An important part of TVA's mission is to support recreational use of the Tennessee Valley's environmental resources. The rivers and reservoirs around TDEC Order plants are used for recreational activities year-round. Fishing from the shore and from boats occurs almost all year, with springtime being particularly popular for sport fishing. Water sports such as swimming, water skiing, and jet skiing occur primarily during the warmer months of the year and coincide with high pool levels in the reservoir sections of the major rivers where TDEC Order plants are located. The cooler months coincide with lower pool levels, which results in areas of seasonally-exposed sediments near the shoreline.

The SSL_{HH} derived for potential human exposures to CCR Parameters during recreational activities assume the receptors are residents who live near TDEC Order plants and actively use the rivers and streams for recreation. Consistent with EPA default exposure factors, the total exposure duration for a resident engaged in recreational activities is assumed to be 26 years. Age-specific exposure factors (e.g., body weight, skin surface area, and sediment ingestion rates) were considered in deriving the SSL_{HH} for the beachcomber receptor exposure to CCR parameters in seasonally-exposed stream sediments. Exposure could begin at birth and continue into adulthood. Very young children (birth to < 6 years of age), and older children/adolescents (older than six years and up to 16 years of age) are considered more sensitive to non-cancer health effects and mutagenic carcinogens than adults. SSL_{HH} derived for non-cancer health effects for a young child exposed to chemical typically are lower (more conservative) than SSL_{HH} for an adult.

Recreational Beachcomber

During the cooler months, people engage in activities such as beachcombing, camping, and fishing along the riverbanks and accessible areas of seasonally-exposed sediments. For the HHRA, seasonally-exposed sediment is defined as sediment in near-shore areas of lakes and streams that are not completely covered by water during seasonally low water levels, thus are accessible to humans and wildlife during those periods. Sediments in the stream channels that are submerged under water all year are not a complete pathway of exposure for this receptor and will not be evaluated in the HHRA.

Recreational beachcomber receptors are likely adults (i.e., 16 years and older) and older children/adolescents (i.e., 6 to <16 years old) who do not require constant adult supervision. However, younger children (i.e., 0 to <6 years old) also may occasionally be present during these activities. Accordingly, a child recreational beachcomber receptor was included in the development of SSL_{HH}. Infants and toddlers (i.e., 0 to <2 years old) may accompany adults but would be expected to be in strollers or on blankets that would have limited opportunity for direct contact with seasonally-exposed sediments.

The following routes of exposure were considered in deriving receptor-specific screening levels for contact with CCR Parameters to seasonally-exposed sediment (Sediment SSL_{HH}):

- Incidental ingestion of sediment
- Dermal exposure
- External exposure to ionizing radiation (radium-226+228).

The recreational beachcomber receptor may occasionally ingest or have dermal contact with surface stream water while walking across wet areas, picking up objects under shallow water, or cleaning hands and fishing tackle. However, these routes of exposure are limited and not expected to contribute substantially to risk for this receptor. Furthermore, recreational exposure with CCR Parameters in surface stream water is covered by screening levels for use of surface stream water as a domestic water supply.

Recreational Swimmer

Swimming, wading, and other water-contact activities occur primarily during the warmer months of the year when water levels are at high pool and most sediments are under water. The same individual may be a recreational swimmer or water skier from April through September and a beachcomber from October through March. Recreational swimmers may come into contact with CCR Parameters in river or stream water via incidental ingestion of surface stream water and dermal contact with surface stream water. Rather than deriving separate screening levels for recreational contact with surface stream water, human health screening levels for domestic water supply, as described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report (EAR)* **(Appendix A),** will be used to evaluate exposure for swimmers. Frequency and intensity of exposure to surface water used as domestic water supply by receptors of all age groups are greater than exposure to surface water through recreational contact, thus the screening levels for domestic water supply are protective of swimmers. CCR Parameters with concentrations higher than the screening levels will be further evaluated in the HHRA but should not be interpreted as evidence of unacceptable risk to human health. No SSL_{HH} were developed for recreational swimmers.

Consumer of Locally-Caught Sport Fish

Fishing, both from shore and from boats, is a popular activity year-round, and people of all ages [adults (ages 16 years and older), adolescents (6 to <16 years old) and children (0 to <6 years old)] eat locally-caught fish. In some cases, the recreational beachcomber also consumes fish that they have caught. Fish are also consumed by members of a fisherperson's family who do not themselves catch the fish. SSL_{HH} for CCR parameters in fish were derived using data presented in *EPA 2014b. Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (*National Health and Nutrition Examination Survey *[NHANES] 2003-2010).* The *NHANES* (part of the National Center for Health Statistics) collected information on the types and amounts of fish consumed by demographics and geographic regions within the U.S. The purpose of the NHANES data was to support the development of ambient water quality standards for protection of human health based on the concentrations of contaminants in fish tissue. However, the data are also relevant for deriving SSL_{HH} for the HHRAs as discussed below.

NHANES collected information on consumption of fish in the following categories: Total Fish (all types); Marine Finfish and Shellfish; Total Finfish; Total Shellfish; Freshwater Finfish and Estuarine Shellfish; and Finfish and Shellfish by Trophic Level. Data were aggregated by demographics (including age ranges), and by U.S. geographic regions. The SSL_{HH} are based on consumption rates for Freshwater Finfish and Estuarine Shellfish for the Inland South geographic region (includes Tennessee). This dataset is most likely to represent the amounts of locally-caught sportfish (finfish) consumed by receptors in the Tennessee Valley. The 95th percentile consumption rates (Table 1) were used in the calculation of the SSL_{HH}.

The types of fish sampled for the environmental investigations represented different feeding guilds, as relevant for the ecological risk assessment. While all fish sampled will be evaluated in the ecological risk assessment, gizzard shad whole-body tissue results will be excluded from the HHRA because humans use this type of fish as bait for game fish. Turtles, frogs, mussels, and crayfish may be infrequently consumed, but their consumption is minor relative to that of fish, thus will not be evaluated separately in the HHRA. Receptor-specific screening levels for consumption of fish (Fish SSL_{HH}) is protective of exposures from ingestion of these other minor sources.

EXPOSURE PARAMETERS FOR DERIVING HUMAN HEALTH SCREENING LEVELS

The exposure parameters and rationale for the derivation of SSL_{HH} are presented in **Table 1**. The sources for the exposure parameters used in the derivation of SSL_{HH} include:

- Risk Assessment Guidance for Superfund (RAGS). Volume I: Human Health Evaluation Manual (Part A) (EPA 1989)
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA 2002)
- Risk Assessment Guidance for Superfund (RAGS) Volume I: Human Health Evaluation Manual (Part E) (EPA 2004)
- Exposure Factors Handbook: 2011 Edition (EPA 2011)
- Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil (EPA 2012)
- Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors (EPA 2014a)
- Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003-2010) (EPA 2014b)
- Region 4 Human Health Risk Assessment Supplemental Guidance (EPA 2018)
- Exposure Factors Handbook Chapter 3 (Update): Ingestion of Water and Other Select Liquids (EPA 2019)
- Preliminary Remediation Goals for Radionuclides (PRG) (EPA 2020b).

TOXICITY VALUES FOR DERIVING HUMAN HEALTH SCREENING LEVELS

Toxicity values for the SSL_{HH} calculations were obtained from the following sources, in general order of preference:

- Integrated Risk Information System (IRIS) Database as cited in EPA's Regional Screening Level (RSL) Tables (EPA 2020a)
- Provisional Peer Reviewed Toxicity Values (PPRTVs) as cited in EPA's RSL Tables (EPA 2020a)
- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicology Profiles as cited in EPA's RSL Tables (EPA 2020a)
- California EPA toxicity values as cited in EPA's RSL Tables (EPA 2020a)
- PPRTV Appendix Screening Toxicity Values as cited in EPA's RSL Tables (EPA 2020a)
- Health Effects Assessment Summary Tables as cited in EPA's RSL Tables (EPA 2020a).

For Radium-226+228 specifically, default slope factors from the Preliminary Remediation Goals (PRG) calculator (EPA, 2020b) were used for the calculation of SSL_{HH}. Inorganic mercury is listed as a CCR parameter and the toxicity factor for the mercuric forms are used in deriving SSL_{HH} for non-biological media (sediment and CCR material). However, inorganic mercury is converted to methyl mercury by biological processes in the aquatic environment which then accumulates in biological tissues including fish muscle (fillet). It is assumed that human exposure from fish consumption is to methyl mercury rather than inorganic mercury. The chronic reference dose (RfD) of 0.0001 milligrams per kilogram per day (mg/kg-day) for methyl mercury was conservatively used to develop the Fish SSL_{HH} for consumption of locally caught fish. The toxicity values are presented in **Table 2**.

RfDs and reference concentrations (RfCs) were used for residential and recreational receptors; however, where available, subchronic RfDs and RfCs were used for onsite workers. Subchronic RfDs are specifically developed to be protective for short-term exposure to a compound, and the EPA recommends that subchronic oral RfDs should generally be used to evaluate the potential noncarcinogenic effects of exposure periods between two weeks and seven years. Therefore, since onsite workers are assumed to have an exposure duration of one year, subchronic RfDs and RfCs were generally considered more applicable than chronic values. However, the available subchronic RfDs for cadmium and copper are more conservative than the chronic toxicity values so additional review of the toxicity data was conducted to confirm the appropriate toxicity values for the onsite worker.

- An intermediate-duration oral minimal risk level (MRL) for cadmium (ATSDR 2012) was developed based on effects on bone density, whereas renal toxicity has been selected as the critical effect for EPA's IRIS chronic RfD (EPA 2020a) and a number of risk assessments (Health Canada 2020). EPA's IRIS chronic RfD of 0.001 mg/kg-day was last revised in 1989, but it is consistent with values developed by newer studies (e.g., 0.0008 mg/kg-day breakpoint indicative of the onset of pathological changes in renal effects [JECFA 2011]). As a result, the cadmium chronic RfD as presented in EPA's

RSL table (EPA 2020a) was used to evaluate both chronic and subchronic effects in the derivation of SSL_{HH} for cadmium for the onsite worker.

- Copper is an essential element, although both copper deficiency and overexposure can result in adverse effects. ATSDR (2004) noted that a number of acute-duration studies support the gastrointestinal tract as the sensitive target of toxicity in human, and therefore developed an intermediate-duration oral MRL for copper based on the only human study identified by ATSDR that evaluated gastrointestinal effects following intermediate exposure. Due to the limited availability of intermediate human studies to support the subchronic oral MRL, the more conservative and widely accepted copper chronic RfD as presented in EPA's RSL table (EPA 2020a) was used to evaluate both chronic and subchronic effects in the derivation of SSL_{HH} for copper.

HUMAN HEALTH SCREENING LEVELS CALCULATIONS

The equations used to develop SSL_{HH} for potentially complete exposure pathways to CCR Parameters by onsite workers, recreational beachcomber, and recreational user with consumption of locally-caught sport fish presented in this section are consistent with EPA guidance (EPA 1989; 1991; 2002; 2004; 2009a). For CCR Parameters that have been identified as producing carcinogenic effects, exposures are averaged for different stages of development by applying age-adjusted factors and equations adjusted in accordance with EPA guidance for carcinogenic effects (EPA 2020a). The exposure assumptions used in the SSL_{HH} calculations are presented in **Table 1**. The toxicity values used in the SSL_{HH} calculations are presented in **Table 2**. The SSL_{HH} for carcinogenic and non-carcinogenic CCR Parameters are based on a target cancer risk and hazard of $1x10^{-6}$ and 0.1, respectively. Detailed calculations of the carcinogenic and non-carcinogenic SSL_{HH} for each receptor are presented in **Tables B.1** through **B.9** in **Attachment B**.

The PRG equations presented in EPA's PRG User's Guide (EPA 2020b) and below were used in the quantification of potentially complete exposure pathways to Radium-226 and -228 within EPA's Peak PRG Calculator (EPA 2020b). Radium-226+228 SSL_{HH} were calculated using EPA's Peak PRG Calculator (EPA 2020b). Inputs and outputs from the Peak PRG calculator are presented in **Attachment C**.

The quantification of lead exposure differs from other analytes. Cause-and-effect relationships in humans have been correlated with blood concentrations of lead. Therefore, the preferred SSL_{HH} derivation approach for lead is the estimation of human blood lead concentrations associated with an exposure situation. The lead soil SSL_{HH} for an onsite worker, and lead sediment SSL_{HH} for an adult and adolescent recreational beachcomber were calculated using EPA's Adult Lead Model (ALM) (EPA 2017a). The ALM calculation output is presented in **Table B.10**. The sediment SSL_{HH} for a child recreational beachcomber was calculated using the Integrated Exposure Uptake Biokinetic Model (IEUBK) Version 1.1 (EPA 2009b). The IEUBK calculation output is presented in **Attachment D**. Default IEUBK input parameters were used except for a mother's blood lead concentration at childbirth of 0.6 microgram per deciliter (µg/dL) (EPA 2017b) and a sediment ingestion rate of 200 mg/day for age groups 12 to 84 months. A defensible SSL_{HH} for the consumption of locally caught sport fish could not be identified in applicable regulatory guidance or the scientific literature, nor could a SSL_{HH} be readily calculated. As such, a fish SSL_{HH} was not established for

lead. Lead will be evaluated as part of the HHRA, in the case that lead is detected in fish filet tissue collected as part of the environmental investigations.

EXPOSURE ROUTE AND PATHWAY-SPECIFIC SSL_{HH}

Soil

Onsite Worker Incidental Soil Ingestion

Cancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times BW_w \times AT}{IR_{soil} \times EF_{soil} \times CSF_o \times ED_w \times RBA \times CF}$$

Where:

TR = Target risk (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

IR_{soil} = Ingestion rate of soil (milligrams per day [mg/day])

EF_{soil} = Exposure frequency (days per year [days/year])

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Radiological Cancer Incidental Ingestion SSL_{HH} (picocuries [pCi] per gram [g]) =

$$\frac{TR}{IR_{soil} \times EF_{soil} \times SF_o \times ED_w \times CF}$$

Where:

TR = Target risk (unitless)

IR_{soil} = Ingestion rate of soil (mg/day)

EF_{soil} = Exposure frequency (days/year)

SF_o = Ingestion slope factor (risk/pCi)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-3} g/mg)

Noncancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{THQ \times BW_w \times AT}{IR_{soil} \times EF_{soil} \times \frac{1}{sRfD_o} \times ED_w \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

IR_{soil} = Ingestion rate of soil (mg/day)

EF_{soil} = Exposure frequency (days/year)

$sRfD_o$ = Subchronic oral reference dose (mg/kg-day)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Onsite Worker Dermal Soil Contact

Cancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{TR \times BW_w \times AT}{AF \times ABS \times SA_{soil} \times CSF_d \times EF_{soil} \times ED_w \times CF}$$

Where:

TR = Target risk (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

AF = Adherence factor of soil to skin (mg/square centimeter [cm^2])

ABS = Dermal absorption factor (unitless)

SA_{soil} = Skin surface area available for contact (cm^2)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$

EF_{soil} = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{THQ \times BW_w \times AT}{AF \times ABS \times SA_{soil} \times \frac{1}{sRfD_d} \times EF_{soil} \times ED_w \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

BW_w = Body weight (kg)

AT = Averaging time (period over which exposure is averaged – days)

AF = Adherence factor of soil to skin (mg/cm^2)

ABS = Dermal absorption factor (unitless)

SA_{soil} = Skin surface area available for contact (cm^2)

$sRfD_d$ = Subchronic dermal reference dose (mg/kg-day)

EF_{soil} = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (10^{-6} kg/mg)

Onsite Worker Inhalation of Soil Particulates

Cancer Inhalation of Particulates SSL_{HH} (mg/kg) =

$$\frac{TR \times AT \times CF}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times IUR \times EF_w \times ED_w}$$

Where:

TR = Target risk (unitless)

AT = Averaging time (days)

CF = Conversion factor (10^{-3} mg per µg)

PEF = Particulate emission factor for Other Construction Activities (cubic meters [m^3]/kg)

ET_w = Exposure time (hours/day)

IUR = Inhalation unit risk $(\mu g/m^3)^{-1}$

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

Radiological Cancer Inhalation of Particulates SSL_{HH} (pCi/g) =

$$\frac{TR}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times SF_i \times EF_w \times IRA_w \times CF \times ED_w}$$

Where:

TR = Target risk (unitless)

PEF = Particulate emission factor for Other Construction Activities (m^3/kg)

ET_w = Exposure time (hours/day)

SF_i = Inhalation slope factor (risk/pCi)

EF_w = Exposure frequency (days/year)

IRA_w = Inhalation rate (m^3/day)

CF = Conversion factor (1000 g/kg)

ED_w = Exposure duration (years)

Noncancer Inhalation of Particulates SSL_{HH} (mg/kg) =

$$\frac{THQ \times AT}{\left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times \frac{1}{RfC} \times EF_w \times ED_w}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

PEF = Particulate emission factor (cubic meters [m^3]/kg)

ET_w = Exposure time (hours/day)

RfC = Reference concentration (mg/m^3)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

Radiological Cancer External Exposure SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_{ext} \times EF_{soil} \times ACF_{ext} \times ED_w \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times GSF}$$

Where:

TR = Target risk (unitless)

SF_{ext} = External exposure slope factor (risk/yr per pCi/g)

EF_{soil} = Exposure frequency (days/year)

ACF_{ext} = Area correction factor (unitless)

ED_w = Exposure duration (years)

ET_w = Exposure time (hours/day)

GSF = Gamma shielding factor (unitless)

Sediment

Recreational Beachcomber Incidental Sediment Ingestion

Cancer Incidental Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_o \times IF_{sed} \times RBA \times CF}$$

Where:

$$IF_{sed} = \frac{ED_{rec-c} \times EF_{rec-c} \times IR_{sed-c}}{BW_{rec-c}} + \frac{ED_{rec\text{-}y} \times EF_{rec\text{-}y} \times IR_{sed\text{-}y}}{BW_{rec\text{-}y}} + \frac{ED_{rec\text{-}a} \times EF_{rec\text{-}a} \times IR_{sed\text{-}a}}{BW_{rec\text{-}a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$

IF_{sed} = Age-adjusted sediment ingestion factor (mg/kg)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

$ED_{rec\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{rec\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{sed\text{-}c}$ = Child (0 to <6) sediment ingestion rate (mg/day)

$BW_{rec\text{-}c}$ = Child (0 to <6) body weight (kg)

$ED_{rec\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$IR_{sed\text{-}y}$ = Adolescent (6 to <16) sediment ingestion rate (mg/day)

$BW_{rec\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

$ED_{rec\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{rec\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$IR_{sed\text{-}a}$ = Adult (16 to <26) sediment ingestion rate (mg/day)

$BW_{rec\text{-}a}$ = Adult (16 to <26) body weight (kg)

Radiological Cancer Incidental Ingestion SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_o \times IF_{sed} \times CF}$$

Where:

$$IF_{sed}=(ED_{rec\text{-}cy} \times EF_{rec\text{-}cy} \times IR_{sed\text{-}cy})+(ED_{rec\text{-}a} \times EF_{rec\text{-}a} \times IR_{sed\text{-}a})\ ;$$

and

TR = Target risk (unitless)

SF_o = Ingestion slope factor (risk/pCi)

IF_{sed} = Age-adjusted sediment ingestion factor (mg)

CF = Conversion factor (10^{-3} g/mg)

$ED_{rec\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) exposure frequency (days/year)

$IR_{sed\text{-}cy}$ = Child (0 to <6) and adolescent (6 to <16) sediment ingestion rate (mg/day)

$ED_{rec\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{rec\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$IR_{sed\text{-}a}$ = Adult (16 to <26) sediment ingestion rate (mg/day)

Noncancer Incidental Ingestion SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}c}}{\frac{1}{RfD_o} \times ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times IR_{sed\text{-}c} \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}c}$ = Child (0 to <6) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{rec\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{rec\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{sed\text{-}c}$ = Child (0 to <6) soil ingestion rate (mg/day)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Incidental Ingestion SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}y}}{\frac{1}{RfD_o} \times ED_{rec\text{-}y} \times EF_{rec\text{-}y} \times IR_{sed\text{-}y} \times RBA \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

$ED_{rec\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$IR_{sed\text{-}y}$ = Adolescent (6 to <16) soil ingestion rate (mg/day)

RBA = Relative bioavailability factor

CF = Conversion factor (10^{-6} kg/mg)

Recreational Beachcomber Dermal Contact with Sediment

Cancer Dermal Absorption SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_d \times DF_{sed} \times ABS \times CF}$$

Where:

$$DF_{sed} = \frac{ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times SA_{rec\text{-}c} \times AF_{rec\text{-}c}}{BW_{rec\text{-}c}} + \frac{ED_{rec\text{-}y} \times EF_{rec\text{-}y} \times SA_{rec\text{-}y} \times AF_{rec\text{-}y}}{BW_{rec\text{-}y}} + \frac{ED_{rec\text{-}a} \times EF_{rec\text{-}a} \times SA_{rec\text{-}a} \times AF_{rec\text{-}a}}{BW_{rec\text{-}a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$

DF_{sed} = Age-adjusted sediment dermal factor (mg/kg)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

$ED_{rec\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{rec\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$SA_{rec\text{-}c}$ = Child (0 to <6) skin surface area (cm^2)

$AF_{rec\text{-}c}$ = Child (0 to <6) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}c}$ = Child (0 to <6) body weight (kg)

$ED_{rec\text{-}y}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{rec\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$SA_{rec\text{-}y}$ = Adolescent (6 to <16) skin surface area (cm^2)

$AF_{rec\text{-}y}$ = Adolescent (6 to <16) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

$ED_{rec\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{rec\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$SA_{rec\text{-}a}$ = Adult (16 to <26) skin surface area (cm^2)

$AF_{rec\text{-}a}$ = Adult (16 to <26) skin adherence factor (mg/cm^2)

$BW_{rec\text{-}a}$ = Adult (16 to <26) body weight (kg)

Noncancer Dermal Absorption SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec\text{-}c}}{\frac{1}{RfD_d} \times ED_{rec\text{-}c} \times EF_{rec\text{-}c} \times SA_{rec\text{-}c} \times AF_{rec\text{-}c} \times ABS \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

$BW_{rec\text{-}c}$ = Child body weight (kg)

RfD_d = Dermal reference dose (mg/kg-day)

ED_{rec-c} = Child (0 to <6) exposure duration (years)

EF_{rec-c} = Child (0 to <6) exposure frequency (days/year)

SA_{rec-c} = Child (0 to <6) skin surface area (cm^2)

AF_{rec-c} = Child (0 to <6) skin adherence factor (mg/cm^2)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Dermal Absorption SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{rec-y}}{\frac{1}{RfD_d} \times ED_{rec-y} \times EF_{rec-y} \times SA_{rec-y} \times AF_{rec-y} \times ABS \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

BW_{rec-y} = Adolescent body weight (kg)

RfD_d = Dermal reference dose (mg/kg-day)

ED_{rec-y} = Adolescent (6 to <16) exposure duration (years)

EF_{rec-y} = Adolescent (6 to <16) exposure frequency (days/year)

SA_{rec-y} = Adolescent (6 to <16) skin surface area (cm^2)

AF_{rec-y} = Adolescent (6 to <16) skin adherence factor (mg/cm^2)

ABS = Skin absorption factor (unitless)

CF = Conversion factor (10^{-6} kg/mg)

Radiological Cancer External Exposure SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_{ext} \times EF_{rec} \times \left(\frac{1\ year}{365\ day}\right) \times ED_{rec} \times ACF_{ext} \times ET_{rec} \times \left(\frac{1\ day}{24\ Hours}\right) \times GSF}$$

Where:

TR = Target risk (unitless)

SF_{ext} = External exposure slope factor (risk/yr per pCi/g)

EF_{rec} = Exposure frequency (days/year)

ED_{rec} = Exposure duration (years)

ACF_{ext} = Area correction factor (unitless)

ET_{rec} = Exposure time (hours/year)

GSF = Gamma shielding factor (unitless)

Fish

Consumer of Locally-Caught Sport Fish

Cancer Ingestion SSL_{HH} (mg/kg) =

$$\frac{TR \times AT}{CSF_o \times IF_{fish} \times CF}$$

Where:

$$IF_{fish} = \frac{ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c}}{BW_{fish\text{-}c}} + \frac{ED_{fish\text{-}y} \times EF_{fish\text{-}y} \times IR_{fish\text{-}y}}{BW_{fish\text{-}y}} + \frac{ED_{fish\text{-}a} \times EF_{fish\text{-}a} \times IR_{fish\text{-}a}}{BW_{fish\text{-}a}};$$

and

TR = Target risk (unitless)

AT = Averaging time (days)

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$

IF_{fish} = Age-adjusted fish ingestion factor (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

$ED_{fish\text{-}c}$ = Child (0 to <6) exposure duration (years)

$EF_{fish\text{-}c}$ = Child (0 to <6) exposure frequency (days/year)

$IR_{fish\text{-}c}$ = Child (0 to <6) fish consumption rate (mg/day)

$BW_{fish\text{-}c}$ = Child (0 to <6) body weight (kg)

$ED_{fish\text{-}c}$ = Adolescent (6 to <16) exposure duration (years)

$EF_{fish\text{-}y}$ = Adolescent (6 to <16) exposure frequency (days/year)

$IR_{fish\text{-}y}$ = Adolescent (6 to <16) fish consumption rate (mg/day)

$BW_{fish\text{-}y}$ = Adolescent (6 to <16) body weight (kg)

$ED_{fish\text{-}a}$ = Adult (16 to <26) exposure duration (years)

$EF_{fish\text{-}a}$ = Adult (16 to <26) exposure frequency (days/year)

$IR_{fish\text{-}a}$ = Adult (16 to <26) fish consumption rate (mg/day)

$BW_{fish\text{-}a}$ = Adult (16 to <26) body weight (kg)

Radionuclide Cancer Ingestion SSL_{HH} (pCi/g) =

$$\frac{TR}{SF_f \times ED_{fish} \times EF_{fish} \times IR_{fish} \times \left(\frac{10^{-3}\ g}{1\ mg}\right) \times CF_{fish}}$$

Where:

TR = Target risk (unitless)

SF_f = Fish slope factor (risk/pCi)

ED_{fish} = Exposure duration (years)

EF_{fish} = Exposure frequency (days/year)

IR_{fish} = Fish consumption rate (mg/day)

CF_{fish} = Contaminated fish fraction (unitless)

Noncancer Ingestion SSL_{HH} for a child (0 to <6) (mg/kg) =

$$\frac{THQ \times AT \times BW_{fish\text{-}c}}{\frac{1}{RfD_o} \times ED_{fish\text{-}c} \times EF_{fish\text{-}c} \times IR_{fish\text{-}c} \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

BW_{fish-c} = Child (0 to <6) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

ED_{fish-c} = Child (0 to <6) exposure duration (years)

EF_{fish-c} = Child (0 to <6) exposure frequency (days/year)

IR_{fish-c} = Child (0 to <6) fish consumption rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

Noncancer Ingestion SSL_{HH} for an adolescent (6 to <16) (mg/kg) =

$$\frac{THQ \times AT \times BW_{fish-y}}{\frac{1}{RfD_o} \times ED_{fish-y} \times EF_{fish-y} \times IR_{fish-y} \times CF}$$

Where:

THQ = Target hazard quotient (unitless)

AT = Averaging time (days)

BW_{fish-y} = Adolescent (6 to <16) body weight (kg)

RfD_o = Oral reference dose (mg/kg-day)

ED_{fish-y} = Adolescent (6 to <16) exposure duration (years)

EF_{fish-y} = Adolescent (6 to <16) exposure frequency (days/year)

IR_{fish-y} = Adolescent (6 to <16) fish consumption rate (mg/day)

CF = Conversion factor (10^{-6} kg/mg)

TOTAL SSL_{HH} CALCULATIONS

Total (i.e., including the relevant exposure pathways) onsite worker and recreational beachcomber SSL_{HH} were calculated based on a combination of exposure pathway-specific SSL_{HH}. In order to calculate a total SSL_{HH} that represents a CCR Parameter concentration in each medium that is protective of the identified exposure routes at a cumulative target cancer risk of 1×10^{-6} or a hazard quotient of 0.1, the target risk or hazard quotient for each exposure pathway-specific SSL_{HH} was apportioned across all routes of exposure within the pathway. A summary of cancer, non-carcinogenic, and lowest SSL_{HH} for each receptor is presented in **Table 3**.

Total SSL_{HH} for onsite workers were estimated using the following equations:

$$\text{Soil } SSL_{HH} = \frac{1}{SUM}$$

where:

$$SUM = \left(\frac{1}{\text{Ingestion } SSL_{HH}}\right) + \left(\frac{1}{\text{Dermal } SSL_{HH}}\right) + \left(\frac{1}{\text{Inhalation } SSL_{HH}}\right)$$

and where:

SSL_{HH} = cumulative SSL_{HH} for onsite workers (mg/kg)

SUM = sum of 1/exposure route-specific SSL_{HH}

Ingestion SSL_{HH} = SSL_{HH} for incidental ingestion of soil (mg/kg)

Dermal SSL_{HH} = SSL_{HH} for dermal contact with soil (mg/kg)

Inhalation SSL_{HH} = SSL_{HH} for inhalation of particulates (mg/kg)

Total SSL_{HH} for recreational beachcombers were estimated using the following equations:

$$\text{Sediment } SSL_{HH} = \frac{1}{SUM}$$

where:

$$SUM = \left(\frac{1}{\text{Ingestion } SSL_{HH}}\right) + \left(\frac{1}{\text{Dermal } SSL_{HH}}\right)$$

and where:

SSL_{HH} = cumulative SSL_{HH} for recreational beachcombers (mg/kg)

SUM = sum of 1/exposure route-specific SSL_{HH}

Ingestion SSL_{HH} = SSL_{HH} for incidental ingestion of sediment (mg/kg)

Dermal SSL_{HH} = SSL_{HH} for dermal contact with sediment (mg/kg)

CONCLUSION

This memorandum describes the methodology and assumptions used to derive SSL_{HH} for 1) onsite workers potentially exposed to CCR Parameters in CCR material or soil, 2) offsite recreational beachcombers potentially exposed to CCR parameters in seasonally exposed sediments, and 3) offsite consumers of locally-

caught sport fish potentially exposed to CCR parameters via the consumption of locally-caught sport fish. Human health screening levels for domestic water supply, as described in the Technical Memorandum, *Proposed Screening Levels for Data Analysis in the Environmental Assessment Report* (EAR) **(Appendix A)**, will be used to evaluate exposure for offsite swimmers. A summary of SSL_{HH} is presented in **Table 3**. These SSL_{HH} and screening levels for domestic water supply will be used to identify CCR parameters and exposure pathways to be further evaluated in the HHRA.

CLOSURE

This Technical Memorandum entitled *Proposed Receptor-Specific Screening Levels for Human Health* was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of TVA (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

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Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Soil and CCR Materials	On-Site Worker	Adult	Ingestion	IR_{soil}	Ingestion Rate of Soil	mg/day	330	-	-	Soil ingestion rate for a construction worker (EPA 2002)
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				CF	Conversion Factor	kg/mg	1E-06	-	-	-
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	-	-	Default (EPA 2012)
				BW_w	Body Weight	kg	80	-	-	Adult worker body weight (EPA 2014a)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	-	-	-
				AF	Adherence factor of soil to skin	mg/cm^2-event	0.3	-	-	Default adherence factors for a construction worker (EPA 2002)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	-	-	EPA 2004
				SA_{soil}	Skin surface area available for contact	cm^2	3527	-	-	Worker skin surface area (EPA 2014a).
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				Edw	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				BW_w	Body Weight	kg	80	-	-	Adult worker body weight (EPA 2014a)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			Inhalation	CF	Conversion Factor	mg/µg	1E-03	-	-	-
				IRA	Inhalation Rate for Radionuclide	m^3/day	60	-	-	EPA 2020b
				ET_w	Exposure Time	hours/day	8	-	-	Worker air exposure time (EPA 2014a)
				PEF	Particulate Emission Factor	m^3/kg	1.56E+06	-	-	Regional Screening Level (RSL) Calculator Construction Worker - Other Construction Activities scenario (Site-specific assumption)
				EF_w	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				$AT\text{-}NC_w$	Averaging Time (noncancer)	days	28	-	-	7 days/week for 4 weeks
				AT- C	Averaging Time (cancer)	days	25,550	-	-	Lifetime (70 years) x 365 days/year (EPA 1989)
			External Exposure	EF_{soil}	Exposure Frequency	days/yr	20	-	-	5 days a week for 4 weeks (Site-specific assumption)
				ED_w	Exposure Duration	yrs	1	-	-	Exposure duration for a construction worker (EPA 2002)
				ACF	Site Area for Area Correction Factor	acres	0.5	-	-	EPA 2020b
				GSF	Clean Soil Thickness for Gamma Shielding Factor	cm	0.0	-	-	EPA 2020b
				ET_o	Exposure Time - Outdoor	unitless	8	-	-	Worker soil exposure time (EPA 2014a)

Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Seasonally Exposed Sediment along Shoreline	Recreational User - Beachcomber	Adult/ Adolescent/ Child	Ingestion	IR_{sed}	Ingestion Rate of Sediment	mg/day	100	200	200	Default Ingestion Rate for adult and child resident (EPA 2014a)
				EF_{rec}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March. No exposure to sediment is assumed from April to through September (Site-specific assumption).
				CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				RBA	Relative Bioavailability Factor	unitless	0.6 (Arsenic) 1 (Other chemicals)	0.6 (Arsenic) 1 (Other chemicals)	0.6 (Arsenic) 1 (Other chemicals)	Default (EPA 2012)
				BW_{rec}	Body Weight	kg	80	44.3	15	Adult and child body weights are equal to default body weights for child and adult residents (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{rec}$	Averaging Time (noncancer)	days	3,650	3650	2190	$ED_{adult/adol/child}$ x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)
			Dermal	CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				AF_{rec}	Adherence factor of soil to skin	mg/cm^2	0.07	0.2	0.2	Default adherence factors for adult and child resident (EPA 2014a)
				ABS	Dermal absorption fraction	unitless	Chemical Specific	Chemical Specific	Chemical Specific	EPA 2004
				SA_{rec}	Skin surface area available for contact	cm^2	6,032	3,754	2,373	The adult and child surface areas are equal to default surface areas for adult and child residents (EPA 2014a). The adolescent surface areas are equal to weighted average of mean values (Tables 7-2, EPA 2011) for head, hands, arms and legs for 6 to <16 years adjusted for forearm and lower leg using forearm and lower leg-specific data (Table 7-12, EPA 2011) for males and lower leg-specific data (Table 7-13, EPA 2011) for females.
				EF_{sed}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March. No exposure to sediment is assumed from April to through September (Site-specific assumption).
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				BW_{rec}	Body Weight	kg	80	44.3	15	Adult and child body weight equal to the adult and child resident (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{rec}$	Averaging Time (noncancer)	days	3,650	3,650	2,190	ED_{adult} x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)

Table 1 – Exposure Assumptions Used in the Development of Receptor-Specific Screening Levels for Human Health

Exposure Point	Potential Receptors	(Adolescent, Adult, Child)	Exposure Route	Parameter Code	Parameter Definition	Units	Adult (age 16 and older)	Adolescent (6 to <16)	Child (0 to <6)	Rationale/Reference
Fish	Recreational User - Consumer of Locally-Caught Sport Fish	Adult/ Adolescent/ Child	Ingestion	CF	Conversion Factor	kg/mg	1E-06	1E-06	1E-06	-
				EF_{fish}	Exposure Frequency	days/yr	350	350	350	Default exposure frequency for residents (EPA 2014a)
				IR_{fish}	Fish intake rate	g ww/day	32.7	12.8	8.7	Adult fish intake rates equal to 95th percentile fish consumption rates for inland south region (Table 9a, EPA 2014b). Adolescent and child fish intake rates are age-adjusted 95th percentile fish consumption rates for 1 to <6 years old and 6 to <16 years old, respectively (Table 20a, EPA 2014b).
				ED_{fish}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to an adult resident (26 years) because recreators are assumed to be an adult living adjacent to the river (EPA 2014a). Child exposure duration equal to a child resident (EPA 2014a). An adolescent is a receptor living adjacent to the river from 6 to <16 years old (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				BW_{fish}	Body Weight	kg	80	44.3	15	Adult and child body weight equal to the adult and child resident (EPA 2014a). Adolescent body weight is equal to the weighted average of mean body weights for 6 to <16 years (Table 8-1, EPA 2011).
				$AT\text{-}NC_{fish}$	Averaging Time (noncancer)	days	3,650	3650	2190	$ED_{adult/adol/child}$ x 365 days/year (EPA 1989)
				AT- C	Averaging Time (cancer)	days	25,550	25,550	25,550	Lifetime (70 years) x 365 days/year (EPA 1989)
Seasonally Exposed Sediment along Shoreline	Recreational User-Beachcomber	Adult/ Adolescent/ Child	External Exposure	EF_{sed}	Exposure Frequency	days/yr	52	52	52	Recreational user may be exposed to sediment during the winter when water levels are lower, exposing the sediment. Exposure to near shore sediments is assumed to be two days per week from October through March (Site-specific assumption)
				ED_{rec}	Exposure Duration	yrs	10	10	6	Total exposure duration is equal to a resident (26 years) because recreators are assumed to living adjacent to the river (EPA 2014a). Child and adolescent are receptors living adjacent to the river from 0 to <6 years old and 6 to <16 years old, respectively (Site-specific). The adult exposure duration is 10 years because the adult exposure duration is equal to the total residential exposure duration (26) minus the adolescent duration (10) and the child duration (6).
				ACF Area	Site Area for Area Correction Factor	acres	0.5	0.5	0.5	EPA 2020b
				GSF Soil Thickness	Clean Soil Thickness for Gamma Shielding Factor	cm	0	0	0	EPA 2020b
				ET_o	Exposure Time - Outdoor	unitless	0.0833	0.0833	0.0833	Beachcomber assumed to be exposed to sediment 2 hours per event (Site-specific)

Notes:

- not applicable
cm - centimeters
cm^2 - square centimeters
days/yr - days per year
g ww/day - grams wet weight per day
kg - kilogram
kg/mg - kilograms per milligram
m^3/day - cubic meters per day
m^3/kg - cubic meters per kilogram
mg/cm^2 - milligrams per square centimeters
mg/cm^2-event - milligrams per square centimeters per event
mg/day - milligrams per day
mg/µg - milligrams per microgram
yrs - year

Table 2 - Toxicity Values Used in the Development of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Cancer Slope Factor (mg/kg-day)$^{-1}$ Oral		Cancer Slope Factor (mg/kg-day)$^{-1}$ Dermal[c]		IUR ($\mu g/m^3$)$^{-1}$ Inhalation		Chronic RfD (mg/kg-day) Oral		Chronic RfD (mg/kg-day) Dermal[c]		Subchronic RfD[a] (mg/kg-day) Oral		Subchronic RfD[a] (mg/kg-day) Dermal[c]		Subchronic RfC[a] (mg/m^3) Inhalation		ABS_{GI}[b] (%)
Inorganics																		
Antimony	7440-36-0	na	na	na	na	na	na	4.0E-04	I	6.0E-05	R	4.0E-04	P	6.0E-05	R	1.0E-03	A	15%
Arsenic	7440-38-2	1.5E+00	I	1.5E+00	R	4.3E-03	I	3.0E-04	I	3.0E-04	R	3.0E-04	cr	3.0E-04	R	1.5E-05	C	100%
Barium	7440-39-3	na	na	na	na	na	na	2.0E-01	I	1.4E-02	R	2.0E-01	A	1.4E-02	R	5.0E-03	H	7%
Beryllium	7440-41-7	na	na	na	na	2.4E-03	I	2.0E-03	I	1.4E-05	R	5.0E-03	H	3.5E-05	R	2.0E-05	I	0.7%
Boron	7440-42-8	na	na	na	na	na	na	2.0E-01	I	2.0E-01	R	2.0E-01	A	2.0E-01	R	2.0E-02	H	100%
Cadmium (soil)	7440-43-9	na	na	na	na	1.8E-03	I	1.0E-03	I	2.5E-05	R	1.0E-03	cr	2.5E-05	R	1.0E-05	A	2.5%
Cadmium (water)	7440-43-9, wate	na	na	na	na	1.8E-03	I	5.0E-04	I	2.5E-05	R	5.0E-04	A	2.5E-05	R	1.0E-05	A	5%
Calcium	7440-70-2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Chromium[d]	7440-47-3	na	na	na	na	na	na	1.5E+00	I	2.0E-02	R	1.5E+00	H	2.0E-02	R	5.0E-03	A	1.3%
Cobalt	7440-48-4	na	na	na	na	9.0E-03	P	3.0E-04	P	3.0E-04	R	3.0E-03	P	3.0E-03	R	2.0E-05	P	100%
Copper	7440-50-8	na	na	na	na	na	na	4.0E-02	H	4.0E-02	R	4.0E-02	cr	4.0E-02	R	na	na	100%
Fluoride	16984-48-8	na	na	na	na	na	na	4.0E-02	C	4.0E-02	R	4.0E-02	cr	4.0E-02	R	1.3E-02	C	100%
Lead	7439-92-1	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	100%
Lithium	7439-93-2	na	na	na	na	na	na	2.0E-03	P	2.0E-03	R	2.0E-03	P	2.0E-03	R	na	na	100%
Mercury[e]	7439-97-6	na	na	na	na	na	na	3.0E-04	I	2.1E-05	R	2.0E-03	A	1.4E-04	R	3.0E-04	I	7%
Methyl Mercury	22967-92-6	na	na	na	na	na	na	1.0E-04	I	na	na	na	na	na	na	na	na	100%
Molybdenum	7439-98-7	na	na	na	na	na	na	5.0E-03	I	5.0E-03	R	6.0E-02	A	6.0E-02	R	2.0E-03	A	100%
Nickel	7440-02-0	na	na	na	na	2.6E-04	C	2.0E-02	I	8.0E-04	R	2.0E-02	H	8.0E-04	R	2.0E-04	A	4%
Selenium	7782-49-2	na	na	na	na	na	na	5.0E-03	I	5.0E-03	R	5.0E-03	H	5.0E-03	R	2.0E-02	C	100%
Silver	7440-22-4	na	na	na	na	na	na	5.0E-03	I	2.0E-04	R	5.0E-03	H	2.0E-04	R	na	na	4%
Sulfate	14808-79-8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na	na	1.0E-05	G	1.0E-05	R	4.0E-05	X	4.0E-05	R	na	na	100%
Vanadium	7440-62-2	na	na	na	na	na	na	5.0E-03	U	1.3E-04	R	1.0E-02	A	2.6E-04	R	1.0E-04	A	2.6%
Zinc	7440-66-6	na	na	na	na	na	na	3.0E-01	I	3.0E-01	R	3.0E-01	A	3.0E-01	R	na	na	100%

Sources:

A Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels as cited in the USEPA RSL Calculator (EPA, 2020a)

C California Environmental Protection Agency (CalEPA) Toxicity Values as cited in the USEPA RSL Calculator (EPA, 2020a)

cr chronic value

G Regional Screening Levels (RSLs) User's Guide (EPA, 2020a)

H Health Effects Assessment Summary Tables (HEAST) as cited in the USEPA RSL Calculator (EPA, 2020a)

I Integrated Risk Information System (IRIS) Database as cited in the USEPA RSL Calculator (EPA, 2020a)

P Provisional Peer Reviewed Toxicity Values (PPRTVs) as cited in the USEPA RSL Calculator (EPA, 2020a)

R route extrapolation

X Screening values in chemical-specific PPRTV Appendices as cited in the USEPA RSL Calculator (EPA, 2020a)

Table 2 - Toxicity Values Used in the Development of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Cancer Slope Factor (mg/kg-day)$^{-1}$		IUR ($\mu g/m^3$)$^{-1}$	Chronic RfD (mg/kg-day)		Subchronic RfD[a] (mg/kg-day)		Subchronic RfC[a] (mg/m^3)	ABS_{GI}[b]
		Oral	Dermal[c]	Inhalation	Oral	Dermal[c]	Oral	Dermal[c]	Inhalation	(%)

Notes:

[a] Subchronic RfDs and RfCs obtained from EPA's RSL Tables (EPA, 2020a) were used unless otherwise noted in text.

[b] Values are from USEPA Risk Assessment Guidance for Superfund (RAGS) Part E. Where no specific ABS_{GI} is available, the ABS_{GI} is assumed to be 100 percent (EPA, 2004).

[c] The following equations are used as recommended by the EPA (2004) to estimate dermal CSFs and RfDs from the ingestion toxicity values when ABS_{GI} is less than 50 percent:

Dermal RfD = Oral RfD x ABS_{GI} and Dermal CSF = Oral SF/ABS_{GI}.

When ABS_{GI} is greater than 50 percent, the dermal CSF and/or RfD is assumed to be equal to the oral CSF and/or RfD (EPA, 2004).

[d] Trivalent chromium used as a surrogate

[e] Mercuric chloride used as a surrogate

% - percent

ABS_{GI} - oral absorption efficiency

CAS - Chemical Abstracts Service registry number

CSF - cancer slope factor

IUR - inhalation unit risk

EPA - United States Environmental Protection Agency

mg/kg-day - milligram(s) per kilogram per day

mg/m^3 - milligram(s) per cubic meter

$\mu g/m^3$ - microgram(s) per cubic meter

na - not available/applicable

RfD - reference dose

RfC - reference concentration

URF - unit risk factor

Table 3 - Summary of Human Health Receptor-Specific Screening Levels

Analyte	CAS	Onsite Worker Soil SSL_{HH}			Recreational User - Beachcomber Sediment SSL_{HH}				Recreational User - Consumer of Locally-Caught Sport Fish Fish SSL_{HH}			
		Cancer	Non-Cancer	Lowest	Cancer	Non-Cancer Child (0 to <6)	Non-Cancer Adolescent (6 to <16)	Lowest	Cancer	Non-Cancer Child (0 to <6)	Non-Cancer Adolescent (6 to <16)	Lowest
		(mg/kg or pCi/g)			(mg/kg or pCi/g)				(mg/kg or pCi/g wet weight)			
Antimony	7440-36-0	na	1.3E+01	1.3E+01	na	2.1E+01	6.2E+01	2.1E+01	na	7.2E-02	1.4E-01	7.2E-02
Arsenic	7440-38-2	2.4E+02	5.9E+00	5.9E+00	3.4E+00	2.4E+01	6.5E+01	3.4E+00	4.7E-03	5.4E-02	1.1E-01	4.7E-03
Barium	7440-39-3	na	2.2E+03	2.2E+03	na	1.1E+04	3.1E+04	1.1E+04	na	3.6E+01	7.2E+01	3.6E+01
Beryllium	7440-41-7	2.5E+03	1.2E+01	1.2E+01	na	1.1E+02	3.1E+02	1.1E+02	na	3.6E-01	7.2E-01	3.6E-01
Boron	7440-42-8	na	4.5E+03	4.5E+03	na	1.1E+04	3.1E+04	1.1E+04	na	3.6E+01	7.2E+01	3.6E+01
Cadmium	7440-43-9	3.3E+03	5.4E+00	5.4E+00	na	4.8E+01	1.4E+02	4.8E+01	na	1.8E-01	3.6E-01	1.8E-01
Calcium	7440-70-2	na	na	na	na	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na	na	na	na	na
Chromium	7440-47-3	na	3.1E+03	3.1E+03	na	7.9E+04	2.3E+05	7.9E+04	na	2.7E+02	5.4E+02	2.7E+02
Cobalt	7440-48-4	6.6E+02	1.2E+01	1.2E+01	na	1.6E+01	4.7E+01	1.6E+01	na	5.4E-02	1.1E-01	5.4E-02
Copper	7440-50-8	na	1.4E+03	1.4E+03	na	2.1E+03	6.2E+03	2.1E+03	na	7.2E+00	1.4E+01	7.2E+00
Fluoride	16984-48-8	na	1.2E+03	1.2E+03	na	2.1E+03	6.2E+03	2.1E+03	na	na	na	na
Lead	7439-92-1	na	na	1.3E+02	na	7.8E+01	1.1E+03	7.8E+01	na	na	na	na
Lithium	7439-93-2	na	6.8E+01	6.8E+01	na	1.1E+02	3.1E+02	1.1E+02	na	3.6E-01	7.2E-01	3.6E-01
Mercury	7439-97-6	na	5.0E+01	5.0E+01	na	1.6E+01	4.7E+01	1.6E+01	na	1.8E-02	3.6E-02	1.8E-02
Molybdenum	7439-98-7	na	8.0E+02	8.0E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Nickel	7440-02-0	2.3E+04	1.1E+02	1.1E+02	na	1.1E+03	3.1E+03	1.1E+03	na	3.6E+00	7.2E+00	3.6E+00
Radium-226+228	13982-63-3/15262-20-1	6.5E+00	na	6.5E+00	3.1E-01	na	na	3.1E-01	na	na	na	na
Selenium	7782-49-2	na	1.7E+02	1.7E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Silver	7440-22-4	na	1.7E+02	1.7E+02	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Sulfate	14808-79-8	na	na	na	na	na	na	na	na	na	na	na
Thallium	7440-28-0	na	1.4E+00	1.4E+00	na	5.3E-01	1.6E+00	5.3E-01	na	1.8E-03	3.6E-03	1.8E-03
Vanadium	7440-62-2	na	5.5E+01	5.5E+01	na	2.6E+02	7.8E+02	2.6E+02	na	9.0E-01	1.8E+00	9.0E-01
Zinc	7440-66-6	na	1.0E+04	1.0E+04	na	1.6E+04	4.7E+04	1.6E+04	na	5.4E+01	1.1E+02	5.4E+01

Notes:

CAS - Chemical Abstracts Service registry number

mg/kg - milligrams per kilogram

na - not available/applicable

pCi/g - picocuries per gram

SSL_{HH} - receptor-specific screening level for human health

1. SSL_{HH} for all receptors calculated using a target risk and hazard of 1×10^{-6} and 0.1, respectively

2. Mercury SSL_{HH} for consumer of sport caught fish were calculated using the chronic reference dose for methyl mercury.

3. Fish SSL_{HH} were not developed for fluoride, sulfate and Radium 226+228 because these parameters were not analyzed in fish tissues as indicated in the Environmental Investigation Plans.

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT A – PROPOSED SCREENING LEVELS FOR DATA ANALYSIS IN ENVIRONMENTAL ASSESSMENT REPORT (EAR)

(SUBMITTED TO TDEC MARCH 31, 2021)

Stantec

Memo

To:	Missy Hedgecoth, Roy Quinn, Brandon Boyd, Paul Thomas	From:	Stantec
File:	Proposed Screening Levels for Sample Results in Environmental Assessment Report (EAR)	Date:	March 26, 2021

Reference: Proposed Screening Levels for Sample Results in the EAR

PURPOSE OF THE TECHNICAL MEMORANDUM

On August 6, 2015, the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to the Tennessee Valley Authority (TVA) for coal combustion residuals (CCR) compliance pursuant to the provisions of Tennessee's solid waste management and remediation laws. As part of the TDEC Order, Stantec is implementing Environmental Investigation Plans (EIPs) at seven TVA Fossil Plants in Tennessee. The EIP for each fossil plant provides Sampling and Analysis Plans (SAPs) for the types of investigations to be conducted at each fossil plant. As specified in the TDEC Order, within 60 days of the completion of the environmental investigations TVA is required to submit an Environmental Assessment Report (EAR), which shall provide *"…an analysis of the extent of soil, surface water, and ground water contamination by CCR at the site. The Department shall evaluate the EAR to determine if the extent of CCR contamination has been fully defined".* Collection of environmental samples is complete or nearing completion at all TVA Fossil Plants subject to the TDEC Order, and development of the EARs has commenced.

As required by the TDEC Order, samples of environmental media were analyzed for the following parameters listed in Appendix III and Appendix IV of the Federal CCR Rule, Title 40 of the Code of Federal Regulations Part 257 (40 CFR 257):

- antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium (total), cobalt, fluoride, lead, lithium, mercury (inorganic), molybdenum, pH (SU), radium 226 & 228, selenium, sulfate, thallium, and total dissolved solids.

Samples were also analyzed for five inorganic constituents listed in Appendix 1 of TN Rule 0400-11-01-.04 that are not listed in 40 CFR 257:

- copper, nickel, silver, vanadium, and zinc.

This Technical Memorandum describes proposed screening levels for the CCR Parameters analyzed in environmental investigation samples. The purpose of the screening levels in the EAR is to identify CCR Parameters in the environmental media that require further assessment in the Corrective Action Risk

Assessment Plan (CARA) to be submitted within 60 days of TDEC approval of the EAR. The screening levels used to evaluate environmental sample results are generic (not specific to an individual person or ecological receptor) and protective – frequently referred to as conservative. Environmental samples were analyzed for up to 26 individual CCR Parameters (listed above), as applicable to the media. CCR Parameters above screening levels will be further evaluated in the human health and ecological risk assessment in the CARA. Screening levels for protection of human health are proposed for groundwater and surface water. Screening levels for protection of ecological receptors are proposed for surface water, mayfly and fish tissue, and sediment. If there is more than one applicable screening level for an environmental medium (e.g. surface water), the lowest value will be selected to evaluate those analytical results in the EAR.

PROPOSED SCREENING LEVELS BY MEDIA

Groundwater

The proposed screening levels for groundwater are protective of the drinking water pathway for residential receptors. Analytical results for parameters detected in groundwater will be compared to screening levels obtained from the following hierarchy of sources:

- US EPA Maximum Contaminant Levels (MCLs)
- Tennessee MCLs in State of Tennessee Solid Waste Processing and Disposal (TN Rule 0400-11-01)
- US EPA groundwater protection standards listed in Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments (40 CFR Part 257.95(h))
- US EPA Secondary Maximum Contaminant Levels (SMCLs)
- US EPA residential tap water Regional Screening Levels (RSL).

The Proposed Human Health Screening Levels for Groundwater for the EAR are presented in Table 1.

Surface Water

Applicable screening levels for surface water are presented for human exposure through use of surface water for drinking water supply and for protection of fish and freshwater aquatic life. When more than one screening level is identified for the same parameter, the lowest of the available values is proposed as the screening level to evaluate surface water analytical results in the EAR.

Analytical results for parameters detected in surface water will be compared to screening levels for domestic water supply obtained from the following hierarchy of sources:

- State of Tennessee Drinking Water Standards (TN DWS) promulgated in the following Rules:
    - General Water Quality Criteria, Surface Water used for Domestic Water Supply (TN Rule 0400-40-03-.03)
    - Solid Waste Processing and Disposal (TN Rule 0400-11-01)

    - Public Water Systems (TN Rule 0400-45-01-.06 MCLS and 0400-45-01-.12 Secondary drinking water regulations)

- US EPA MCLs
- US EPA SMCLs
- US EPA residential tap water RSL
- US EPA Drinking Water Lifetime Health Advisory Level or HAL; (March 2018).

The proposed human health screening levels for surface water are identical to the screening levels for groundwater described previously, except for lead and zinc. The Tennessee criteria for lead for surface water used for Domestic Water Supply (TN Rule 0400-40-03-.03) is 5 micrograms per liter (µg/L) compared to the Tennessee Solid Waste Rule (TN Rule 0400-11-01) criteria of 15 µg/L which is also the alternative GWPS under the CCR Rule. The human health screening level for zinc in surface water is the US EPA Lifetime Health Advisory Level (HAL) of 2,000 µg/L derived from the oral RfD of 0.3 mg/kg bw-day to protect against immune and hematological effects. For groundwater, the screening level for zinc is the SMCL of 5,000 µg/L based on objectionable metallic taste. Selection of the SMCL for groundwater is consistent with the proposed hierarchy of sources.

The Proposed Human Health Screening Levels for Surface Water in the EAR are presented in Table 2.

Surface water screening levels for protection of freshwater aquatic life were identified from the sources described below. Published values for both acute and chronic effects are not available for all parameters analyzed in surface water. Where both acute and chronic values were available, the chronic values were selected since they are lower and more protective than acute values. For some parameters chronic screening levels are published for both total and dissolved concentrations. Hardness-dependent parameters (cadmium, chromium, lead, copper, nickel, silver, and zinc) are expressed as dissolved concentrations and adjusted where appropriate based on stream-specific water chemistry. All other parameters are expressed as total recoverable concentrations (TN Rule 0400-40-03-.03).

The majority of the surface water screening values to be used in the EARs and Ecological Risk Assessments (ERAs) for the TVA fossil plants under the TDEC Order are the Surface Water Screening Values for Hazardous Waste Sites referenced from *USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update)* or the TDEC General Water Quality Criteria (Chapter 0400-40-03, General Water Quality Criteria). Surface water screening levels that are hardness-dependent have been calculated using the formulae presented in the TDEC General Water Quality Criteria guidelines using site-specific hardness values for the major water bodies at each of the fossil plants. The mean hardness values for each of the major water bodies were determined using the data collected during the Environmental Investigations (EI) at each fossil plant and conservatively rounded down for use in the calculations.

The only surface water screening values that were not referenced from the TDEC or USEPA Region 4 sources cited above were for Radium-226 & -228. The surface water screening values for Radium-226 & -228 were the Biota Concentration Guides (BCG) for water referenced from the U. S. Department of Energy (DOE) report titled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE Standard (DOE-STD-1153-2019). The BCG is the limiting concentration of a radionuclide in soil, sediment,

or water that would not cause dose rate criteria for protection of populations of aquatic and terrestrial biota to be exceeded.

Human Health and Ecological Screening Levels for Surface Water are presented in Table 2. The proposed screening level for evaluation of surface water in the EAR is the lowest (most conservative) of the available values for each parameter. National Oceanic and Atmospheric Administration's (NOAA) Screening Quick Reference Tables (SQuiRTs) (Buchman 2008) were also reviewed to determine whether additional surface water screening values could be derived for constituents without screening levels in Table 2. Although the SQuiRTs provide screening levels for the dissolved fraction for several constituents where USEPA Region 4 and TDEC screening levels are unavailable, these screening values were not selected because some primary sources presented in SQuiRTs have been superseded and the SQuiRTs were developed in 2008 and are no longer being maintained by NOAA.

Mayfly Critical Body Residues

The mayfly tissue critical body residue values proposed as screening levels were referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment* (BERA) (Arcadis 2012), which used values from the USEPA/USACE Environmental Residue-Effects Database (ERED). A number of other potential sources of critical body residue data were searched in order to identify additional data and to fill data gaps but no additional data were located. Per Arcadis (2012) "CBR data were selected from literature-derived values from the ERED. The selection process included only whole-body data for the closest relevant species (i.e., mayfly) and life stages (e.g., adult selected over egg) for growth, mortality, or reproductive endpoints. Combined or absorbed doses were preferred over water only exposures. If the data were unpaired (i.e., only a NOAEL or LOAEL was available), either the highest NOAEL or the lowest LOAEL was selected. The corresponding value was extrapolated from the available value by a factor of 10. If only effects concentrations were available (e.g., LC_{50}, ED_{25}, etc.), the lowest effects concentration was selected as the LOAEL, and the estimated NOAEL was set at 1/10th the LOAEL value." The screening levels based on CBR values presented in Arcadis (2012) have been reviewed and accepted by TDEC and USEPA as part of their review and acceptance of the River System BERA (Arcadis 2012). As such, these values have been vetted and deemed acceptable for use as screening levels in the EAR for the fossil plants under the Commissioner's Order. Data presented in the ERED will be further evaluated and CBR values revised, if necessary, as part of the ecological risk assessments presented in the Corrective Action/Risk Assessment (CARA) reports for each of the fossil plants under the Commissioner's Order.

The Proposed Screening Levels for Mayfly Tissue Critical Body Residues for the EAR are presented in Table 3.

Fish Tissue Critical Body Residues

Human consumption of CCR parameters detected in fish fillet samples will be evaluated in the Human Health Risk Assessment in the CARA Plan.

The fish tissue critical body residue values proposed as screening levels for most of the constituents were referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment* (BERA) (Arcadis 2012), which used values from the USEPA/USACE ERED. As discussed above, the methodology for selecting the fish tissue critical body residue values and the screening levels based on CBR values presented in Arcadis (2012) have been

reviewed and accepted by TDEC and USEPA as part of their review and acceptance of the River System BERA (Arcadis 2012). As such, these values have been vetted and deemed acceptable for use as screening levels in the EAR for the fossil plants under the Commissioner's Order. Data presented in the ERED will be further evaluated and CBR values revised, if necessary, as part of the ecological risk assessments presented in the CARA reports for each of the fossil plants under the Commissioner's Order.

The fish tissue screening levels for selenium were referenced from the Chronic Ambient Water Quality Criterion for Selenium (USEPA 2016). A number of other potential sources of critical body residue data were searched in order to identify additional data and to fill data gaps but no additional data were located.

The Proposed Screening Levels for Fish Tissue Critical Body Residues for the EAR are presented in Table 4.

Sediment

Most of the proposed sediment screening values to be used to evaluate investigation analytical results in the EAR were derived by MacDonald, et al. (2003) in their paper *Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters* and adopted by USEPA Region 4 as their recommended Freshwater Sediment Screening Values presented in *Region 4 Ecological Risk Assessment Supplemental Guidance, March 2018 Update, Screening Values*. The Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) values derived by MacDonald, et al. (2003) are consensus-based values derived from multiple toxicity test results for a number of benthic species and are the basis for the majority of the USEPA Region 4 freshwater sediment screening values and correspond to USEPA Region 4 Ecological Screening Value (chronic) and Refinement Screening Value (acute) sediment screening values, respectively.

The USEPA Region 4 Freshwater Sediment Screening Values are recommended to be used for sediment screening values for the following constituents in sediment: antimony, arsenic, cadmium, chromium, cobalt, lead, mercury, selenium (acute), copper, nickel, silver, and zinc.

Several other sources, including NOAA's Screening Quick Reference Tables (SQuiRTs) (Buchman 2008), were referenced to identify sediment screening values in instances where USEPA Region 4 did not have recommended screening values or where other screening values were deemed more toxicologically defensible.

USEPA Region 4 does not have sediment screening values for percent ash; therefore, site-specific values were referenced from the approved EIP and the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System BERA* (Arcadis 2012). Sediment samples from the Emory and Clinch Rivers submitted for laboratory toxicity testing using standard aquatic organisms contained approximately 20 to 90 percent ash. Exposure to sediment with 40 percent ash was associated with 25 percent decreased survival and growth reduction in the test organisms compared to reference sediments. This was considered a biologically significant effect. 20 percent ash was proposed as the threshold triggering quantitative analysis of a sediment sample in the EIPs approved by TDEC. The EIPs for each fossil plant used a value of 20 percent ash in sediment samples as a Phase 1 screening level to determine if additional chemical analyses would be required. If a sediment sample from the zero to six-inch depth increment had less than 20 percent ash composition, then the sample was deemed to have insufficient ash content to pose deleterious effects from ash itself and sediment samples from deeper depth

increments would not be analyzed further. Based on this rationale, the 20 percent ash content is proposed as the chronic sediment screening value for percent ash.

The acute sediment screening value for percent ash is referenced from the *Kingston Ash Recovery Project Non-Time Critical Removal Action River System BERA* (Arcadis 2012). The Kingston BERA (Arcadis 2012) presented multiple toxicity test results that indicated sediment samples with 40 percent ash or greater were associated with statistically and biologically significant adverse effects. Based on these toxicity test results; 40 percent ash content is proposed as the acute sediment screening value for percent ash.

USEPA Region 4 provides sediment screening values for barium based on a study conducted by USEPA Region 5 in 1977 titled *Guidelines for the Pollution Classification of Great Lakes Harbor Sediments*. The sediment ESVs for barium derived by USEPA Region 5 (1977) and cited by USEPA Region 4 (2018) are not effects-based and are not based on measured toxicity to benthic or other organisms, which brings into question their defensibility for use in determining potential ecological risk to sediment-dwelling organisms. An alternative to the USEPA Region 4 sediment screening values for barium (and several other inorganics) is provided by The Netherlands National Institute for Public Health and the Environment (RIVM) in their report titled *Environmental Risk Limits for Nine Trace Elements* (van Vlaardingen, et al., 2005). The RIVM methodology utilizes toxicity data from the scientific literature to derive Environmental Risk Limits (ERL) including: 1) Maximum Permissible Concentration (MPC); and 2) Serious Risk Addition (SRA_{eco}).

The MPC as defined in the Netherlands report (RIVM 2005) is the concentration of a substance in air, water, soil, or sediment that should protect all species in ecosystems from adverse effects of that substance. Depending on the amount of toxicological data available, the lowest toxicity result is divided by a fixed value (assessment factor). When enough data are available, a cut-off value is used. This is the fifth percentile if a species sensitivity distribution of No-Observed-Effect-Concentration (NOEC) is used. This is the hazardous concentration for five percent of the species. This definition correlates well with the definition of the TEC as defined by MacDonald, et al. (2003) and adopted by USEPA Region 4 for chronic sediment screening levels.

The Serious Risk Addition (SRA_{eco}) concentration is the concentration of a substance in soil, sediment, or groundwater at which functions in these compartments will be seriously affected or are threatened to be negatively affected. This is assumed to occur when 50 percent of the species and/or 50 percent of the microbial and enzymatic processes are possibly affected. This definition correlates well with the definition of Probable Effect Concentration (PEC) as defined by MacDonald, et al. (2003) and adopted by USEPA Region 4 for acute sediment screening levels.

Literature-based toxicity data for effects on growth, reproduction or survival are used in the derivation of MPC and SRA_{eco} values. All categories are further subdivided into chronic and acute toxicity values. Chronic values (NOEC or EC_{10}) and acute values (EC_{50} or LC_{50}) are referenced or derived from the relevant studies. The lowest value (the most sensitive toxicity endpoint) of the available data per species is selected. The SRA_{eco} for the water compartment is derived by applying an assessment factor of 10 to the geometric mean of the selected acute toxicity data, which results in an SRA_{eco}, acute. This SRA_{eco}, acute is then compared to the geometric mean of all selected chronic data (SRA_{eco}, chronic). The lower of the SRA_{eco}, acute and the SRA*eco*, chronic value is defined as the SRA_{eco} for the water compartment. No toxicity data were identified for sediment; therefore, all of the MPC and the SRA_{eco} values for sediment

were calculated using surface water toxicity data and equilibrium partitioning by applying sediment-to-water partition coefficients.

The MPC of 240 mg/kg is proposed as the chronic sediment screening value for barium and the SRA_{eco} value of 22,925 mg/kg is proposed as the acute sediment screening value for barium.

USEPA Region 4, or any of the other sources researched for potential sediment screening values, does not provide sediment screening values for beryllium, molybdenum, thallium, or vanadium. As such, the MPC and the SRA_{eco} values for these constituents as derived using the RIVM (van Vlaardingen, et al., 2005) methodology are proposed as sediment screening values.

USEPA Region 4 references the Los Alamos National Laboratory (LANL) ECORISK database (2017) as the source for the sediment screening values for selenium. The chronic sediment screening value is identified as the "No Effect Ecological Screening Value" and the acute sediment screening value is identified as the "Low Effect Ecological Screening Value" in the ECORISK database; however, the source and toxicological basis (if any) of these values is not presented in the ECORISK database. Alternatively, Lemly (2002) has proposed a sediment screening value of 2.0 mg/kg in his book *Selenium Assessment in Aquatic Ecosystems* (2002). The screening level proposed by Lemly (2002) is based on selenium concentrations in sediment that result in body residues in benthic invertebrates that result in deleterious effects to fish and aquatic birds that consume benthic invertebrates. According to Lemly (2002), benthic invertebrates can tolerate significantly higher concentrations of selenium in sediment. Thus, the most important aspect of selenium concentrations in sediment is not direct toxicity to benthic invertebrates themselves, but the dietary source of selenium that benthic invertebrates provide to fish and wildlife species that feed on benthic invertebrates. Based on the information presented by Lemly (2002), 2.0 mg/kg is proposed as the chronic screening value for selenium in sediment and the acute sediment screening value is proposed as 2.9 mg/kg, which is the Refinement Screening Value as presented in USEPA Region 4 (2018). These sediment screening values are conservative compared to the remediation goals for selenium in sediment (3.0 – 3.2 mg/kg) presented in *the Kingston Ash Recovery Project Non-Time Critical Removal Action for the River System Long-Term Monitoring Sampling and Analysis Plan* (TVA, 2013).

USEPA Region 4 does not provide sediment screening values for Radium-226 or Radium-228. However, the DOE provides Biota Concentration Guides (BCG) for sediment in their guidance *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). The BCG is defined as the limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose rate criteria for protection of populations of aquatic and terrestrial biota to be exceeded. DOE (2019) presents BCG of 100 pCi/g for Radium-226 and 90 pCi/g for Radium-228. These values are recommended for sediment screening values for Radium-226 and Radium-228 individually and the lower of these two values (90 pCi/g) is recommended as the sediment screening value for combined Radium-226 & -228.

The Proposed Ecological Screening Levels for Freshwater Sediment for the EAR are presented in Table 5.

REFERENCES

Arcadis, 2012. *Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment* (BERA).

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Van Vlaardingen, et. al., 2005. The Netherlands National Institute for Public Health and the Environment (RIVM) report; *Environmental Risk Limits for Nine Trace Elements*.

ATTACHMENTS

Table 1. Proposed Human Health Screening Levels for Groundwater. Environmental Assessment Report

Table 2. Proposed Human Health and Ecological Screening Levels for Surface Water. Environmental Assessment Report

Table 3. Proposed Screening Levels for May Fly Tissue Critical Body Residues. Environmental Assessment Report

Table 4. Proposed Screening Levels for Fish Tissue Critical Body Residues. Environmental Assessment Report

Table 5. Proposed Ecological Screening Levels for Freshwater Sediment. Environmental Assessment Report

Table 1. Proposed Human Health Screening Levels for Groundwater
Environmental Assessment Report

CCR Parameters	Groundwater Screening Levels (µg/L)	Source
CCR Rule Appendix III Constituents :		
Boron	4,000	RSL
Calcium	--	--
Chloride	250,000	SMCL
Fluoride	4,000	MCL
pH	6.5-8.5 S.U.	SMCL
Sulfate	250,000	SMCL
Total Dissolved Solids	500,000	SMCL
CCR Rule Appendix IV Constituents :		
Antimony	6	MCL
Arsenic	10	MCL
Barium	2,000	MCL
Beryllium	4	MCL
Cadmium	5	MCL
Chromium (total)	100	MCL
Cobalt	6	CCR Rule GWPS
Fluoride	4,000	MCL
Lead	15	CCR Rule GWPS
Lithium	40	CCR Rule GWPS
Mercury	2	MCL
Molybdenum	100	CCR Rule GWPS
Radium-226 & 228	5 pCi/L	MCL
Selenium	50	MCL
Thallium	2	MCL
TDEC Appendix I Constituents :		
Copper	1,300	MCLG
Nickel	100	TN MCL
Silver	100	TN MCL
Vanadium	86	RSL
Zinc	5,000	SMCL

Notes:

CCR: coal combustion residuals
GWPS: groundwater protection standards
MCL: USEPA maximum contaminant level
MCLG: Maximum contaminant level goal
pCi/L: picocuries per liter
RSL: USEPA regional screening level
SMCL: USEPA secondary maximum contaminant level
TN MCL: maximum contaminant level promulgated by State of Tennessee
µg/L: micrograms per liter

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Bull Run Fossil Plant																
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels														
			Bull Run Creek (Hardness = 140 mg/L)					Clinch River (Hardness = 120 mg/L)					Worthington Branch (Hardness = 175 mg/L)				
			Total Chronic	Total Acute	Dissolved Chronic	Dissolved Acute		Total Chronic	Total Acute	Dissolved Chronic	Dissolved Acute		Total Chronic	Total Acute	Dissolved Chronic	Dissolved Acute	
	(µg/L)	Source	(µg/L)	(µg/L)	(µg/L)	(µg/L)		(µg/L)	(µg/L)	(µg/L)	(µg/L)		(µg/L)	(µg/L)	(µg/L)	(µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900	NA	NA	a	190	900	NA	NA	a	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	1.03	2.65	0.925	2.47	b	0.914	2.28	0.824	2.14	b	1.23	3.30	1.09	3.04	b
Chromium*	100	TN DWS/MCL	114	2375	97.6	751	b	100	2093	86.1	662	b	136	2851	117	901	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	4.88	125	3.62	93.0	b	4.01	103	3.07	78.7	b	6.49	166	4.60	118	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	12.4	19.2	11.9	18.5	b	10.9	16.6	10.5	16.0	b	15.0	23.7	14.4	22.8	b
Nickel*	100	TN DWS	69.3	624	69.1	622	b	60.9	547	60.7	546	b	83.7	753	83.5	752	b
Silver*	100	TN DWS/SMCL	NA	6.75	NA	5.74	b	NA	5.18	NA	4.40	b	NA	9.91	NA	8.42	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	159	159	157	156	b	140	140	138	137	b	193	193	190	188	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Cumberland Fossil Plant																
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels														
			Cumberland River (Hardness = 100 mg/L)					Wells Creek (Hardness = 140 mg/L)					Unnamed Tributary (Hardness = 750 mg/L)[d]				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900			a	190	900			a	190	900			a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.790	1.91	0.718	1.80	b	1.03	2.65	0.925	2.47	b	2.39	7.42	2.03	6.58	b
Chromium*	100	TN DWS/MCL	86.2	1803	74.1	570	b	114	2375	97.6	751	b	268	5612	231	1773	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	3.18	81.6	2.52	64.6	b	4.88	125	3.62	93.0	b	18.6	477	10.9	281	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	9.33	14.0	8.96	13.4	b	12.4	19.2	11.9	18.5	b	30.5	51.7	29.3	49.6	b
Nickel*	100	TN DWS	52.2	469	52.0	468	b	69.3	624	69.1	622	b	169	1516	168	1513	b
Silver*	100	TN DWS/SMCL	NA	3.78	NA	3.22	b	NA	6.75	NA	5.74	b	NA	41.1	NA	34.9	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	120	120	118	117	b	159	159	157	156	b	388	388	382	379	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Johnsonville Fossil Plant							John Sevier Fossil Plant								
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels					Ecological Surface Water Screening Levels								
			Tennessee River (Hardness = 60 mg/L)					Holston River (Hardness = 100 mg/L)					Polly Branch (Hardness = 100 mg/L)				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)		Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :																	
Boron	4,000	RSL	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b	6.5 - 9	NA	NA	NA	b	6 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA		NA	NA	NA	NA		NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :																	
Antimony	6	TN DWS/MCL	190	900	NA	NA	a	190	900	NA	NA	a	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a	150	340	150	340	a	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a	220	2,000	NA	NA	a	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a	11	93	NA	NA	a	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.526	1.16	0.489	1.12	b	0.790	1.91	0.718	1.80	b	0.790	1.91	0.718	1.80	b
Chromium*	100	TN DWS/MCL	56.7	1187	48.8	375	b	86.2	1803	74.1	570	b	86.2	1803	74.1	570	b
Cobalt	6	RSL	19	120	NA	NA	a	19	120	NA	NA	a	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	1.66	42.6	1.44	36.9	b	3.18	81.6	2.52	64.6	b	3.18	81.6	2.52	64.6	b
Lithium	40	RSL	440	910	NA	NA	a	440	910	NA	NA	a	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a	800	7,200	NA	NA	a	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b	3.1	20	NA	NA	b	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a	6	54	NA	NA	a	6	54	NA	NA	a
TDEC Appendix I Constituents :																	
Copper*	1,300	MCL	6.03	8.65	5.79	8.31	b	9.33	14.0	8.96	13.4	b	9.33	14.0	8.96	13.4	b
Nickel*	100	TN DWS	33.9	305	33.8	304	b	52.2	469	52.0	468.24	b	52.2	469	52.0	468	b
Silver*	100	TN DWS/SMCL	NA	1.57	NA	1.34	b	NA	3.78	NA	3.22	b	NA	3.78	NA	3.22	b
Vanadium	86	RSL	27	79	NA	NA	a	27	79	NA	NA	a	27	79	NA	NA	a
Zinc*	2,000	HAL	77.7	77.7	76.6	76.0	b	120	120	118	117	b	120	120	118	117	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

CCR Parameters	Watts Bar Fossil Plant						
	Human Health Surface Water Screening Levels		Ecological Surface Water Screening Levels				
			Tennessee River (Hardness = 75 mg/L)				
	(µg/L)	Source	Total Chronic (µg/L)	Total Acute (µg/L)	Dissolved Chronic (µg/L)	Dissolved Acute (µg/L)	
CCR Rule Appendix III Constituents :							
Boron	4,000	RSL	7,200	34,000	NA	NA	a
Calcium	--	--	116,000	NA	NA	NA	a
Chloride	250,000	SMCL	230,000	860,000	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a
pH	6 - 9 S.U.	TN DWS	6.5 - 9	NA	NA	NA	b
Sulfate	250,000	SMCL	NA	NA	NA	NA	
Total Dissolved Solids	500,000	TN DWS/SMCL	NA	NA	NA	NA	
CCR Rule Appendix IV Constituents :							
Antimony	6	TN DWS/MCL	190	900	NA	NA	a
Arsenic	10	TN DWS/MCL	150	340	150	340	a
Barium	2,000	TN DWS/MCL	220	2,000	NA	NA	a
Beryllium	4	TN DWS/MCL	11	93	NA	NA	a
Cadmium*	5	TN DWS/MCL	0.628	1.44	0.579	1.38	b
Chromium*	100	TN DWS/MCL	68.1	1425	58.6	450	b
Cobalt	6	RSL	19	120	NA	NA	a
Fluoride	4,000	MCL	2,700	9,800	NA	NA	a
Lead*	5	TN DWS	2.21	56.6	1.84	47.2	b
Lithium	40	RSL	440	910	NA	NA	a
Mercury	2	TN DWS/MCL	0.77	1.4	0.77	1.4	a
Molybdenum	100	RSL	800	7,200	NA	NA	a
Radium-226 & 228	5 pCi/L	MCL	3 pCi/L	3 pCi/L	NA	NA	c
Selenium	50	TN DWS/MCL	3.1	20	NA	NA	b
Thallium	2	TN DWS/MCL	6	54	NA	NA	a
TDEC Appendix I Constituents :							
Copper*	1,300	MCL	7.30	10.7	7.00	10.2	b
Nickel*	100	TN DWS	40.9	368	40.8	367	b
Silver*	100	TN DWS/SMCL	NA	2.31	NA	1.96	b
Vanadium	86	RSL	27	79	NA	NA	a
Zinc*	2,000	HAL	93.9	93.9	92.6	91.8	b

Table 2. Proposed Human Health and Ecological Site Specific Screening Levels for Surface Water
Environmental Assessment Report

Notes:

* The freshwater screening values are hardness dependent. These screening values were adjusted using the following equations and parameters provided in TDEC 2019:

Acute Screening Levels (dissolved) = exp{mA[ln(hardness)]+bA } (CF)

Chronic Screening Levels (dissolved) = exp{mC [ln(hardness)]+bC} (CF)

Parameters	mA	bA	mC	bC	Conversation Factor (CF)	
					CMC	CCC
Cadmium	0.9798	-3.866	0.7977	-3.909	1.136672-[(ln hardness)(0.041838)]	1.101672-[(ln hardness)(0.041838)]
Chromium III	0.819	3.7256	0.8190	0.6848	0.316	0.860
Copper	0.9422	-1.700	0.8545	-1.702	0.960	0.960
Lead	1.273	-1.460	1.273	-4.705	1.46203-[(ln hardness)(0.145712)]	1.46203-[(ln hardness)(0.145712)]
Nickel	0.8460	2.555	0.8460	0.0584	0.998	0.997
Silver	1.72	-6.59			0.85	
Zinc	0.8473	0.884	0.8473	0.884	0.978	0.986

ug/L: micrograms per liter
NA = not applicable
SMCL: USEPA secondary maximum contaminant level
HAL: Health advisory level
MCL: USEPA maximum contaminant level
MCLG: Maximum contaminant level goal
TN DWS: drinking water standard promulgated by State of Tennessee
RSL: USEPA regional screening level for residential tapwater (November 2020)

a USEPA Region 4 Surface Water Screening Values for Hazardous Waste Sites (March 2018 Revision).
b Tennessee Department of Environment and Consevation (TDEC), 2019. Chapter 0400-40-03, General Water Quality Criteria.
c U.S. Department of Energy (DOE), 2019. DOE Standard (DOE-STD-1153-2019), A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. Biota Concentration Guides for water of 4 pCi/L for Radium-226 and 3 pCi/L for Radium-228.
d The mean hardness of surface water in the Unnamed Tributary is approximately 750 mg/L; however, per TDEC water quality guidelines TDEC, 2019), a hardness value of 400 mg/L was used to calculate hardness-dependent water quality criteria.

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 3. Proposed Screening Levels for Mayfly Tissue Critical Body Residues
Environmental Assessment Report

CCR Parameters	Mayfly Tissue Critical Body Residue NOAEL (mg/kg-ww)	Mayfly Tissue Critical Body Residue LOAEL (mg/kg-ww)	
CCR Rule Appendix III Constituents :			
Boron	NA	NA	
Calcium	NA	NA	
Chloride	NA	NA	
Fluoride	NA	NA	
pH	NA	NA	
Sulfate	NA	NA	
Total Dissolved Solids	NA	NA	
CCR Rule Appendix IV Constituents :			
Antimony	NA	NA	
Arsenic	0.0249	0.249	a
Barium	NA	NA	
Beryllium	NA	NA	
Cadmium	15.6	156	a
Chromium (total)	0.144	1.44	a
Cobalt	0.1061	1.061	
Fluoride	NA	NA	
Lead	269	2690	a
Lithium	NA	NA	
Mercury	2.7	27	a
Molybdenum	NA	NA	
Radium-226 & 228	NA	NA	
Selenium	0.051	0.51	a
Thallium	1.206	12.06	a
TDEC Appendix I Constituents :			
Copper	26	260	a
Nickel	0.115	1.15	a
Silver	0.23	2.3	a
Vanadium	0.604	6.04	a
Zinc	382	3820	a

Notes:

a Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).

Toxicity values were selected from the U.S. Army Corps of Engineers/ USEPA Environmental Residue-Effects Database (ERED).

mg/kg-ww - milligrams per kilogram, wet weight

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 4. Proposed Screening Levels for Fish Tissue Critical Body Residues
Environmental Assessment Report

CCR Parameters	Whole Body Fish Tissue Critical Body Residue			Liver Tissue Critical Body Residue			Muscle Tissue Critical Body Residue			Ovary Tissue Critical Body Residue		
	NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)		NOAEL (mg/kg-ww)	LOAEL (mg/kg-ww)	
CCR Rule Appendix III Constituents :												
Boron	NA	NA		NA	NA		NA	NA		NA	NA	
Calcium	NA	NA		NA	NA		NA	NA		NA	NA	
Chloride	NA	NA		NA	NA		NA	NA		NA	NA	
Fluoride	NA	NA		NA	NA		NA	NA		NA	NA	
pH	NA	NA		NA	NA		NA	NA		NA	NA	
Sulfate	NA	NA		NA	NA		NA	NA		NA	NA	
Total Dissolved Solids	NA	NA		NA	NA		NA	NA		NA	NA	
CCR Rule Appendix IV Constituents :												
Antimony	NA	NA		NA	NA		NA	NA		NA	NA	
Arsenic	0.04	0.4	a	0.569	5.69	a	0.076	0.76	a	8.4	84	a
Barium	NA	NA		NA	NA		NA	NA		NA	NA	
Beryllium	5.13	51.3	a	NA	NA		NA	NA		NA	NA	
Cadmium	0.0019	0.019	a	0.0000137	0.000137	a	0.03	0.12	a	NA	NA	
Chromium (total)	0.128	1.28	a	0.042	0.42	a	NA	NA		NA	NA	
Cobalt	NA	NA		NA	NA		NA	NA		NA	NA	
Fluoride	NA	NA		NA	NA		NA	NA		NA	NA	
Lead	0.0278	0.278	a	0.0393	0.393	a	2.3	23	a	NA	NA	
Lithium	NA	NA		NA	NA		NA	NA		NA	NA	
Mercury	0.006	0.06	a	0.0009	0.009	a	0.08	0.8	a	NA	NA	
Molybdenum	NA	NA		NA	NA		NA	NA		NA	NA	
Radium-226 & 228	NA	NA		NA	NA		NA	NA		NA	NA	
Selenium	8.5	8.5	b	0.524	5.24	a	11.3	11.3	b	15.1	15.1	b
Thallium	0.027	0.27	a	NA	NA		NA	NA		NA	NA	
TDEC Appendix I Constituents :												
Copper	0.196	1.96	a	6.52	65.2	a	3.4	34	a	NA	NA	
Nickel	11.81	118.1	a	8.22	82.2	a	11.81	118.1	a	NA	NA	
Silver	0.0114	0.114	a	19	190	a	NA	NA		NA	NA	
Vanadium	0.68	2.7	a	0.03	0.3	a	NA	NA		NA	NA	
Zinc	0.45	4.5	a	3.4	34	a	NA	NA		NA	NA	

Notes:

a Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).
Toxicity values were selected from the U.S. Army Corps of Engineers/USEPA Environmental Residue-Effects Database (ERED).

b USEPA, 2016. Chronic Ambient Water Quality Criterion for Selenium. Fish tissue concentrations expressed as mg/kg-dry weight.

mg/kg-ww - milligrams per kilogram, wet weight

Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Table 5. Proposed Ecological Screening Levels for Freshwater Sediment
Environmental Assessment Report

CCR Parameters	Freshwater Sediment Screening Values		Sediment Quality Assessment Guidelines[a]	
	Chronic (mg/kg-dw)	Acute (mg/kg-dw)	TEC (mg/kg-dw)	PEC (mg/kg-dw)
CCR Rule Appendix III Constituents :				
Percent Ash	20% b	40% c	NA	NA
Boron	NA	NA	NA	NA
Calcium	NA	NA	NA	NA
Chloride	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA
pH	NA	NA	NA	NA
Sulfate	NA	NA	NA	NA
Total Dissolved Solids	NA	NA	NA	NA
CCR Rule Appendix IV Constituents :				
Antimony	2	25 e	NA	NA
Arsenic	9.8	33 e	9.8	33
Barium	240	22925 f	NA	NA
Beryllium	1.2	42 f	NA	NA
Cadmium	1	5 e	1	5
Chromium	43.4	111 e	43	110
Cobalt	50	NA e	50	NA
Fluoride	NA	NA	NA	NA
Lead	35.8	128 e	36	130
Lithium	NA	NA	NA	NA
Mercury	0.18	1.1 e	0.18	1.1
Molybdenum	38	69760 f	NA	NA
Radium-226 & 228	90 pCi/g	90 pCi/g d	NA	NA
Selenium	2 g	2.9 e	NA	NA
Thallium	1.2	10 f	NA	NA
TDEC Appendix I Constituents :				
Copper	31.6	149 e	32	150
Nickel	22.7	48.6 e	23	49
Silver	1	2.2 e	NA	NA
Vanadium	66	564 f	NA	NA
Zinc	121	459 e	120	460

Notes:
mg/kg-dw - Milligrams per kilogram dry weight
NA - Not Available

a MacDonald, et al., 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters. TEC - Threshold Effect Concentration, PEC - Probable Effect Concentration.
b Environmental Investigation Plans (EIP) for TVA fossil plants under the TDEC Consent Order.
c Arcadis, 2012. Kingston Ash Recovery Project Non-Time Critical Removal Action River System Baseline Ecological Risk Assessment (BERA).
d U.S. Department of Energy (DOE), 2019. DOE Standard (DOE-STD-1153-2019), A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. Biota Concentration Guides for sediment of 100 pCi/g for Radium-226 and 90 pCi/g for Radium-228.
e USEPA Region 4 Sediment Screening Values for Hazardous Waste Sites (March 2018 Revision).
f National Institute for Public Health and the Environment (RIVM), 2005. Environmental Risk Limits for Nine Trace Elements. The Maximum Permissible Concentration (MPC) is used for the chronic value and the Serious Risk Addition (SRAeco) is used for the acute value.
g Lemly, A.D., 2002. Selenium Assessment in Aquatic Ecosystems
Red highlight denotes bioaccumulative constituent (USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (March 2018 Update).

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT B - DEVELOPMENT OF RECEPTOR-SPECIFIC SCREENING LEVELS FOR HUMAN HEALTH

Table B.1 - Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil

Analyte	CAS	Soil SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}			Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$		Unit Risk Factor $(\mu g/m^3)^{-1}$
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Inhalation SSL_{HH} (mg/kg)	Oral	Dermal	Inhalation
Antimony	7440-36-0	na	na	na	na	na	na	na
Arsenic	7440-38-2	2.4E+02	3.4E+02	2.1E+03	1.4E+03	1.5E+00	1.5E+00	4.3E-03
Barium	7440-39-3	na	na	na	na	na	na	na
Beryllium	7440-41-7	2.5E+03	na	na	2.5E+03	na	na	2.4E-03
Boron	7440-42-8	na	na	na	na	na	na	na
Cadmium	7440-43-9	3.3E+03	na	na	3.3E+03	na	na	1.8E-03
Calcium	7440-70-2	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na
Chromium	7440-47-3	na	na	na	na	na	na	na
Cobalt	7440-48-4	6.6E+02	na	na	6.6E+02	na	na	9.0E-03
Copper	7440-50-8	na	na	na	na	na	na	na
Fluoride	16984-48-8	na	na	na	na	na	na	na
Lead	7439-92-1	na	na	na	na	na	na	na
Lithium	7439-93-2	na	na	na	na	na	na	na
Mercury	7439-97-6	na	na	na	na	na	na	na
Molybdenum	7439-98-7	na	na	na	na	na	na	na
Nickel	7440-02-0	2.3E+04	na	na	2.3E+04	na	na	2.6E-04
Selenium	7782-49-2	na	na	na	na	na	na	na
Silver	7440-22-4	na	na	na	na	na	na	na
Sulfate	14808-79-8	na	na	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na	na	na
Vanadium	7440-62-2	na	na	na	na	na	na	na
Zinc	7440-66-6	na	na	na	na	na	na	na

Notes:

CAS - Chemical Abstracts Service registry number

mg/kg - milligrams per kilogram

mg/kg-d - milligrams per kilogram per day

$\mu g/m^3$ - micrograms per cubic meter

na - not available/applicable

SSL_{HH} - receptor-specific screening levels for human health

Table B.2 - Non-Cancer Receptor-Specific Screening Level Calculations for an Onsite Worker Exposed to Soil

Analyte	CAS	Soil SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}			Subchronic Reference Dose (mg/kg-d)		Subchronic Reference Concentration (mg/m^3)
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Inhalation SSL_{HH} (mg/kg)	Oral	Dermal	Inhalation
Antimony	7440-36-0	1.3E+01	1.4E+01	na	6.5E+02	4.0E-04	6.0E-05	1.0E-03
Arsenic	7440-38-2	5.9E+00	1.7E+01	1.1E+02	9.8E+00	3.0E-04	3.0E-04	1.5E-05
Barium	7440-39-3	2.2E+03	6.8E+03	na	3.3E+03	2.0E-01	1.4E-02	5.0E-03
Beryllium	7440-41-7	1.2E+01	1.7E+02	na	1.3E+01	5.0E-03	3.5E-05	2.0E-05
Boron	7440-42-8	4.5E+03	6.8E+03	na	1.3E+04	2.0E-01	2.0E-01	2.0E-02
Cadmium	7440-43-9	5.4E+00	3.4E+01	2.6E+02	6.5E+00	1.0E-03	2.5E-05	1.0E-05
Calcium	7440-70-2	na	na	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na	na	na
Chromium	7440-47-3	3.1E+03	5.1E+04	na	3.3E+03	1.5E+00	2.0E-02	5.0E-03
Cobalt	7440-48-4	1.2E+01	1.0E+02	na	1.3E+01	3.0E-03	3.0E-03	2.0E-05
Copper	7440-50-8	1.4E+03	1.4E+03	na	na	4.0E-02	4.0E-02	na
Fluoride	16984-48-8	1.2E+03	1.4E+03	na	8.5E+03	4.0E-02	4.0E-02	1.3E-02
Lead	7439-92-1	na	na	na	na	na	na	na
Lithium	7439-93-2	6.8E+01	6.8E+01	na	na	2.0E-03	2.0E-03	na
Mercury	7439-97-6	5.0E+01	6.8E+01	na	2.0E+02	2.0E-03	1.4E-04	3.0E-04
Molybdenum	7439-98-7	8.0E+02	2.0E+03	na	1.3E+03	6.0E-02	6.0E-02	2.0E-03
Nickel	7440-02-0	1.1E+02	6.8E+02	na	1.3E+02	2.0E-02	8.0E-04	2.0E-04
Selenium	7782-49-2	1.7E+02	1.7E+02	na	1.3E+04	5.0E-03	5.0E-03	2.0E-02
Silver	7440-22-4	1.7E+02	1.7E+02	na	na	5.0E-03	2.0E-04	na
Sulfate	14808-79-8	na	na	na	na	na	na	na
Thallium	7440-28-0	1.4E+00	1.4E+00	na	na	4.0E-05	4.0E-05	na
Vanadium	7440-62-2	5.5E+01	3.4E+02	na	6.5E+01	1.0E-02	2.6E-04	1.0E-04
Zinc	7440-66-6	1.0E+04	1.0E+04	na	na	3.0E-01	3.0E-01	na

Notes:

CAS - Chemical Abstracts Service registry number

mg/kg - milligrams per kilogram

mg/kg-d - milligrams per kilogram per day

mg/m^3 - milligrams per cubic meter

na - not available/applicable

SSL_{HH} - receptor-specific screening levels for human health

Table B.3 - Particulate Emissions Factor Calculation for an Onsite Worker

Site-specific

Construction Worker Equation Inputs for Soil - Other Construction Activities

Variable	Construction Worker Soil - Other Default Value	Form-input Value
$A_{c\text{-}doz}$ (areal extent of dozing) acres	0	0.5
A_{excav} (area of excavation site) m^2	0	2023.42821
$A_{c\text{-}grade}$ (areal extent of grading) acres	0	0.5
A (PEF Dispersion Constant)	2.4538	2.4538
A_{surf} (areal extent of site) m^2	2023.43	2023.43
A_{till} (areal extent of tilling) acres	0	0.5
$B_{l\text{-}doz}$ (dozing blade length) m	0	2.44
$B_{l\text{-}grade}$ (grading blade length) m	0	2.44
B (PEF Dispersion Constant)	17.566	17.566
C (PEF Dispersion Constant)	189.0426	189.0426
d_{excav} (average depth of excavation site) m	0	1
F_D Unitless Dispersion Correction Factor	0.185837208	0.193145487
F(x) (function dependant on U_m/U_t derived using Cowherd et al. (1985))	0.194	0.194
$M_{m\text{-}doz}$ (Gravimetric soil moisture content) %	7.9	7.9
$M_{m\text{-}excav}$ (Gravimetric soil moisture content) %	12	12
M_{wind} (dust emitted by wind erosion) g	51288.84717	51288.84717
$N_{A\text{-}doz}$ (number of times site was dozed)	0	2
$N_{A\text{-}dump}$ (number of times soil is dumped)	2	2
$N_{A\text{-}grade}$ (number of times site was graded)	0	2
$N_{A\text{-}till}$ (number of times soil is tilled)	2	2
Q/C_{sa} (inverse of the ratio of the geometric mean air concentration to the emission flux at the center of a square source) g/m^2-s per kg/m^3	14.31407	14.31407
p_{soil} (density) g/cm^3 - chemical-specific	1.68	1.68
s_{doz} (soil silt content) %	6.9	6.9
AF_{cw} (skin adherence factor - construction worker) mg/cm^2	0.3	0.3
AT_{cw} (averaging time - construction worker) days	365	28
BW_{cw} (body weight - construction worker) kg	80	80
ED_{cw} (exposure duration - construction worker) yr	1	1
EF_{cw} (exposure frequency - construction worker) day/yr	250	20
ET_{cw} (exposure time - construction worker) hr/day	8	8
THQ (target hazard quotient) unitless	0.1	1
IRS_{cw} (soil ingestion rate - construction worker) mg/day	330	330
LT (lifetime) yr	70	70
SA_{cw} (surface area - construction worker) cm^2/day	3527	3527
TR (target cancer risk) unitless	0.000001	0.000001
S_{doz} (dozing speed) kph	11.4	11.4
S_{grade} (grading speed) kph	11.4	11.4
s_{till} (soil silt content) %	18	18
t_c (overall duration of construction) hours	8400	672
T_c (overall duration of construction) s	30240000	2419200
T (time over which traffic occurs) s	7200000	576000
T_t (overall duration of traffic) s	7200000	576000

Table B.3 - Particulate Emissions Factor Calculation for an Onsite Worker

Site-specific

Construction Worker Equation Inputs for Soil - Other Construction Activities

Variable	Construction Worker Soil - Other Default Value	Form-input Value
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value) m/s	11.32	11.32
V (fraction of vegetative cover)	0	0
Particulate Emission Factor (m3/kg)		**1558751**

Output generated 01DEC2020:14:08:30

Notes:

The particulate emission factor (PEF) was calculated using the inputs shown and the Regional Screening Level (RSL) Calculator Construction Worker - Other Construction Activities scenario. https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search

site-specific value

% - percent
cm^2 - square centimeters
hr - hours
g - grams
g/cm^2 - grams per square centimeter
g/cm^3 - grams per cubic centimeter
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
kg - kilograms
km - kilometers
kph - kilometers per hour
m - meters
m^2 - square meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
mg/cm^2 - milligrams per square centimeters
m/s - meter(s) per second
s - second(s)
yr - year(s)

Table B.4 - Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Beachcomber Exposed to Sediment

Analyte	CAS	Sediment SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}		Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$ [b]	
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	na	na	na	na	na
Arsenic	7440-38-2	3.4E+00	3.9E+00	2.6E+01	1.5E+00	1.5E+00
Barium	7440-39-3	na	na	na	na	na
Beryllium	7440-41-7	na	na	na	na	na
Boron	7440-42-8	na	na	na	na	na
Cadmium	7440-43-9	na	na	na	na	na
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	na	na	na	na	na
Cobalt	7440-48-4	na	na	na	na	na
Copper	7440-50-8	na	na	na	na	na
Fluoride	16984-48-8	na	na	na	na	na
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	na	na	na	na	na
Mercury	7439-97-6	na	na	na	na	na
Molybdenum	7439-98-7	na	na	na	na	na
Nickel	7440-02-0	na	na	na	na	na
Selenium	7782-49-2	na	na	na	na	na
Silver	7440-22-4	na	na	na	na	na
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	na	na	na	na	na
Vanadium	7440-62-2	na	na	na	na	na
Zinc	7440-66-6	na	na	na	na	na

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.5 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Beachcomber Exposed to Sediment

Analyte	CAS	Sediment SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}		Reference Dose (mg/kg-d) [b]	
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	2.1E+01	2.1E+01	na	4.0E-04	6.0E-05
Arsenic	7440-38-2	2.4E+01	2.6E+01	2.2E+02	3.0E-04	3.0E-04
Barium	7440-39-3	1.1E+04	1.1E+04	na	2.0E-01	1.4E-02
Beryllium	7440-41-7	1.1E+02	1.1E+02	na	2.0E-03	1.4E-05
Boron	7440-42-8	1.1E+04	1.1E+04	na	2.0E-01	2.0E-01
Cadmium	7440-43-9	4.8E+01	5.3E+01	5.5E+02	1.0E-03	2.5E-05
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	7.9E+04	7.9E+04	na	1.5E+00	2.0E-02
Cobalt	7440-48-4	1.6E+01	1.6E+01	na	3.0E-04	3.0E-04
Copper	7440-50-8	2.1E+03	2.1E+03	na	4.0E-02	4.0E-02
Fluoride	16984-48-8	2.1E+03	2.1E+03	na	4.0E-02	4.0E-02
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	1.1E+02	1.1E+02	na	2.0E-03	2.0E-03
Mercury	7439-97-6	1.6E+01	1.6E+01	na	3.0E-04	2.1E-05
Molybdenum	7439-98-7	2.6E+02	2.6E+02	na	5.0E-03	5.0E-03
Nickel	7440-02-0	1.1E+03	1.1E+03	na	2.0E-02	8.0E-04
Selenium	7782-49-2	2.6E+02	2.6E+02	na	5.0E-03	5.0E-03
Silver	7440-22-4	2.6E+02	2.6E+02	na	5.0E-03	2.0E-04
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	5.3E-01	5.3E-01	na	1.0E-05	1.0E-05
Vanadium	7440-62-2	2.6E+02	2.6E+02	na	5.0E-03	1.3E-04
Zinc	7440-66-6	1.6E+04	1.6E+04	na	3.0E-01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.6 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Beachcomber Exposed to Sediment

Analyte	CAS	Sediment SSL_{HH} (mg/kg)	Pathway-Specific SSL_{HH}		Reference Dose (mg/kg-d) [b]	
			Ingestion SSL_{HH} (mg/kg)	Dermal SSL_{HH} (mg/kg)	Oral	Dermal
Antimony	7440-36-0	6.2E+01	6.2E+01	na	4.0E-04	6.0E-05
Arsenic	7440-38-2	6.5E+01	7.8E+01	4.1E+02	3.0E-04	3.0E-04
Barium	7440-39-3	3.1E+04	3.1E+04	na	2.0E-01	1.4E-02
Beryllium	7440-41-7	3.1E+02	3.1E+02	na	2.0E-03	1.4E-05
Boron	7440-42-8	3.1E+04	3.1E+04	na	2.0E-01	2.0E-01
Cadmium	7440-43-9	1.4E+02	1.6E+02	1.0E+03	1.0E-03	2.5E-05
Calcium	7440-70-2	na	na	na	na	na
Chloride	16887-00-6	na	na	na	na	na
Chromium	7440-47-3	2.3E+05	2.3E+05	na	1.5E+00	2.0E-02
Cobalt	7440-48-4	4.7E+01	4.7E+01	na	3.0E-04	3.0E-04
Copper	7440-50-8	6.2E+03	6.2E+03	na	4.0E-02	4.0E-02
Fluoride	16984-48-8	6.2E+03	6.2E+03	na	4.0E-02	4.0E-02
Lead	7439-92-1	na	na	na	na	na
Lithium	7439-93-2	3.1E+02	3.1E+02	na	2.0E-03	2.0E-03
Mercury	7439-97-6	4.7E+01	4.7E+01	na	3.0E-04	2.1E-05
Molybdenum	7439-98-7	7.8E+02	7.8E+02	na	5.0E-03	5.0E-03
Nickel	7440-02-0	3.1E+03	3.1E+03	na	2.0E-02	8.0E-04
Selenium	7782-49-2	7.8E+02	7.8E+02	na	5.0E-03	5.0E-03
Silver	7440-22-4	7.8E+02	7.8E+02	na	5.0E-03	2.0E-04
Sulfate	14808-79-8	na	na	na	na	na
Thallium	7440-28-0	1.6E+00	1.6E+00	na	1.0E-05	1.0E-05
Vanadium	7440-62-2	7.8E+02	7.8E+02	na	5.0E-03	1.3E-04
Zinc	7440-66-6	4.7E+04	4.7E+04	na	3.0E-01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.7 - Cancer Receptor-Specific Screening Level Calculations for a Recreational User - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$ Oral
Antimony	7440-36-0	na	na
Arsenic	7440-38-2	4.7E-03	1.5E+00
Barium	7440-39-3	na	na
Beryllium	7440-41-7	na	na
Boron	7440-42-8	na	na
Cadmium	7440-43-9	na	na
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	na	na
Cobalt	7440-48-4	na	na
Copper	7440-50-8	na	na
Fluoride	16984-48-8	na	na
Lead	7439-92-1	na	na
Lithium	7439-93-2	na	na
Mercury	7439-97-6	na	na
Molybdenum	7439-98-7	na	na
Nickel	7440-02-0	na	na
Selenium	7782-49-2	na	na
Silver	7440-22-4	na	na
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	na	na
Vanadium	7440-62-2	na	na
Zinc	7440-66-6	na	na

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.8 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Child) - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Reference Dose (mg/kg-d) Oral
Antimony	7440-36-0	7.2E-02	4.0E-04
Arsenic	7440-38-2	5.4E-02	3.0E-04
Barium	7440-39-3	3.6E+01	2.0E-01
Beryllium	7440-41-7	3.6E-01	2.0E-03
Boron	7440-42-8	3.6E+01	2.0E-01
Cadmium	7440-43-9	1.8E-01	1.0E-03
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	2.7E+02	1.5E+00
Cobalt	7440-48-4	5.4E-02	3.0E-04
Copper	7440-50-8	7.2E+00	4.0E-02
Fluoride	16984-48-8	na	4.0E-02
Lead	7439-92-1	na	na
Lithium	7439-93-2	3.6E-01	2.0E-03
Mercury	7439-97-6	1.8E-02	1.0E-04
Molybdenum	7439-98-7	9.0E-01	5.0E-03
Nickel	7440-02-0	3.6E+00	2.0E-02
Selenium	7782-49-2	9.0E-01	5.0E-03
Silver	7440-22-4	9.0E-01	5.0E-03
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	1.8E-03	1.0E-05
Vanadium	7440-62-2	9.0E-01	5.0E-03
Zinc	7440-66-6	5.4E+01	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.9 - Non-Cancer Receptor-Specific Screening Level Calculations for a Recreational User (Adolescent) - Consumer of Locally-Caught Sport Fish

Analytes	CAS	Fish SSL_{HH} (mg/kg wet weight)	Reference Dose (mg/kg-d) Oral
Antimony	7440-36-0	1.4E-01	4.0E-04
Arsenic	7440-38-2	1.1E-01	3.0E-04
Barium	7440-39-3	7.2E+01	2.0E-01
Beryllium	7440-41-7	7.2E-01	2.0E-03
Boron	7440-42-8	7.2E+01	2.0E-01
Cadmium	7440-43-9	3.6E-01	1.0E-03
Calcium	7440-70-2	na	na
Chloride	16887-00-6	na	na
Chromium	7440-47-3	5.4E+02	1.5E+00
Cobalt	7440-48-4	1.1E-01	3.0E-04
Copper	7440-50-8	1.4E+01	4.0E-02
Fluoride	16984-48-8	na	4.0E-02
Lead	7439-92-1	na	na
Lithium	7439-93-2	7.2E-01	2.0E-03
Mercury	7439-97-6	3.6E-02	1.0E-04
Molybdenum	7439-98-7	1.8E+00	5.0E-03
Nickel	7440-02-0	7.2E+00	2.0E-02
Selenium	7782-49-2	1.8E+00	5.0E-03
Silver	7440-22-4	1.8E+00	5.0E-03
Sulfate	14808-79-8	na	na
Thallium	7440-28-0	3.6E-03	1.0E-05
Vanadium	7440-62-2	1.8E+00	5.0E-03
Zinc	7440-66-6	1.1E+02	3.0E-01

Notes:

CAS - Chemical Abstracts Service registry number
mg/kg - milligrams per kilogram
mg/kg-d - milligrams per kilogram per day
na - not available/applicable
SSL_{HH} - receptor-specific screening levels for human health

Table B.10 – Adult Lead Model Calculation Spreadsheet

Calculations of Preliminary Remediation Goals (PRGs) for Soil in Nonresidential Areas

U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee

Version date 06/14/2017

EDIT RED CELLS

Variable	Description of Variable	Units	On-Site Worker GSDi and PbBo from Analysis of NHANES 2009-2014	Recreational User (Adolescent) - Beachcomber GSDi and PbBo from Analysis of NHANES 2009-2014
$PbB_{fetal,\ 0.95}$	Target PbB in fetus (e.g., 2-8 µg/dL)	µg/dL	5	5
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4	0.4
GSD_i	Geometric standard deviation PbB	--	1.8	1.8
PbB_0	Baseline PbB	µg/dL	0.6	0.6
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.330	0.200
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	--	0.12	0.12
$EF_{S,\ D}$	Exposure frequency (same for soil and dust)	days/yr	20	52
$AT_{S,\ D}$	Averaging time (same for soil and dust)	days/yr	28	365
PRG in Soil for no more than 5% probability that fetal PbB exceeds target PbB		**ppm**	**134**	**1,106**

Notes:

days/yr - days per year

g/day - grams per day

NHANES - National Health and Nutrition Examination Survey

PbB - blood lead concentration

PRG - Preliminary Remediation Goals

ppm - parts per million

µg/day - micrograms per day

µg/dL - micrograms per deciliter

USEPA - United States Environmental Protection Agency

Stantec

TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT C – EPA PRG CALCULATOR INPUTS AND OUTPUTS

Table C.1 - Peak PRG Calculator Input for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Variable	Construction Worker Soil - Other Default Value	Form-input Value
A (PEF Dispersion Constant)	2.45	2.45
B (PEF Dispersion Constant)	17.6	17.6
C (PEF Dispersion Constant)	189	189
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
F_D Unitless Dispersion Correction Factor	0.186	0.193
F(x) (function dependant on U_m/U_t derived using Cowherd	0.194	0.194
PEF`$_{sc}$ (subchronic particulate emission factor) m^3/kg		1,558,751
concentration to the emission flux at the center of a square source) g/m^2-s per kg/m^3	14.3	14.3
Site area for ACF (area correction factor) m^2	1,000,000 m^2	2,000 m^2
ED_{cw} (exposure duration - construction worker) yr	1.00	1.00
EF_{cw} (exposure frequency - construction worker) day/yr	250	20.0
ET_{cw} (exposure time - construction worker) hr/day	8.00	8.00
IRA_{cw} (soil inhalation rate - construction worker) m^3/day	60.0	60.0
IRS_{cw} (soil ingestion rate - construction worker) mg/day	330	330
t_{cw} (time - construction worker) yr	1.00	1.00
TR (target cancer risk) unitless	1.00E-06	1.00E-06
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value) m/s	11.3	11.3
V (fraction of vegetative cover)	0	0

Notes:

site-specific value

cm - centimeters
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
hr - hours
m^2 - square meters
m^3 - cubic meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
m/s - meter(s) per second
yr - year(s)

Table C.2 - Peak PRG Calculator Ra-226 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Construction Worker Peak Risk PRGs for Soil - Other Construction Activities

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-226 @ PRG units	*6.89E+01*	*6.98E+01*	*7.73E+00*	*6.53E+00*
Peak start time for maximum risk (yrs)	*1.35E+02*	*1.17E+02*	*1.18E-01*	*7.38E+01*
Maximum risk during peak interval (unitless)	*1.45E-08*	*1.43E-08*	*1.29E-07*	*1.53E-07*
Maximum risk-rate during peak interval (risk/yr)	*8.91E-09*	*7.23E-09*	*1.14E-07*	*1.14E-07*

Table C.3 - Peak PRG Calculator Ra-228 Output for Onsite Worker (Construction Worker Soil Exposure to Other Construction Activities Calculator Scenario)

Construction Worker Peak Risk PRGs for Soil - Other Construction Activities

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-228 @ PRG units	*2.31E+02*	*3.55E+01*	*9.32E+00*	*7.20E+00*
Peak start time for maximum risk (yrs)	*1.00E-08*	*3.31E+00*	*2.81E+00*	*2.87E+00*
Maximum risk during peak interval (unitless)	*4.33E-09*	*2.82E-08*	*1.07E-07*	*1.39E-07*
Maximum risk-rate during peak interval (risk/yr)	*4.42E-09*	*1.96E-08*	*6.36E-08*	*6.36E-08*

Table C.4 - Peak PRG Calculator Input for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Variable	Recreator Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
Cover layer thickness for GSF (gamma shielding factor) cm	0 cm	0 cm
$CF_{rec\text{-}fowl}$ (fowl contaminated fraction) unitless	1	0
$CF_{rec\text{-}game}$ (game contaminated fraction) unitless	1	0
ED_{rec} (exposure duration - recreator) yr		26
EF_{rec} (exposure frequency - recreator) day/yr		52
$f_{p\text{-}fowl}$ (fowl on-site fraction) unitless	1	1
$f_{p\text{-}game}$ (land game on-site fraction) unitless	1	1
$f_{s\text{-}fowl}$ (fraction of year fowl is on site) unitless	1	1
$f_{s\text{-}game}$ (fraction of year land game is on site) unitless	1	1
$IRGF_{rec}$ (fowl consumption rate) g/day		0
$IRGL_{rec}$ (land game consumption rate) g/day		0
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25	0.25
$Q_{p\text{-}fowl}$ (fowl fodder intake rate) kg/day		0
$Q_{p\text{-}game}$ (land game fodder intake rate) kg/day		0
$Q_{s\text{-}fowl}$ (fowl soil intake rate) kg/day		0
$Q_{s\text{-}game}$ (land game soil intake rate) kg/day		0
t_{rec} (time - recreator) yr		26
TR (target cancer risk) unitless	0.000001	0.000001
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
Site area for ACF (area correction factor) m^2	1000029 m^2	2000 m^2
ED_{rec} (exposure duration - recreator) yr		26
$ED_{rec\text{-}a}$ (exposure duration - recreator adult) yr		10
$ED_{resc\text{-}c}$ (exposure duration - recreator child) yr		16
EF_{rec} (exposure frequency - recreator) day/yr		52
$EF_{rec\text{-}a}$ (exposure frequency - recreator adult) day/yr		52
$EF_{rec\text{-}c}$ (exposure frequency - recreator child) day/yr		52
ET_{rec} (exposure time - recreator) hr/day		2
$ET_{rec\text{-}a}$ (exposure time - recreator) hr/day		2
$ET_{rec\text{-}c}$ (exposure time - recreator) hr/day		2
$IFA_{rec\text{-}adj}$ (age-adjusted inhalation rate - recreator) m^3		0
$IFS_{rec\text{-}adj}$ (age-adjusted soil intake rate - recreator) mg		218400
$IRA_{rec\text{-}a}$ (inhalation rate - recreator adult) m^3/day	20	0
$IRA_{rec\text{-}c}$ (inhalation rate - recreator child) m^3/day	10	0

Table C.4 - Peak PRG Calculator Input for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Variable	Recreator Soil Default Value	Form-input Value
IRS_{rec-a} (soil intake rate - recreator adult) mg/day	100	100
IRS_{rec-c} (soil intake rate - recreator child) mg/day	200	200
t_{rec} (time - recreator) yr		26
TR (target cancer risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Notes:

site-specific value

cm - centimeters
g - grams
g/m^2-s per kg/m^3 - grams per square meter - second per kilogram per cubic meter
hr - hours
kg - kilograms
m^2 - square meters
m^3 - cubic meters
m^3/kg - cubic meter(s) per kilogram
mg - milligrams
m/s - meter(s) per second
yr - year(s)

Table C.5 - Peak PRG Calculator Ra-226 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Recreator Peak Risk PRGs for Soil

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Soil to Game Consumption PRG TR=1.0E-06 (pCi/g)	Soil to Fowl Consumption PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-226 @ PRG units	*8.54E-01*	*-*	*4.60E-01*	*-*	*-*	*3.08E-01*
Peak start time for maximum risk (yrs)	*1.23E+02*	*-*	*6.82E-02*	*-*	*-*	*9.04E+01*
Maximum risk during peak interval (unitless)	*1.17E-06*	*-*	*2.17E-06*	*-*	*-*	*3.25E-06*
Maximum risk-rate during peak interval (risk/yr)	*2.59E-08*	*-*	*7.40E-08*	*-*	*-*	*7.40E-08*

Table C.6 - Peak PRG Calculator Ra-228 Output for a Recreational User - Beachcomber (Recreator Soil Calculator Scenario)

Recreator Peak Risk PRGs for Soil

Peak PRG Results	Ingestion PRG TR=1.0E-06 (pCi/g)	Inhalation PRG TR=1.0E-06 (pCi/g)	External Exposure PRG TR=1.0E-06 (pCi/g)	Soil to Game Consumption PRG TR=1.0E-06 (pCi/g)	Soil to Fowl Consumption PRG TR=1.0E-06 (pCi/g)	Total PRG TR=1.0E-06 (pCi/g)
Peak PRG for Ra-228 @ PRG units	*5.55E+00*	-	*1.09E+00*	-	-	*9.11E-01*
Peak start time for maximum risk (yrs)	*1.00E-08*	-	*1.00E-08*	-	-	*1.00E-08*
Maximum risk during peak interval (unitless)	*1.80E-07*	-	*9.18E-07*	-	-	*1.10E-06*
Maximum risk-rate during peak interval (risk/yr)	*1.66E-08*	-	*4.14E-08*	-	-	*4.14E-08*

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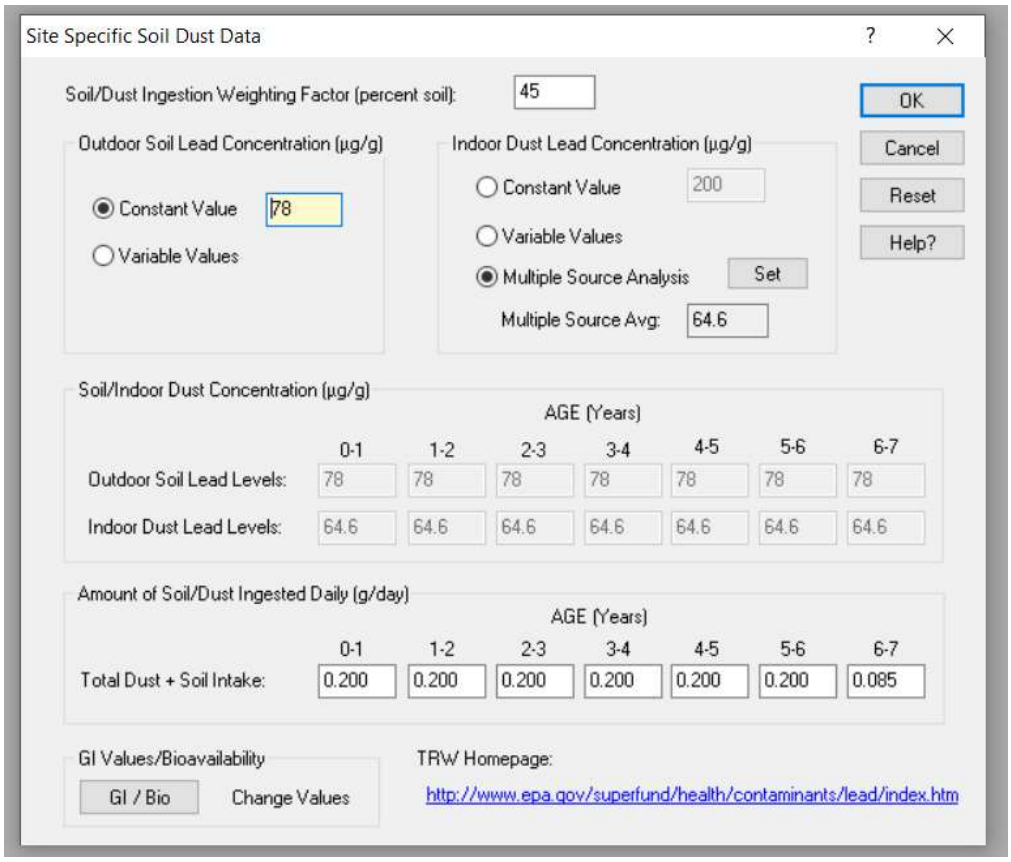
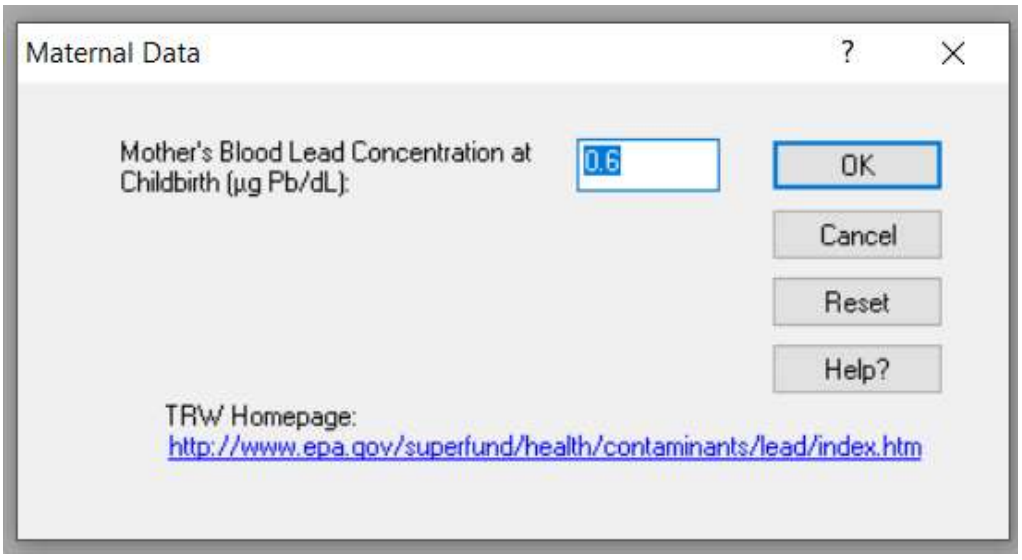
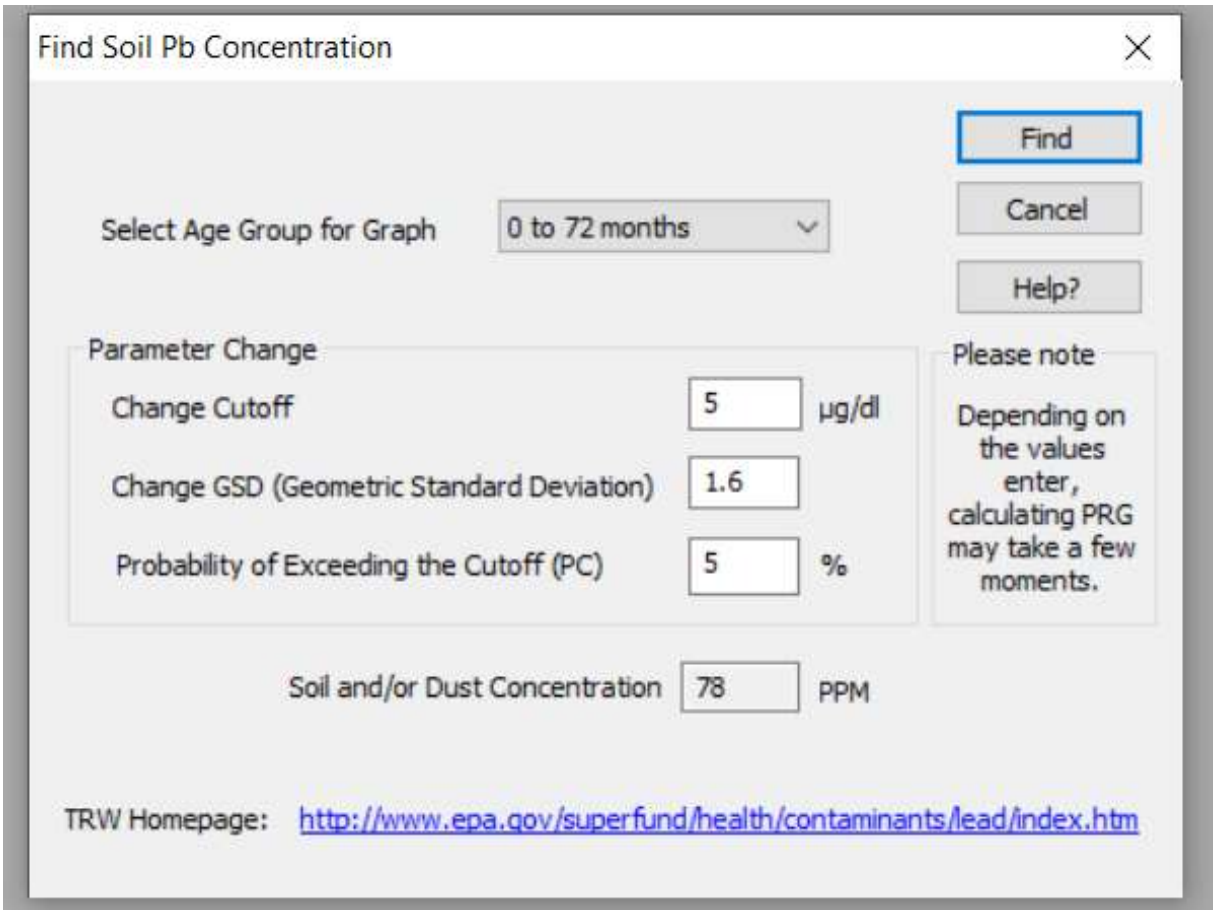
TVA Core Team Tennessee Valley Authority

Reference: Proposed Receptor-Specific Screening Levels for Human Health

ATTACHMENT D – IEUBK CALCULATION OUTPUT


Site Specific Soil Dust Data
Soil/Dust Ingestion Weighting Factor (percent soil): 45
OK
Cancel
Reset
Help?
Outdoor Soil Lead Concentration (µg/g)
Constant Value 78
Variable Values
Indoor Dust Lead Concentration (µg/g)
Constant Value 200
Variable Values
Multiple Source Analysis Set
Multiple Source Avg: 64.6
Soil/Indoor Dust Concentration (µg/g)
AGE (Years)
0-1 1-2 2-3 3-4 4-5 5-6 6-7
Outdoor Soil Lead Levels: 78 78 78 78 78 78 78
Indoor Dust Lead Levels: 64.6 64.6 64.6 64.6 64.6 64.6 64.6
Amount of Soil/Dust Ingested Daily (g/day)
AGE (Years)
0-1 1-2 2-3 3-4 4-5 5-6 6-7
Total Dust + Soil Intake: 0.200 0.200 0.200 0.200 0.200 0.200 0.085
GI Values/Bioavailability
GI / Bio
Change Values
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm


Maternal Data
Mother's Blood Lead Concentration at Childbirth (µg Pb/dL): 0.6
OK
Cancel
Reset
Help?
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm


Find Soil Pb Concentration
Find
Cancel
Help?
Select Age Group for Graph
0 to 72 months
Parameter Change
Change Cutoff
5
µg/dl
Change GSD (Geometric Standard Deviation)
1.6
Probability of Exceeding the Cutoff (PC)
5
%
Please note
Depending on the values enter, calculating PRG may take a few moments.
Soil and/or Dust Concentration
78
PPM
TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm

LEAD MODEL FOR WINDOWS Version 1.1

==========

Model Version: 1.1 Build11
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research

==========

******** Air ********

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100
4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

******** Diet ********

Age	Diet Intake(µg/day)
.5-1	2.260
1-2	1.960
2-3	2.130
3-4	2.040
4-5	1.950
5-6	2.050
6-7	2.220

******** Drinking Water ********

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 4.000 µg Pb/L

******** Soil & Dust ********

Multiple Source Analysis Used
Average multiple source concentration: 64.600 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.700
Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
.5-1	78.000	64.600
1-2	78.000	64.600
2-3	78.000	64.600
3-4	78.000	64.600
4-5	78.000	64.600
5-6	78.000	64.600
6-7	78.000	64.600

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	0.000
1-2	0.000
2-3	0.000
3-4	0.000
4-5	0.000
5-6	0.000
6-7	0.000

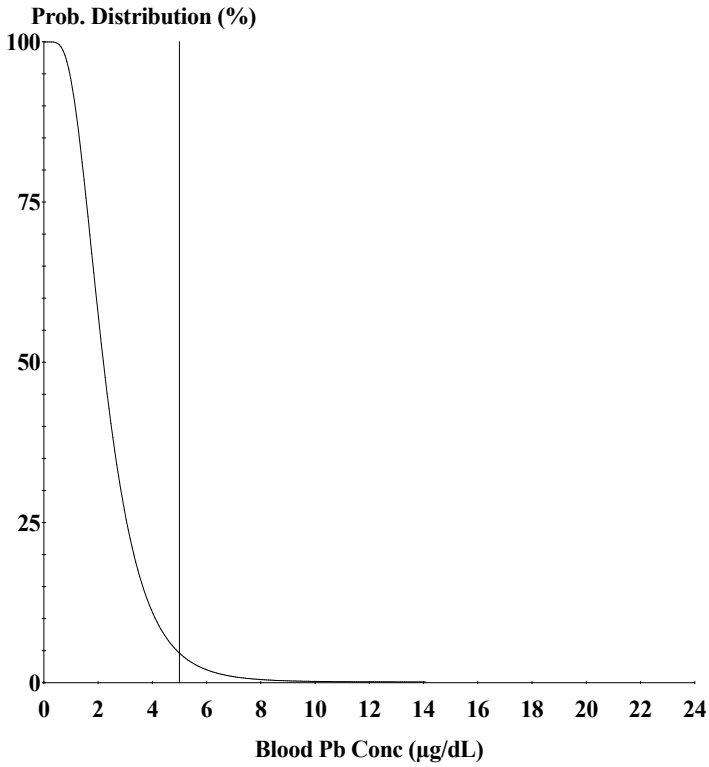
****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 0.600 µg Pb/dL

****
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	1.062	0.000	0.376
1-2	0.034	0.931	0.000	0.950
2-3	0.062	1.018	0.000	0.994
3-4	0.067	0.981	0.000	1.020
4-5	0.067	0.943	0.000	1.064
5-6	0.093	0.995	0.000	1.126
6-7	0.093	1.090	0.000	1.159

Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	3.984	5.443	3.0
1-2	4.025	5.939	2.6
2-3	4.051	6.126	2.3
3-4	4.078	6.146	2.2
4-5	4.099	6.172	2.1
5-6	4.112	6.325	1.9
6-7	1.769	4.112	1.4



Cutoff = 5.000 µg/dl
Geo Mean = 2.302
GSD = 1.600
% Above = 4.947

Age Range = 12 to 84 months

Run Mode = Research

APPENDIX C – SUPPORTING INFORMATION FOR DATA EVALUATION AND CALCULATION OF EXPOSURE POINT CONCENTRATIONS

APPENDIX C.1

EAR STATISTICAL ANALYSES

(APPENDIX E OF THE KIF PLANT ENVIRONMENTAL ASSESSMENT REPORT)

APPENDIX E –
STATISTICAL ANALYSES

APPENDIX E.1

STATISTICAL ANALYSIS OF BACKGROUND SOIL DATA

Appendix E.1 – Statistical Analysis of Background Soil Data

TDEC Commissioner's Order:
Environmental Assessment Report
Kingston Fossil Plant
Harriman, Tennessee

March 12, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

REVISION LOG

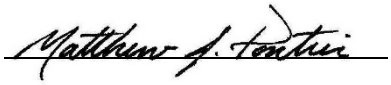
Revision	Description	Date
0	EAR Submittal to TDEC	May 30, 2023
1	Addresses August 16, 2023 TDEC Review Comments and Issued for TDEC	November 14, 2023
2	Addresses January 12, 2024 TDEC Review Comments and Issued for TDEC	March 12, 2024

Sign-off Sheet

This document entitled Appendix E.1 – Statistical Analysis of Background Soil Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by

Chris La Londe, Senior Risk Assessor

Reviewed by 

Matthew Pontier, Staff Engineer

Approved by

Carole M. Farr, Senior Principal Geologist

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Abbreviations

BGS	Background Soil
BTVs	Background Threshold Values
CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameter	Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
EI	Environmental Investigation
ft bgs	Feet Below Ground Surface
IQR	Interquartile Range
KIF Plant	Kingston Fossil Plant
NA	Not Available
%	Percent
SAR	Sampling and Analysis Report
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
UTLs	Upper Tolerance Limits

APPENDIX E.1 – STATISTICAL ANALYSIS OF BACKGROUND SOIL DATA

March 12, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this statistical analysis report on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on background soil (BGS) data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Kingston Fossil Plant (KIF Plant) located in Harriman, Tennessee. The BGS samples were collected as part of the Tennessee Department of Environment and Conservation (TDEC) Order Environmental Investigation (EI) between March 2019 and February 2020 in the vicinity of the KIF Plant from locations where naturally occurring, *in situ*, native soils unaffected by Coal Combustion Residual (CCR) materials were present. Further details regarding the BGS sampling program and results are available in the *KIF Plant Background Soil Investigation Sampling and Analysis Report* (SAR) (Appendix F.1), including the BGS investigation boring locations (Exhibit A.2), and a list of the BGS investigation borings and associated soil samples and analyses (Table B.1).

21 samples were excluded from the statistical analysis datasets for being collected in the saturated zone. The Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) included in the analysis are presented below in Table E.1-1.

Table E.1-1 – CCR Parameters Evaluated in Statistical Analysis

Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
TDS	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
% Ash	NA

Notes: CASRN - Chemical Abstracts Service Registry Number; CCR Rule - Title 40, Code of Federal Regulations, Part 257; NA - Not available; % - Percent

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV parameter. In this table, and in the results presented herein, fluoride has been grouped with the Appendix III parameters only to avoid duplication.

The following sections present the methods and results from general exploratory data analysis using summary statistics, data plots, outlier screening methods and the calculation of Background Threshold Values (BTVs).

2.0 METHODS

The statistical evaluation for the BGS data collected at the KIF Plant for the EI was conducted in two parts: 1) exploratory data analysis and 2) calculation of site-specific BTVs. The analyses relied on available background soil data collected as part of the BGS EI. Quality assurance and quality control samples (e.g. field duplicates) were excluded from the statistical analysis.

2.1 EXPLORATORY DATA ANALYSIS

Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation and percentiles) and graphical representations to identify important characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, spatial patterns, presence of outliers, and randomness.

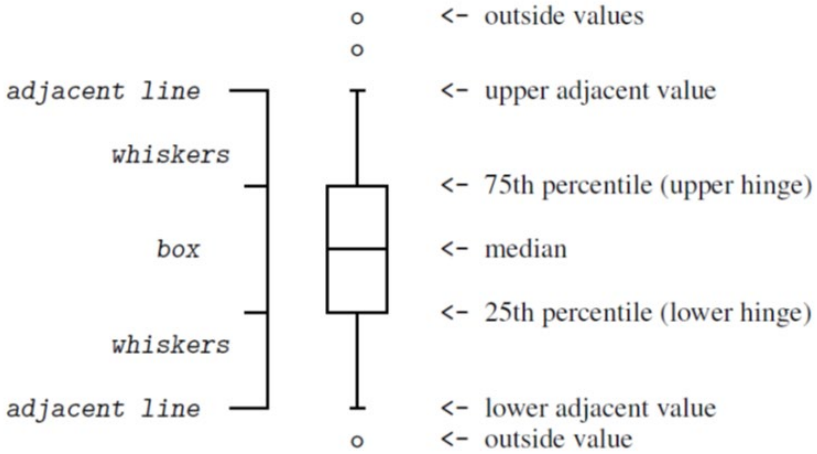
For the EI, surficial soil samples were typically collected at depths ranging from 0.0 to approximately 0.5 feet below ground surface (ft bgs). In addition to the CCR parameters (Table E.1-1), these samples were analyzed for the presence of CCR Material (% Ash). Along with surficial samples, the field sampling personnel collected approximately two feet of soil from each five-foot soil run (one foot in both directions from the midpoint of the five-foot interval) for the total depth of the boring. For the statistical analysis, soil depths were aggregated into the following depth intervals: surficial (0 to approximately 0.5 ft bgs), approximately 0.5 to less than or equal to 10 ft bgs, and greater than 10 ft bgs.

2.1.1 Summary Statistics

Summary statistics were calculated for each CCR Parameter grouped by depth interval and the entire set of BGS samples (including all depth intervals and boring locations). Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations and the 95th percentile concentrations. A summary statistics table is presented in Attachment E.1-A.

2.1.2 Exploratory Data Plots

Exploratory data plots (box plots) were constructed to support a visual review of the data. Box plots identify the center of the data, distribution, variability, and to visually identify potential outliers. The diagram below graphically depicts the basics of the construction of the box plots (StataCorp LLC 2017).



The box portion of the plot is the interquartile range (IQR), which represents the middle 50% of data, with the bottom of the box being the 25th percentile and the top of the box being the 75th percentile. The line inside the box is the median concentration. The top of the upper "whisker" represents the first observed concentration above the 75th percentile, whereas the bottom of the lower "whisker" represents the first observed concentration below the 25th percentile (upper adjacent value and lower adjacent value, respectively). Values that lie outside of the adjacent values represent outside concentrations (i.e. concentrations at the upper and lower ends of the distribution of the data). The method detection limit was used as the reported value in order to construct the box plot when analytical results were reported as non-detects.

Two sets of side-by-side box plots were constructed for the BGS CCR Parameter data: 1) results by depth interval and 2) results by BGS boring location. These box plots were useful in identifying differences in CCR Parameter concentrations between depth intervals and between boring locations and were especially useful for visually identifying potential outliers. Box plots for CCR Parameters aggregated by depth interval and by boring location are provided in Attachment E.1-B.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to the rest of the measurements and may represent anomalous data or data errors, but may also represent natural variation of CCR Parameter concentrations in environmental systems. Screening for outliers is a critical step because outliers can bias statistical estimates, statistical testing results, and inferences. The size of the datasets for each depth interval (a minimum of 10 samples) were sufficiently large to capture natural variation commonly seen in environmental datasets.

Outlier values were initially screened visually using the side-by-side box plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the IQR, which is defined as the 75th percentile value minus the 25th percentile value.

Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Finally, when the potential outlier(s) were identified visually and by Tukey's procedure, then statistical testing for outliers (Dixon or Rosner's Test) was conducted to determine if the data points were statistically significant outliers.

Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional error). Field forms, data validation reports, and other variables in the dataset that could influence analytical results were also evaluated. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset. The results of the outlier screening for the CUF Plant CCR material dataset are provided in Section 3.1.

2.2 ESTIMATES OF BACKGROUND CONDITIONS

BTVs were calculated as conservative estimates of CCR Parameter concentrations in BGS. Specifically, 95% upper tolerance limits (UTLs) with 95% coverage were calculated for each parameter at each soil depth interval defined for the statistical datasets and with all depths combined to establish conservative estimates of background soil concentrations. The UTL represents the upper bound of a pre-specified proportion of the underlying data population with a specified level of confidence. For example, for a "95% UTL with 95% coverage", there is 95% confidence that, on average, 95% of the data are below the UTL. The upper one-sided UTL is commonly used in environmental monitoring and is constructed using background data (Ofungwu 2014). In the case of pH, 95% tolerance intervals with 95% coverage were calculated to bound the range of pH values. BTVs aggregated by soil depth interval and with all depths combined are presented in Attachment E.1-A.

2.2.1 Tests for Normality of Background Data

Prior to the calculation of UTLs, the data were evaluated for normality. Parametric methods to establish background conditions (UTLs) can be applied to data that are normally distributed or to data that fit another defined statistical distribution (e.g. gamma distribution), or to data that can be transformed to normal using mathematical transformations (e.g. lognormal transformation). Testing data for normality was done using formal statistical methods, known as goodness-of-fit-testing (e.g. Shapiro-Wilk or Lilliefors tests). If the data did not fit a defined statistical distribution or could not be transformed to normal, then non-parametric methods were used.

2.2.2 Parametric UTLs

Parametric UTLs were used when the background data were normally distributed, gamma distributed, or transformed using the lognormal transformation. A background sample size or dataset consisting of at least eight observations was required to generate an adequate tolerance limit.

The calculation of the UTL is straightforward:

$$UTL = \overline{x} + \tau s$$

Where:

$\overline{x}$ = mean CCR parameter concentration in the background dataset

s = standard deviation of CCR parameter in the background dataset

τ = multiplier based on size of dataset, confidence (95%) and desired coverage (95%).

2.2.3 Non-parametric UTLs

When the background data do not fit the normal or gamma distribution or cannot be normalized via the lognormal transformation, non-parametric UTLs were used. The non-parametric UTL is an order statistic, typically the maximum or the second largest observed concentration in the background dataset. Unlike parametric methods, the desired coverage and confidence interval cannot be pre-specified for non-parametric tolerance limits. In the case of non-parametric methods, the level of confidence increases with increasing sample size. If non-parametric methods were used, the approximate level of confidence was reported.

UTLs, especially non-parametric UTLs, are sensitive to outliers and are biased high in the presence of outliers. For this initial analysis, no suspect outliers were removed from the data set. If the UTLs presented in this report are going to be used to inform corrective actions, then additional analysis to account for the presence of outliers is warranted.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics for each CCR Parameter are provided in Attachment E.1-A, with results aggregated by depth interval and with all depths combined. Summary statistics are sorted by CCR Parameter type (i.e., CCR Rule Appendix III Parameters, CCR Rule Appendix IV Parameters, TDEC Appendix I Parameters, and Other). Box plots for each CCR Parameter aggregated by depth and boring location are provided in Attachment E.1-B.

The number of values identified as potential outliers using Tukey's procedure for each depth interval and with all depths combined is identified in Attachment E.1-A. For these potential outliers, no definitive reasons were identified for the outlier values and the values identified were assumed to be representative of natural conditions and natural variation within native soil. These values were flagged as statistical outliers in the dataset and retained for subsequent calculations and analysis if needed for future evaluations (see columns labelled "Number of Statistical Outliers" and "Number of Outliers Removed" in Attachment E.1-A).

3.2 ESTIMATES OF BACKGROUND CONDITIONS

BTVs for the BGS investigation at the KIF Plant were calculated using UTLs (and Tolerance Intervals in the case of pH). The resulting BTV concentrations and the statistical distribution and methods used to calculate the UTLs are identified for each CCR Parameter aggregated by depth interval and with all depths combined in Attachment E.1-A.

4.0 REFERENCES

Ofungwu, J. (2014), Statistical Applications for Environmental Analysis and Risk Assessment. Hoboken, New Jersey: John Wiley and Sons, Inc.

StataCorp. (2017), Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, TX: StataCorp LLC.

Tukey, J.W. (1977), Exploratory data analysis. Reading, Massachusetts: Addison-Wesley, 1977.

ATTACHMENT E.1-A
SUMMARY STATISTICS TABLES

Summary Statistics - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

Parameter	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using all Detects & Non-Detects									
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
Percent Ash																
Ash	Surficial	11/12	(1 - 1)	8.3%	1	5	2.67	1.31	1.75	2.50	4.00	4.45	0	0	NA	NA
CCR Rule Appendix IV Parameters																
Boron	Surficial	10/14	(1.53 - 1.85)	28.6%	1.68	9.51	3.36	2.37	1.73	2.58	3.41	8.01	2	0	11.0	95% WH Approximate Gamma UTL 95% Coverage
	0.5' to 10' bgs	12/20	(1.6 - 1.81)	40.0%	1.84	7.99	2.88	1.82	1.68	1.98	3.42	6.72			7.23	95% UTL (Normal) 95% Coverage
	>10' bgs	10/19	(1.54 - 1.74)	47.4%	1.83	12.9	3.17	2.76	1.64	1.83	3.40	8.16			10.2	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	32/53	(1.53 - 1.85)	39.6%	1.68	12.9	3.10	2.35	1.68	2.06	3.52	7.77			8.32	95% KM UTL (Lognormal) 95% Coverage
Calcium	Surficial	14/14	--	0.0%	260	15,400	3,390	5,000	654	1,040	3,690	14,600	4	0	22,100	95% WH Approximate Gamma UTL 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	35.6	13,500	1,280	2,990	62.9	232	973	3,080			17,500	95% (Lognormal) 95% Coverage
	>10' bgs	19/19	--	0.0%	23.1	1,000	186	243	36.5	67.6	235	628			1,520	95% (Lognormal) 95% Coverage
	All Depth	53/53	--	0.0%	23.1	15,400	1,450	3,340	66.6	260	906	8,020			10,900	95% (Lognormal) 95% Coverage
Chloride	Surficial	2/14	(4.37 - 5.62)	85.7%	4.37	6.34	4.51	0.507	4.54	4.70	5.12	5.87	8	0	6.34	95% UTL (NP-51.2%) 95% Coverage
	0.5' to 10' bgs	4/20	(4.11 - 5.25)	80.0%	6.83	15.6	5.44	3.06	4.59	4.77	5.18	12.2			15.6	95% UTL (NP-64.2%) 95% Coverage
	>10' bgs	6/19	(4.48 - 5.67)	68.4%	6.78	19.3	7.03	4.51	4.53	4.89	7.30	16.8			19.3	95% UTL (NP-62.3%) 95% Coverage
	All Depth	12/53	(4.11 - 5.67)	77.4%	4.37	19.3	5.66	3.49	4.53	4.76	5.28	14.0			16.5	95% UTL (NP-75%) 95% Coverage
Fluoride	Surficial	10/14	(0.792 - 0.831)	28.6%	0.869	3.76	1.77	1.01	0.841	1.35	2.56	3.54	9	0	4.40	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	5/20	(0.761 - 0.903)	75.0%	1.15	3.17	1.13	0.736	0.807	0.824	0.965	2.75			3.17	95% UTL (NP-64.2%) 95% Coverage
	>10' bgs	1/19	(0.715 - 1.11)	94.7%	4.40	4.40	0.91	0.823	0.793	0.833	0.944	1.44			4.40	95% UTL (NP-62.3%) 95% Coverage
	All Depth	16/53	(0.715 - 1.11)	69.8%	0.869	4.40	1.20	0.922	0.800	0.840	1.15	3.27			3.76	95% UTL (NP-75%) 95% Coverage
pH (lab)	Surficial	14/14	--	0.0%	5.4	7.8	6.6	0.88	5.8	6.7	7.4	7.7	0	0	(4.0-9.1)	95% Tolerance Interval (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	4.6	8.1	5.7	1.1	5.1	5.4	6.3	8.1			(4.6-8.1)	95% Tolerance Interval (NP-64.2%) 95% Coverage
	>10' bgs	19/19	--	0.0%	4.6	7.2	5.2	0.56	5.0	5.2	5.4	5.8			(3.7-6.8)	95% Tolerance Interval (Lognormal) 95% Coverage
	All Depth	53/53	--	0.0%	4.6	8.1	5.8	1.0	5.1	5.4	6.5	7.7			(4.6-8.1)	95% Tolerance Interval (NP-75%) 95% Coverage
pH (field)	Surficial	14/14	--	0.0%	5.20	7.49	6.35	0.789	5.70	6.05	6.92	7.47	0	0	(4.09-8.60)	95% Tolerance Interval (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	4.02	7.86	5.47	1.05	4.75	5.12	5.96	7.76			(2.53-8.40)	95% Tolerance Interval (Gamma) 95% Coverage
	>10' bgs	19/19	--	0.0%	4.07	6.79	5.01	0.619	4.73	5.02	5.22	5.75			(3.40-6.63)	95% Tolerance Interval (Normal) 95% Coverage
	All Depth	53/53	--	0.0%	4.02	7.86	5.54	0.986	4.87	5.25	5.89	7.47			(3.20-7.87)	95% Tolerance Interval (Lognormal) 95% Coverage
Sulfate	Surficial	13/14	(9.83 - 9.83)	7.1%	8.35	30.1	19.0	7.90	10.7	19.1	27.1	29.5	1	0	39.6	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	13/20	(7.86 - 8.53)	35.0%	14.3	213	31.7	43.9	8.31	22.0	32.9	63.2			131	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	4/19	(7.14 - 11.1)	79.0%	12.6	25.6	9.73	5.45	7.92	8.56	11.1	21.3			25.6	95% UTL (NP-62.3%) 95% Coverage
	All Depth	30/53	(7.14 - 11.1)	43.4%	8.35	213	20.4	29.1	8.32	12.6	25.4	43.6			64.7	95% KM UTL (Lognormal) 95% Coverage
CCR Rule Appendix IV Parameters																
Antimony	Surficial	13/14	(0.0783 - 0.0783)	7.1%	0.0868	0.353	0.199	0.0864	0.135	0.203	0.270	0.329	0	0	0.425	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	14/20	(0.0721 - 0.0824)	30.0%	0.0727	0.345	0.161	0.0937	0.0810	0.139	0.219	0.338			0.386	95% UTL (Normal) 95% Coverage
	>10' bgs	15/19	(0.0719 - 0.0829)	21.1%	0.0775	0.502	0.185	0.127	0.0871	0.123	0.221	0.419			0.493	95% UTL (Normal) 95% Coverage
	All Depth	42/53	(0.0719 - 0.0829)	20.8%	0.0727	0.502	0.180	0.107	0.0847	0.139	0.230	0.370			0.397	95% UTL (Normal) 95% Coverage
Arsenic	Surficial	14/14	--	0.0%	2.42	11.9	5.76	2.62	3.87	5.56	6.32	10.2	2	0	12.6	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	1.59	9.16	4.80	1.94	3.08	4.79	6.14	7.40			9.44	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	2.32	40.4	8.82	11.5	3.01	4.95	7.79	40.0			40.4	95% UTL (NP-62.3%) 95% Coverage
	All Depth	53/53	--	0.0%	1.59	40.4	6.49	7.20	3.08	4.97	6.30	12.3			40.0	95% UTL (NP-75%) 95% Coverage
Barium	Surficial	14/14	--	0.0%	25.6	199	93.2	49.8	50.9	90.6	120	170	0	0	223	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	16.3	251	82.7	70.6	26.2	57.1	142	191			333	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	10.0	156	49.8	42.9	18.1	24.8	75.6	133			280	95% (Lognormal) 95% Coverage
	All Depth	53/53	--	0.0%	10.0	251	73.7	58.5	24.8	58.0	107	188			308	95% (Lognormal) 95% Coverage
Beryllium	Surficial	14/14	--	0.0%	0.152	1.11	0.652	0.365	0.290	0.627	1.01	1.08	0	0	1.61	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	0.109	1.14	0.559	0.375	0.204	0.473	0.953	1.11			1.94	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	0.105	2.51	0.664	0.685	0.163	0.301	1.01	1.72			3.1	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	0.105	2.51	0.621	0.499	0.202	0.451	0.987	1.45			1.63	95% UTL (NP-75%) 95% Coverage
Cadmium	Surficial	13/14	(0.0211 - 0.0211)	7.1%	0.0232	0.188	0.0681	0.0465	0.0375	0.0527	0.0783	0.152	4	0	0.19	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	5/20	(0.0198 - 0.0228)	75.0%	0.0234	0.128	0.0291	0.0245	0.0205	0.0213	0.0230	0.0552			0.0877	95% UTL (Normal) 95% Coverage
	>10' bgs	6/19	(0.0194 - 0.0228)	68.4%	0.0243	0.273	0.0485	0.0637	0.0206	0.0215	0.0288	0.164			0.203	95% UTL (Normal) 95% Coverage
	All Depth	24/53	(0.0194 - 0.0228)	54.7%	0.0232	0.273	0.0462	0.0500	0.0207	0.0227	0.0478	0.141			0.143	95% WH Approximate Gamma UTL 95% Coverage

Summary Statistics - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

Parameter	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using all Detects & Non-Detects									
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
Chromium	Surficial	14/14	--	0.0%	6.85	38.1	21.0	9.42	14.3	17.7	29.8	34.7	0	0	45.6	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	8.55	41.1	21.1	8.99	14.6	19.4	26.1	39.7			42.7	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	5.17	30.5	14.9	8.31	8.42	12.0	21.1	29.0			42.0	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	5.17	41.1	18.9	9.19	12.0	16.2	25.4	34.9			42.4	95% WH Approximate Gamma UTL 95% Coverage
Cobalt	Surficial	14/14	--	0.0%	1.70	27.3	12.1	7.81	6.34	11.1	18.9	22.6	0	0	32.5	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	1.33	30.6	11.5	8.80	2.05	11.2	15.3	28.2			32.6	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	1.24	50.2	11.8	12.5	2.76	7.45	15.4	34.0			55.9	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	1.24	50.2	11.8	9.88	2.80	9.44	16.5	29.1			40.2	95% WH Approximate Gamma UTL 95% Coverage
Fluoride	Surficial	10/14	(0.792 - 0.831)	28.6%	0.869	3.76	1.77	1.01	0.841	1.35	2.56	3.54	9	0	4.40	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	5/20	(0.761 - 0.903)	75.0%	1.15	3.17	1.13	0.736	0.807	0.824	0.965	2.75			3.17	95% UTL (NP-64.2%) 95% Coverage
	>10' bgs	1/19	(0.715 - 1.11)	94.7%	4.40	4.40	0.909	0.823	0.793	0.833	0.944	1.44			4.40	95% UTL (NP-62.3%) 95% Coverage
	All Depth	16/53	(0.715 - 1.11)	69.8%	0.869	4.40	1.20	0.922	0.800	0.840	1.15	3.27			3.76	95% UTL (NP-75%) 95% Coverage
Lead	Surficial	14/14	--	0.0%	7.73	49.6	18.0	11.1	11.1	14.1	19.9	36.7	3	0	47.1	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	5.42	25.4	14.0	5.48	10.2	13.3	16.3	23.6			27.1	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	3.23	61.8	17.0	15.5	7.99	11.1	19.3	47.9			63.6	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	3.23	61.8	16.1	11.3	9.62	12.7	18.5	40.8			40.5	95% WH Approximate Gamma UTL 95% Coverage
Lithium	Surficial	14/14	--	0.0%	3.86	23.2	11.6	6.78	6.52	8.61	17.5	21.3	0	0	29.3	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	4.77	28.5	12.8	6.52	8.76	10.7	13.8	25.2			31.7	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	2.88	26.4	9.76	7.10	4.31	6.30	14.9	24.1			41.2	95% (Lognormal) 95% Coverage
	All Depth	53/53	--	0.0%	2.88	28.5	11.4	6.80	5.79	9.40	15.1	24.3			28.8	95% WH Approximate Gamma UTL 95% Coverage
Mercury	Surficial	11/14	(0.0257 - 0.0722)	21.4%	0.0175	0.174	0.0532	0.0384	0.0387	0.0548	0.0651	0.111	0	0	0.178	95% WH Approximate Gamma UTL 95% Coverage
	0.5' to 10' bgs	13/20	(0.0155 - 0.0483)	35.0%	0.0165	0.188	0.0654	0.0556	0.0289	0.0461	0.0900	0.187			0.199	95% UTL (Normal) 95% Coverage
	>10' bgs	16/19	(0.0162 - 0.0275)	15.8%	0.0172	0.149	0.0600	0.0416	0.0275	0.0483	0.0834	0.139			0.161	95% UTL (Normal) 95% Coverage
	All Depth	40/53	(0.0155 - 0.0722)	24.5%	0.0165	0.188	0.0601	0.0469	0.0275	0.0483	0.0765	0.159			0.179	95% WH Approximate Gamma UTL 95% Coverage
Molybdenum	Surficial	14/14	--	0.0%	0.235	2.35	0.848	0.575	0.520	0.744	1.06	1.80	2	0	2.35	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	18/20	(0.19 - 0.214)	10.0%	0.284	1.30	0.624	0.321	0.383	0.630	0.706	1.22			1.39	95% UTL (Normal) 95% Coverage
	>10' bgs	15/19	(0.189 - 0.583)	21.1%	0.253	5.84	0.938	1.37	0.331	0.427	0.655	3.57			5.84	95% UTL (NP-62.3%) 95% Coverage
	All Depth	47/53	(0.189 - 0.583)	11.3%	0.235	5.84	0.796	0.899	0.343	0.568	0.886	2.07			2.55	95% KM UTL (Lognormal) 95% Coverage
Radium-226+228	Surficial	14/14	--	0.0%	1.181	3.09	2.31	0.659	1.67	2.51	2.84	2.94	0	0	4.03	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	1.618	3.56	2.58	0.585	2.07	2.80	2.94	3.34			3.98	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	0.696	4.26	2.49	1.09	1.65	2.17	3.12	4.22			5.14	95% UTL (Normal) 95% Coverage
	All Depth	53/53	--	0.0%	0.696	4.26	2.48	0.810	1.70	2.59	2.95	4.02			4.13	95% UTL (Normal) 95% Coverage
Selenium	Surficial	14/14	--	0.0%	0.389	1.60	0.854	0.363	0.619	0.744	1.02	1.47	0	0	1.80	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	0.244	1.63	0.704	0.311	0.470	0.699	0.866	0.977			1.45	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	0.162	1.34	0.674	0.395	0.336	0.485	0.984	1.33			2.05	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	0.162	1.63	0.732	0.358	0.450	0.704	0.893	1.36			1.46	95% UTL (Normal) 95% Coverage
Thallium	Surficial	14/14	--	0.0%	0.124	0.453	0.248	0.0994	0.187	0.219	0.273	0.443	2	0	0.508	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	0.127	0.417	0.230	0.0717	0.186	0.218	0.255	0.356			0.402	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	0.0542	1.01	0.245	0.238	0.108	0.170	0.255	0.702			0.926	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	0.0542	1.01	0.240	0.155	0.164	0.200	0.259	0.458			0.621	95% (Lognormal) 95% Coverage

Summary Statistics - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

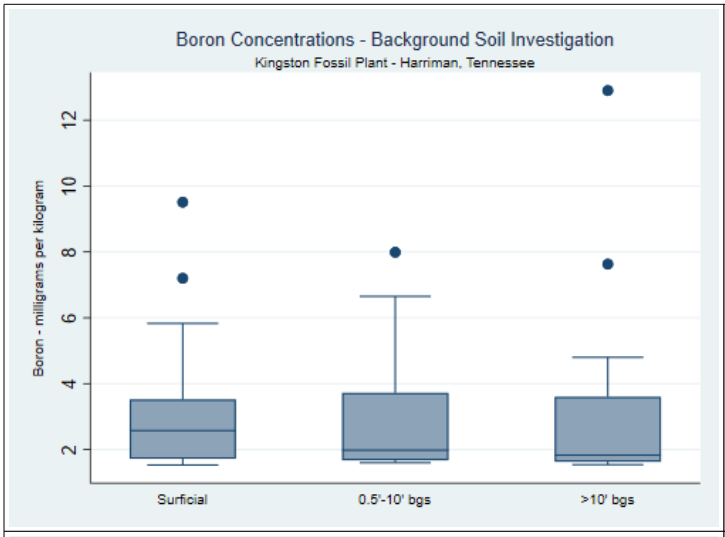
Parameter	Soil Depth	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using all Detects & Non-Detects									
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Number of Statistical Outliers	Number of Outliers Removed	Background Threshold Value	Statistical Distribution & Method
TDEC Appendix I Parameters																
Copper	Surficial	14/14	--	0.0%	2.89	28.0	13.5	8.88	7.24	8.83	20.5	27.6	1	0	48.3	95% WH Approximate Gamma UTL 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	4.49	36.7	13.9	7.43	9.81	11.5	15.8	25.7			34.7	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	3.39	60.4	15.6	14.2	5.95	8.58	24.0	32.6			61.2	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	2.89	60.4	14.4	10.5	7.47	10.3	20.6	28.8			45.5	95% (Lognormal) 95% Coverage
Nickel	Surficial	14/14	--	0.0%	3.41	38.4	15.7	12.6	5.61	8.31	26.1	36.6	0	0	67.4	95% WH Approximate Gamma UTL 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	3.40	37.8	13.3	11.3	4.98	8.63	19.1	33.5			49.9	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	2.25	47.4	13.1	13.7	3.22	4.98	20.7	34.7			47.4	95% UTL (NP-62.3%) 95% Coverage
	All Depth	53/53	--	0.0%	2.25	47.4	13.9	12.3	4.48	7.77	21.1	36.5			38.4	95% UTL (NP-75%) 95% Coverage
Silver	Surficial	2/14	(0.0304 - 0.039)	85.7%	0.0641	0.102	0.0379	0.0198	0.0333	0.0343	0.0378	0.0774	2	0	0.102	95% UTL (NP-51.2%) 95% Coverage
	0.5' to 10' bgs	0/20	(0.0304 - 0.0362)	100.0%	--	--	--	--	0.0322	0.0332	0.0346	0.0359			0.0362	95% UTL (NP-64.2%) 95% Coverage
	>10' bgs	0/19	(0.0308 - 0.0445)	100.0%	--	--	--	--	0.0326	0.0337	0.0362	0.0434			0.0445	95% UTL (NP-62.3%) 95% Coverage
	All Depth	2/53	(0.0304 - 0.0445)	96.2%	0.0641	0.102	0.0324	0.0107	0.0325	0.0335	0.0355	0.0438			0.0641	95% UTL (NP-75%) 95% Coverage
Vanadium	Surficial	14/14	--	0.0%	12.9	32.7	25.1	5.72	21.0	25.9	28.3	32.7	0	0	40.1	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	15.2	33.6	24.7	4.38	22.2	24.2	27.1	31.5			35.2	95% UTL (Normal) 95% Coverage
	>10' bgs	19/19	--	0.0%	6.84	42.0	20.9	9.59	13.2	20.5	27.9	34.0			44.1	95% UTL (Normal) 95% Coverage
	All Depth	53/53	--	0.0%	6.84	42.0	23.4	7.13	19.9	23.8	28.0	32.9			38	95% UTL (Normal) 95% Coverage
Zinc	Surficial	14/14	--	0.0%	15.4	75.9	45.0	19.9	26.3	45.2	58.1	73.8	2	0	97.1	95% UTL (Normal) 95% Coverage
	0.5' to 10' bgs	20/20	--	0.0%	12.5	64.4	30.8	13.6	22.4	26.5	36.4	58.0			69.6	95% WH Approximate Gamma UTL 95% Coverage
	>10' bgs	19/19	--	0.0%	8.06	170	44.7	46.1	15.1	27.8	52.6	141			190	95% WH Approximate Gamma UTL 95% Coverage
	All Depth	53/53	--	0.0%	8.06	170	39.5	30.8	22.0	29.3	48.8	87.9			121	95% (Lognormal) 95% Coverage

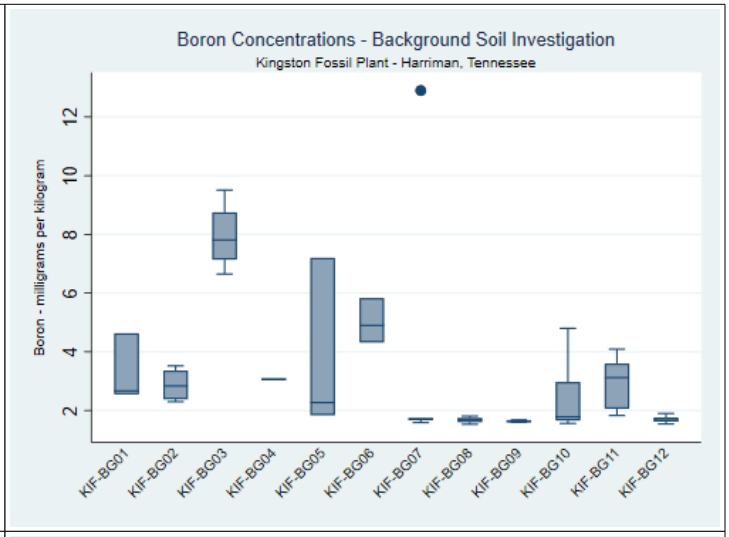
Notes:
CCR Rule - Title 40, Code of Federal Regulations, Part 257
bgs - below ground surface
KM - Kaplan-Meier, For Parameters with non-detects reported at the method detection limit, the mean, standard deviation, and background threshold values were calculated using Kaplan-Meier methods
'--" - Not Applicable
NP-% - Non-parametric method and associated confidence level of the estimate
TDEC - Tennessee Department of Environment and Conservation
UTL - Upper Tolerance Limit
WH - Background Threshold Limits based on the gamma distribution utilize Wilson Hiferty (WH) estimates
% - Percent

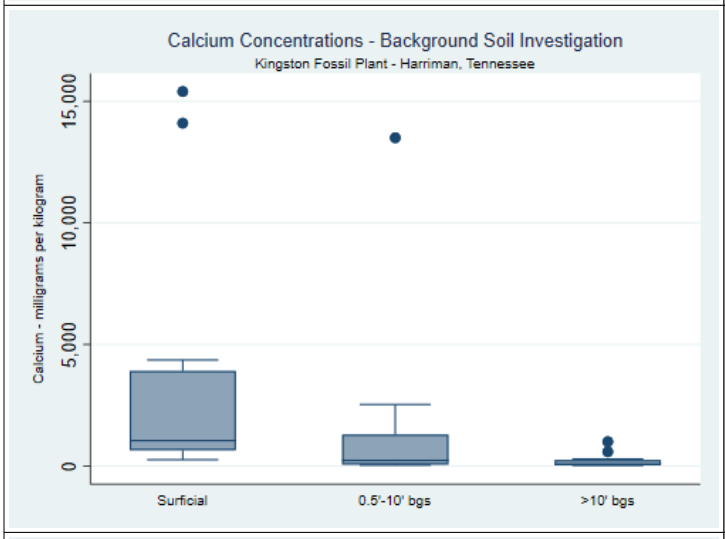
Except for Ash, pH & Radium 226 + 228, all units milligrams per kilogram (mg/kg)
Units for Ash are percent (%)
Units for pH are Standard Units (S.U.)
Units for Radium 226+228 are picocuries per gram (pCi/g)
All non-detects reported at the laboratory reporting limit
Surficial soil samples were collected in the 0 to 0.5 feet below ground surface (bgs) soil depth interval

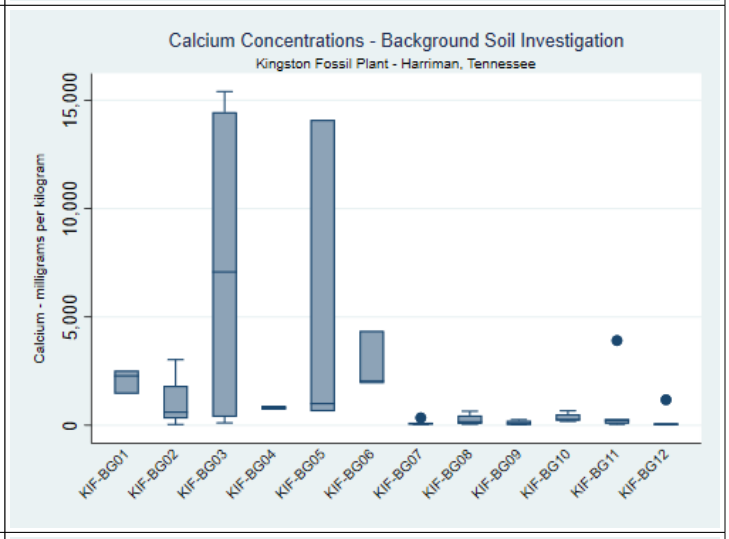
ATTACHMENT E.1-B
BOX PLOTS

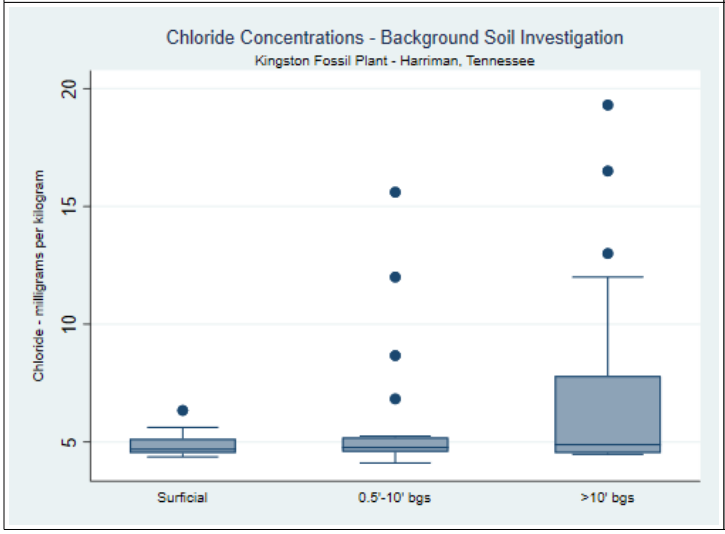
Box Plots
CCR Rule Appendix III Parameters
Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

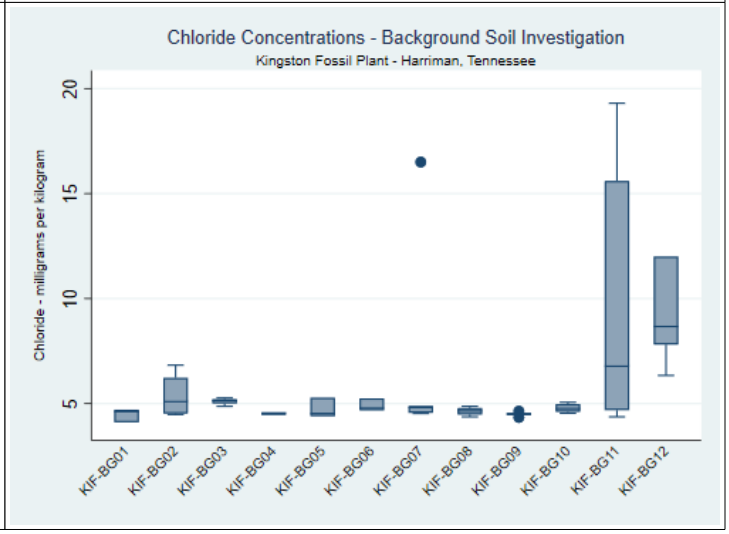


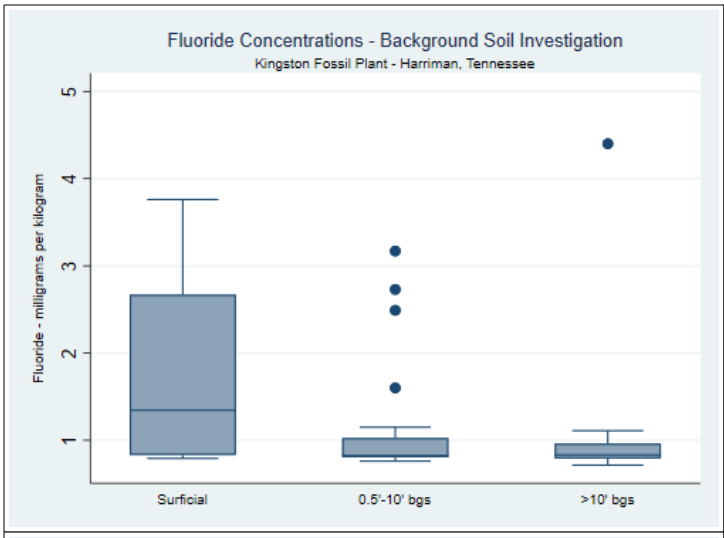


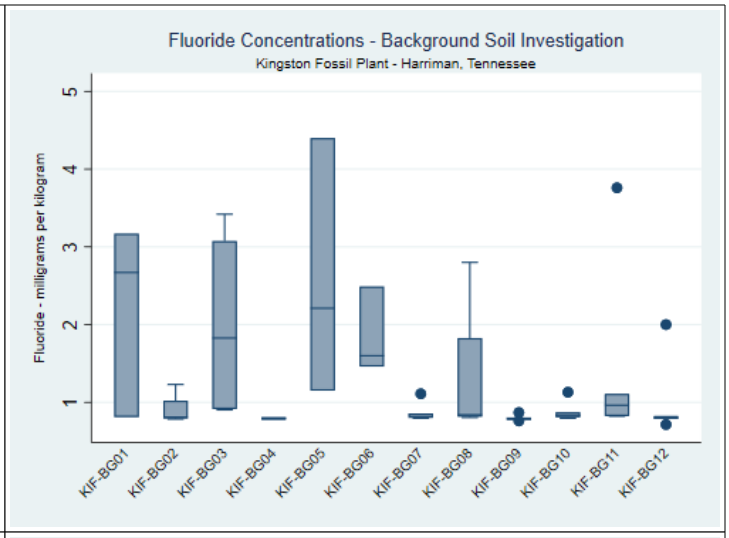


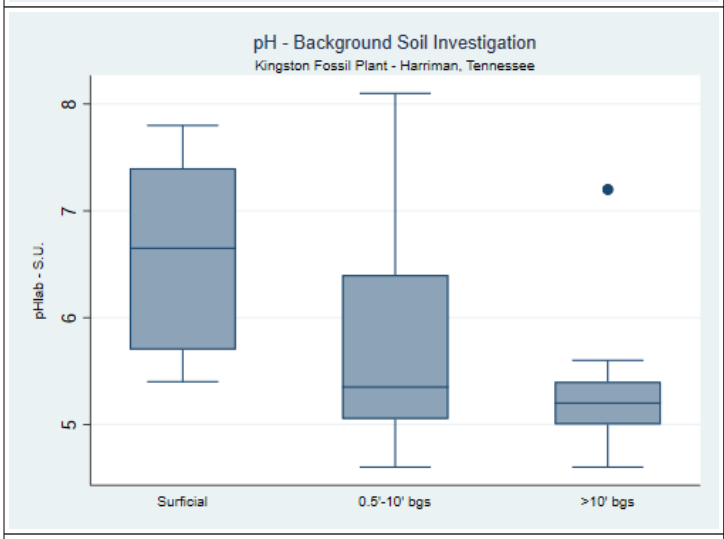


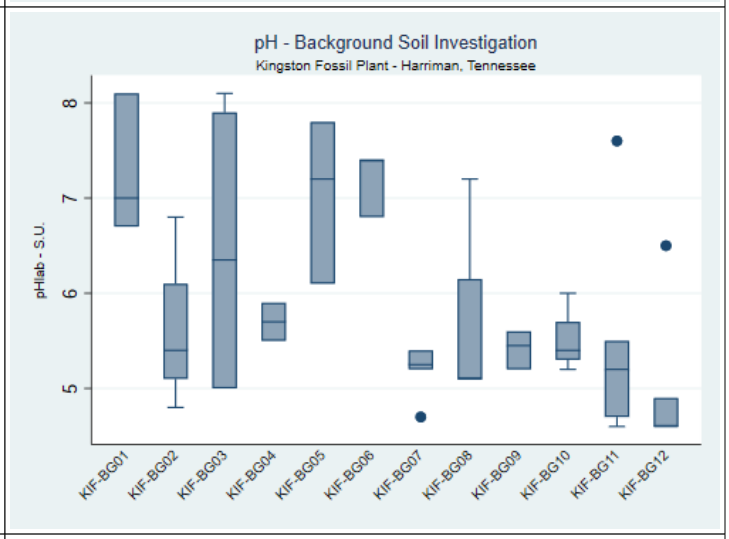


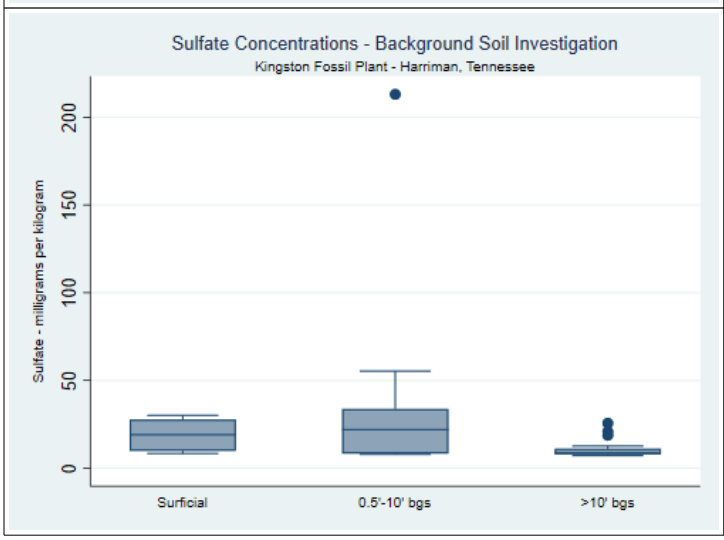


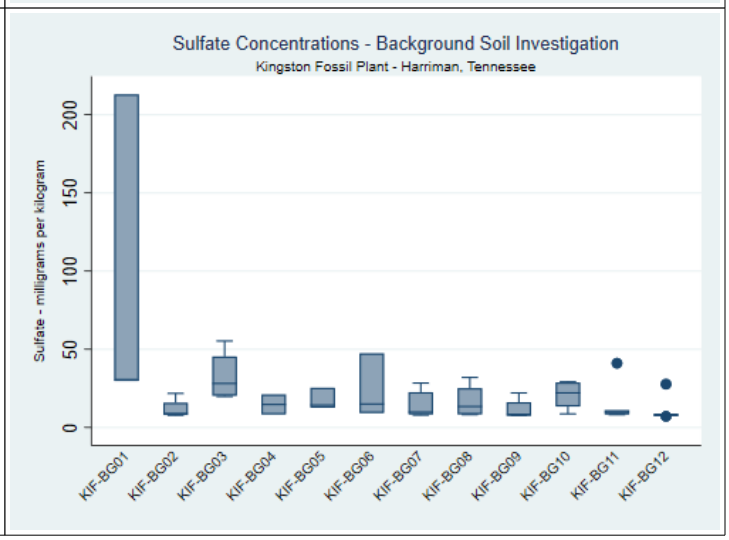

Fluoride Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Fluoride - milligrams per kilogram
1
2
3
4
5
Surficial
0.5'-10' bgs
>10' bgs


Fluoride Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Fluoride - milligrams per kilogram
1
2
3
4
5
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12

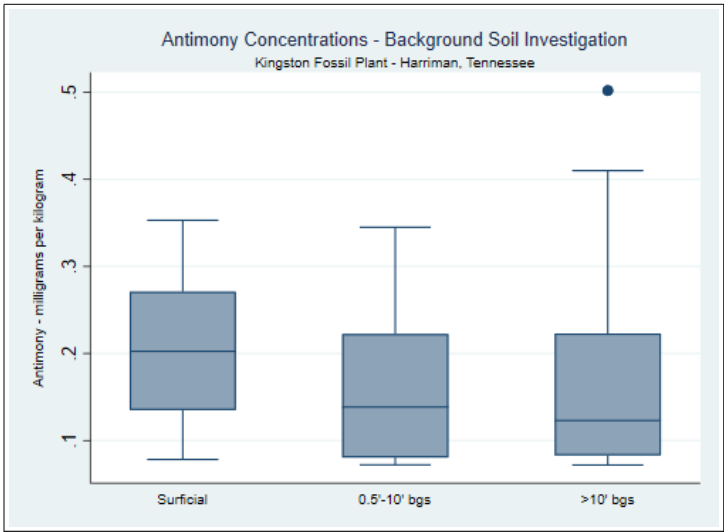

pH - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
pHlab - S.U.
5
6
7
8
Surficial
0.5'-10' bgs
>10' bgs

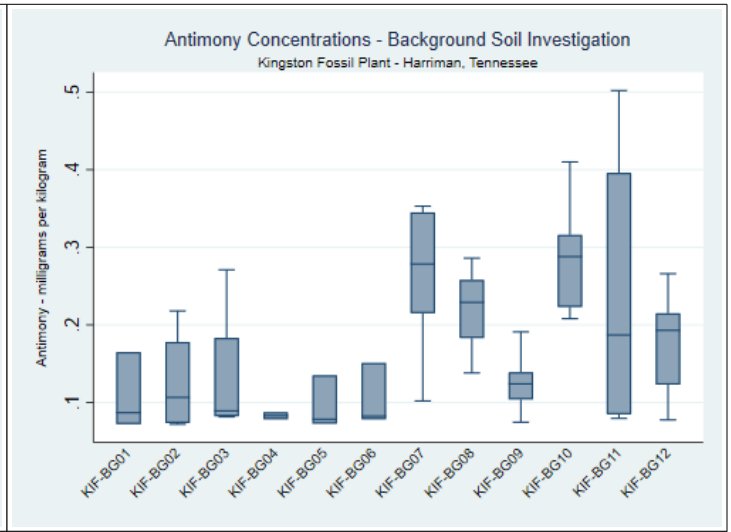

pH - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
pHlab - S.U.
5
6
7
8
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12

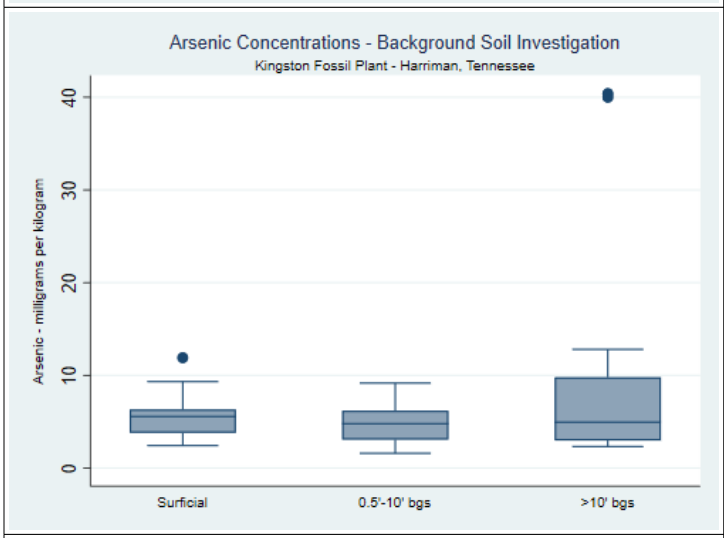

Sulfate Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Sulfate - milligrams per kilogram
0
50
100
150
200
Surficial
0.5'-10' bgs
>10' bgs

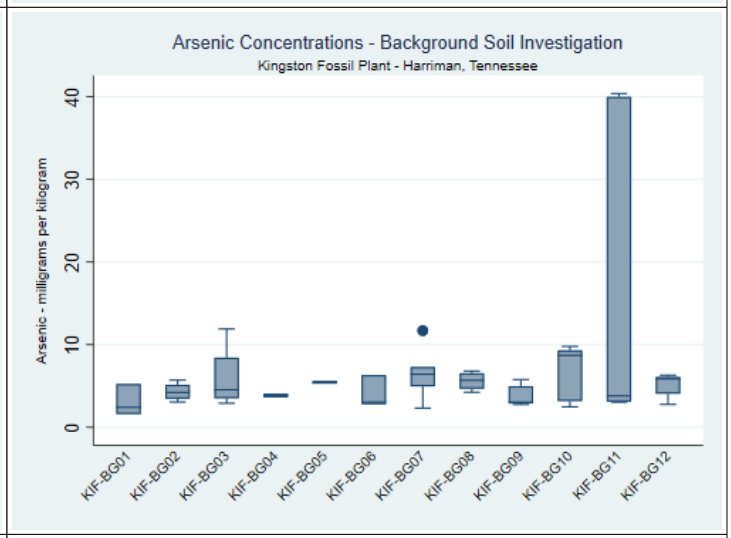

Sulfate Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Sulfate - milligrams per kilogram
0
50
100
150
200
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12

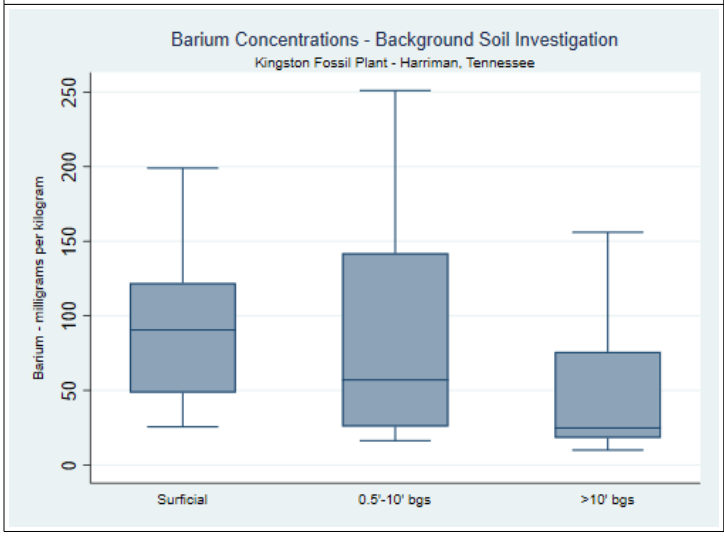
Box Plots
CCR Rule Appendix IV Parameters
Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

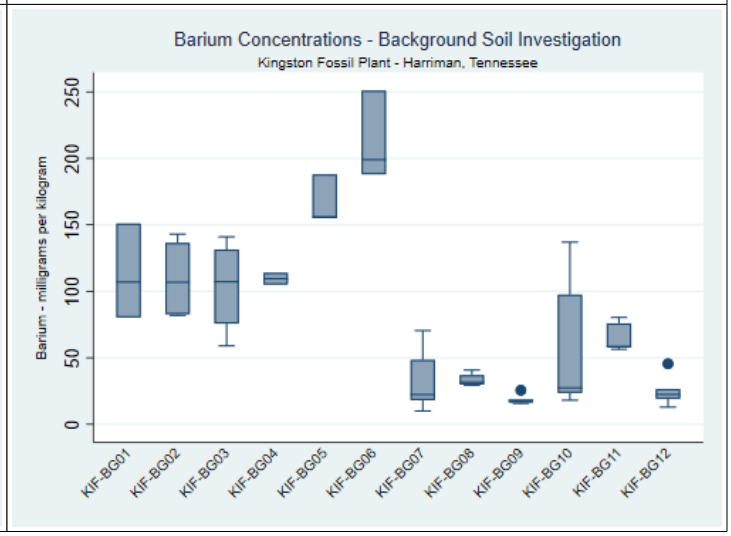


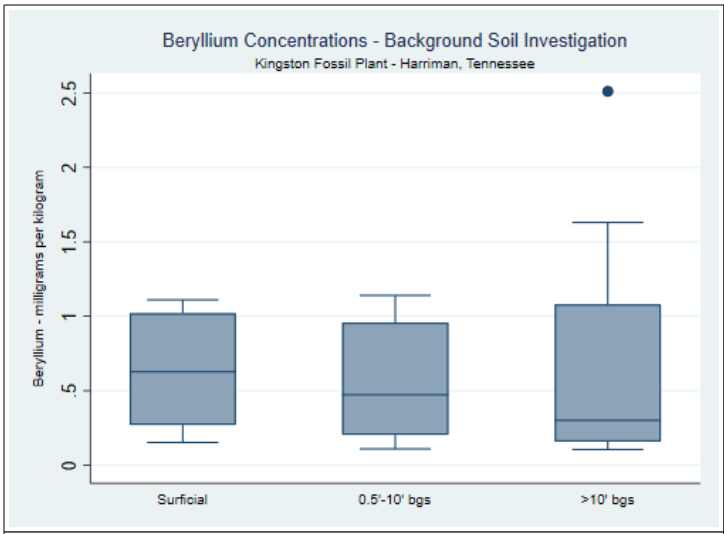


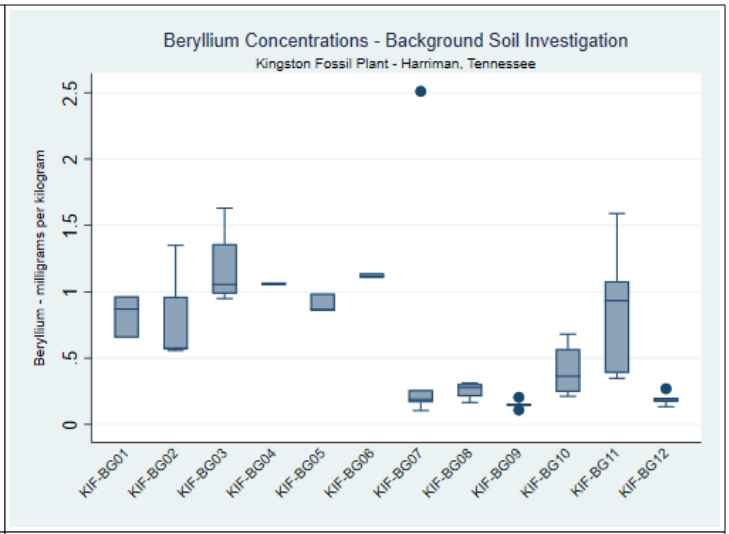


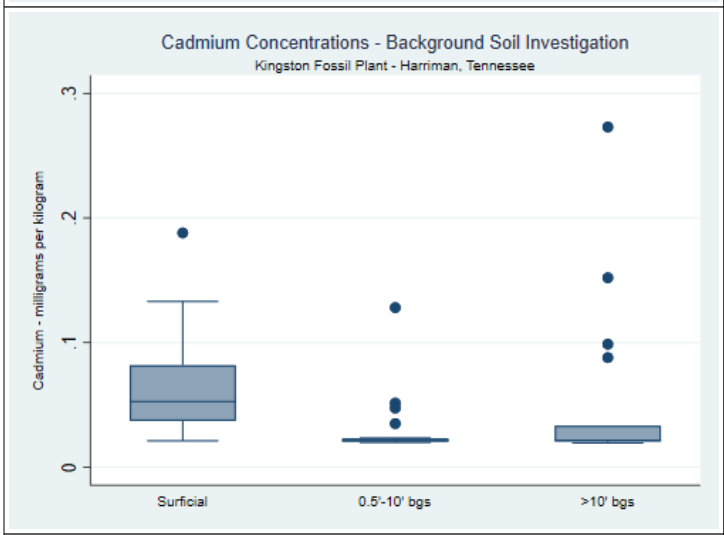


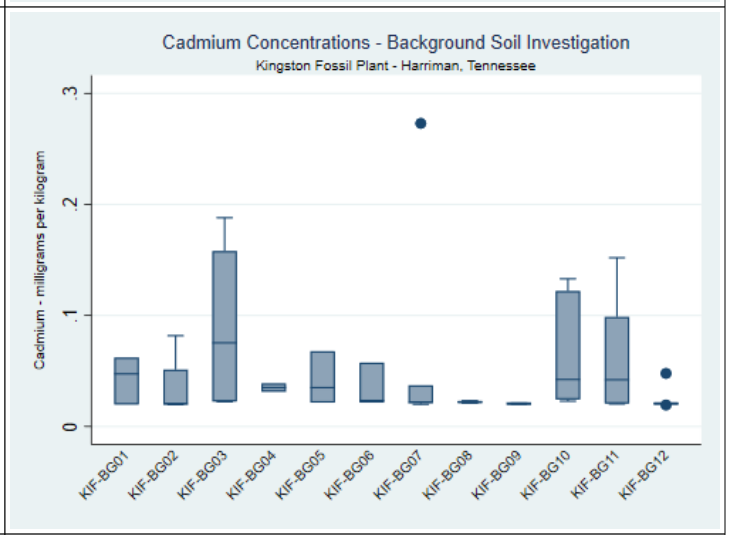


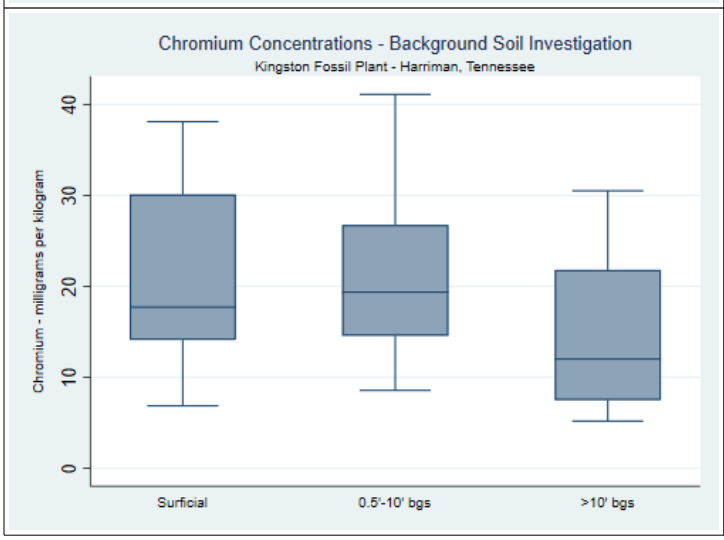


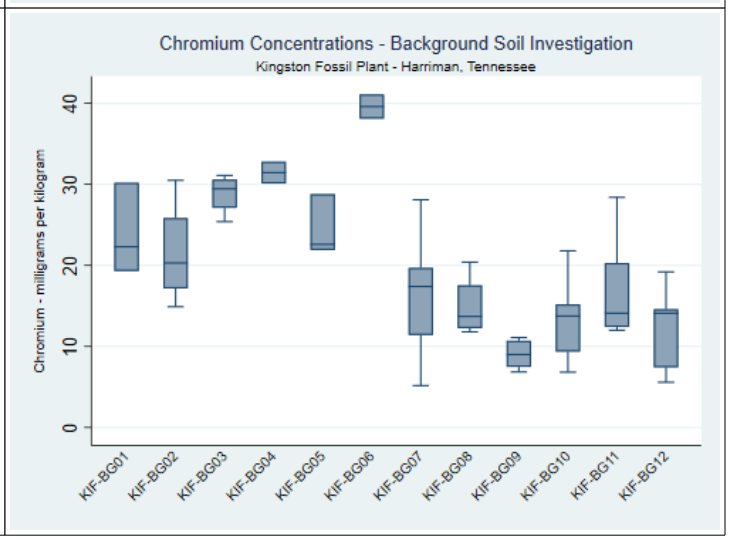

Beryllium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Beryllium - milligrams per kilogram
0
.5
1
1.5
2
2.5
Surficial
0.5'-10' bgs
>10' bgs


Beryllium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Beryllium - milligrams per kilogram
0
.5
1
1.5
2
2.5
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Cadmium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Cadmium - milligrams per kilogram
0
.1
.2
.3
Surficial
0.5'-10' bgs
>10' bgs


Cadmium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Cadmium - milligrams per kilogram
0
.1
.2
.3
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Chromium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Chromium - milligrams per kilogram
0
10
20
30
40
Surficial
0.5'-10' bgs
>10' bgs


Chromium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Chromium - milligrams per kilogram
0
10
20
30
40
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
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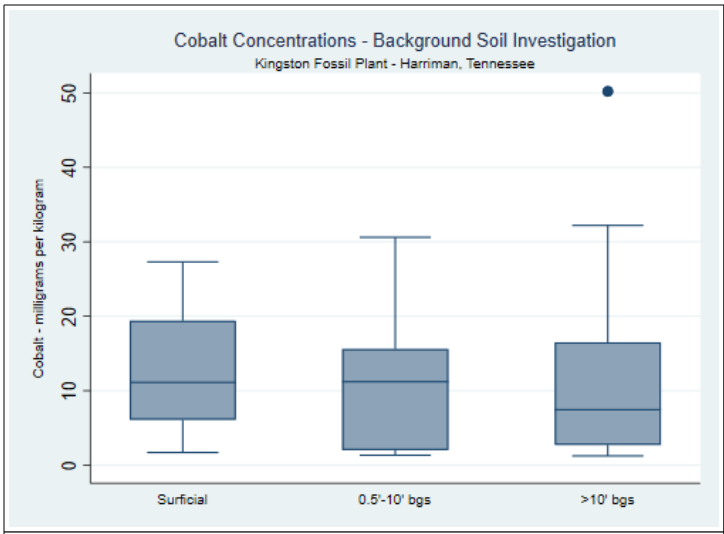
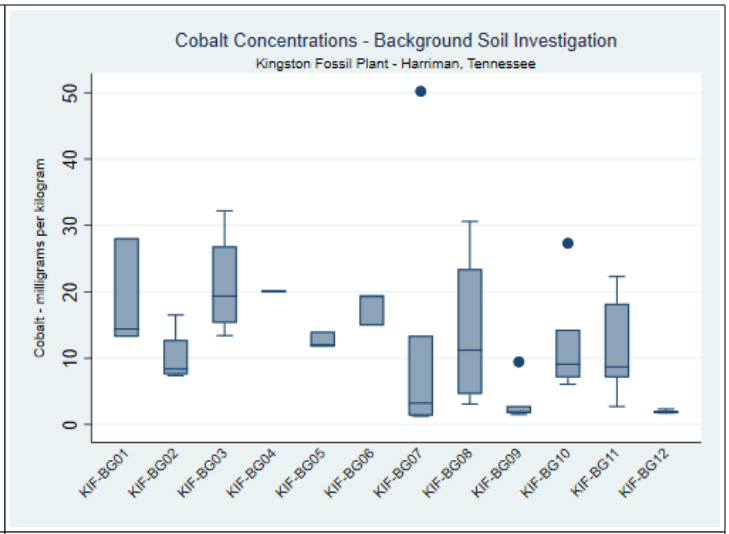
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Cobalt Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Cobalt - milligrams per kilogram
0
10
20
30
40
50
Surficial
0.5'-10' bgs
>10' bgs


Cobalt Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Cobalt - milligrams per kilogram
0
10
20
30
40
50
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
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KIF-BG06
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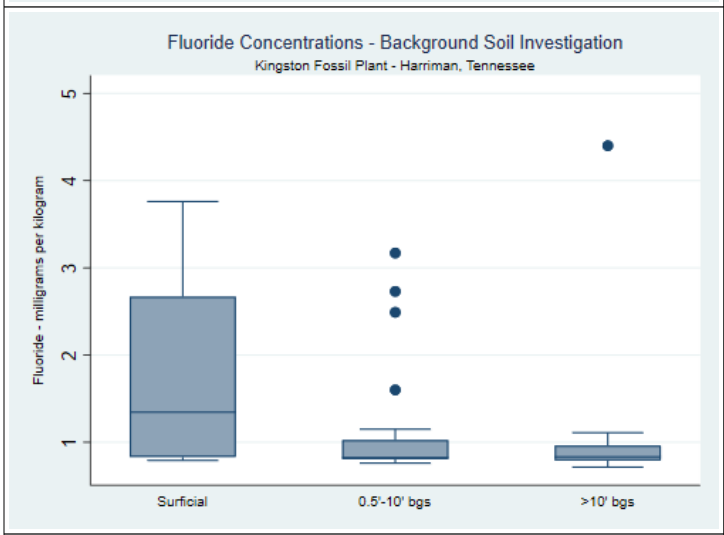
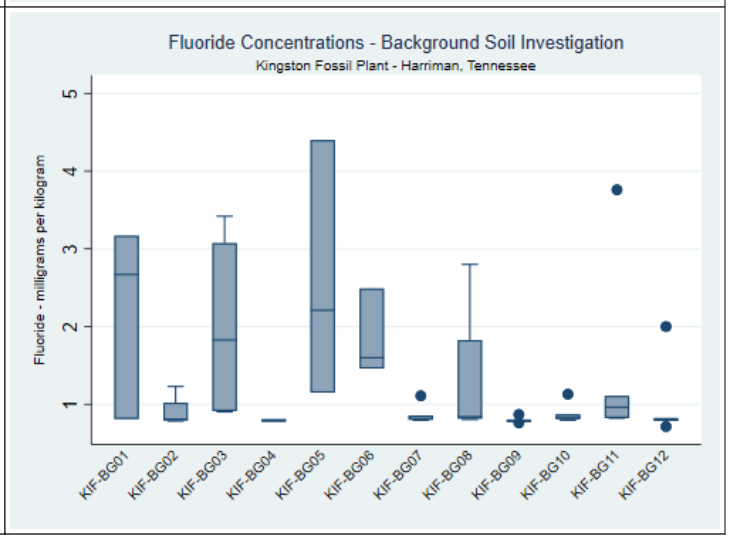
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Fluoride Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Fluoride - milligrams per kilogram
1
2
3
4
5
Surficial
0.5'-10' bgs
>10' bgs


Fluoride Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Fluoride - milligrams per kilogram
1
2
3
4
5
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
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KIF-BG06
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KIF-BG08
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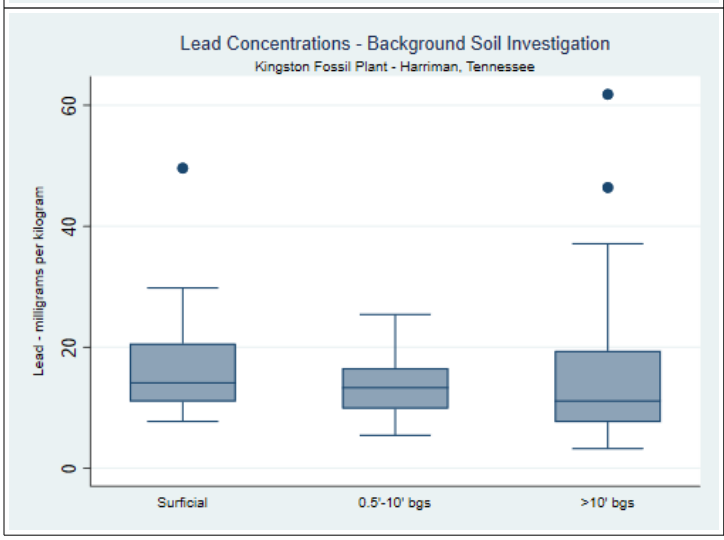
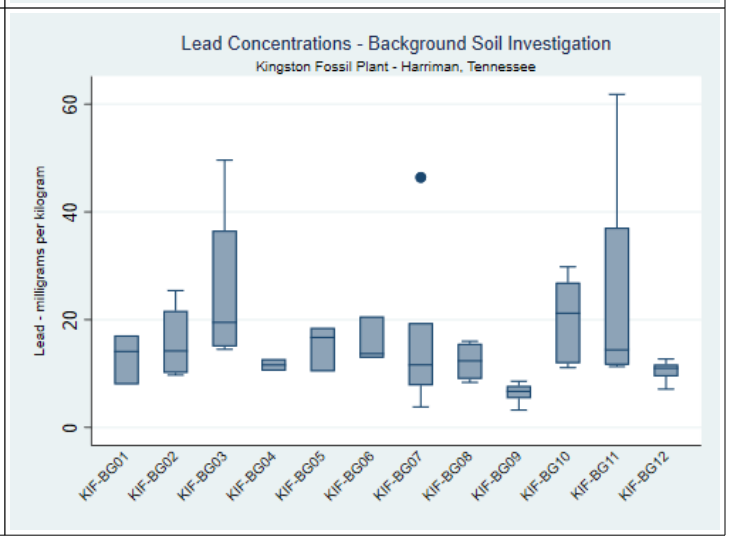
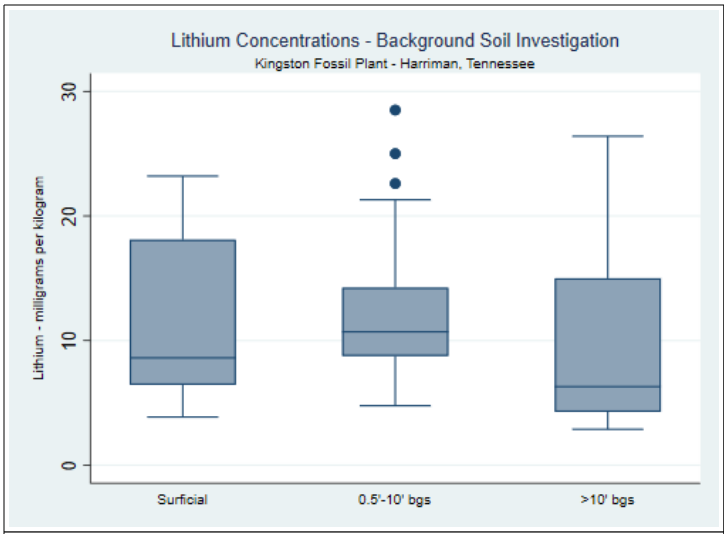
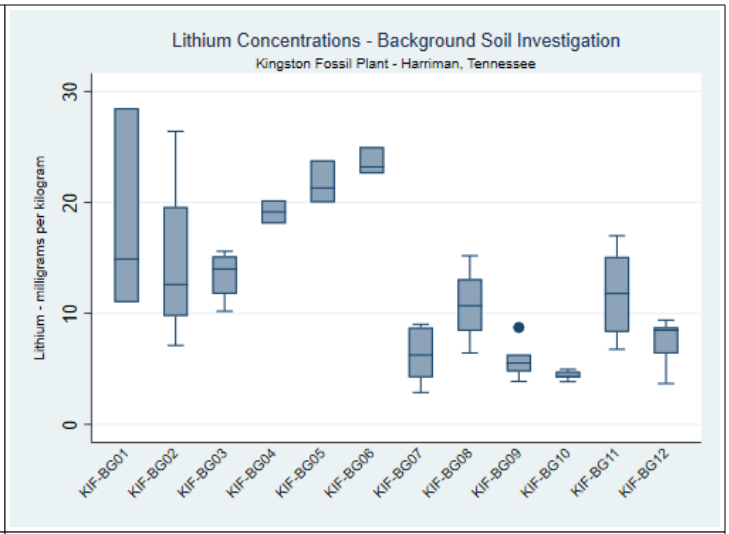
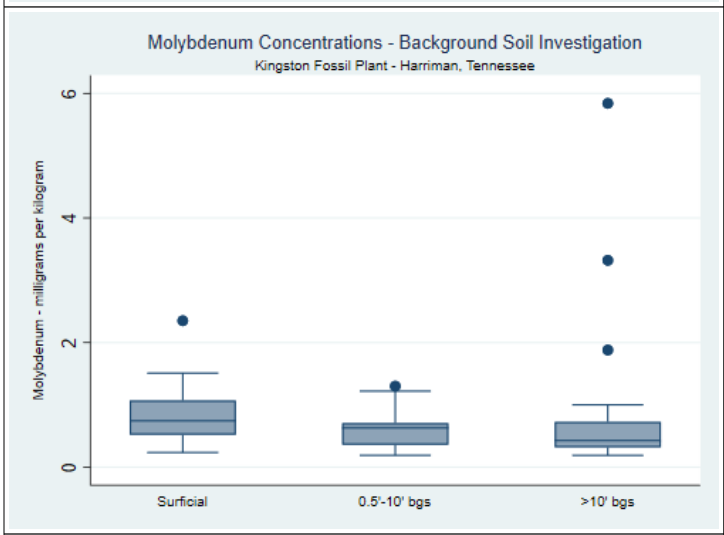
KIF-BG11
KIF-BG12

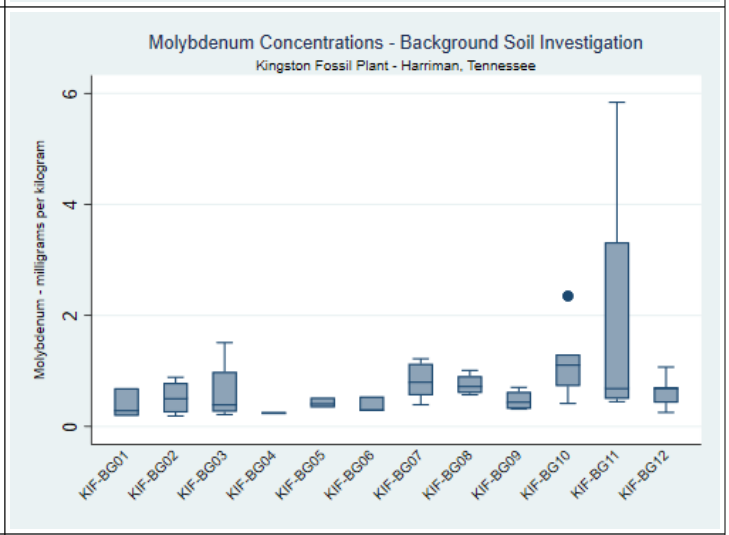

Lead Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Lead - milligrams per kilogram
0
20
40
60
Surficial
0.5'-10' bgs
>10' bgs


Lead Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Lead - milligrams per kilogram
0
20
40
60
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Lithium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Lithium - milligrams per kilogram
0
10
20
30
Surficial
0.5'-10' bgs
>10' bgs


Lithium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Lithium - milligrams per kilogram
0
10
20
30
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Molybdenum Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Molybdenum - milligrams per kilogram
0
2
4
6
Surficial
0.5'-10' bgs
>10' bgs


Molybdenum Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Molybdenum - milligrams per kilogram
0
2
4
6
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
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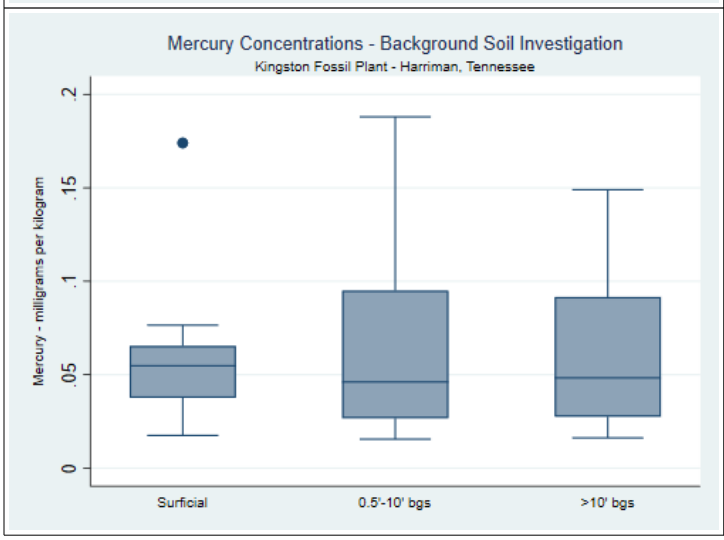
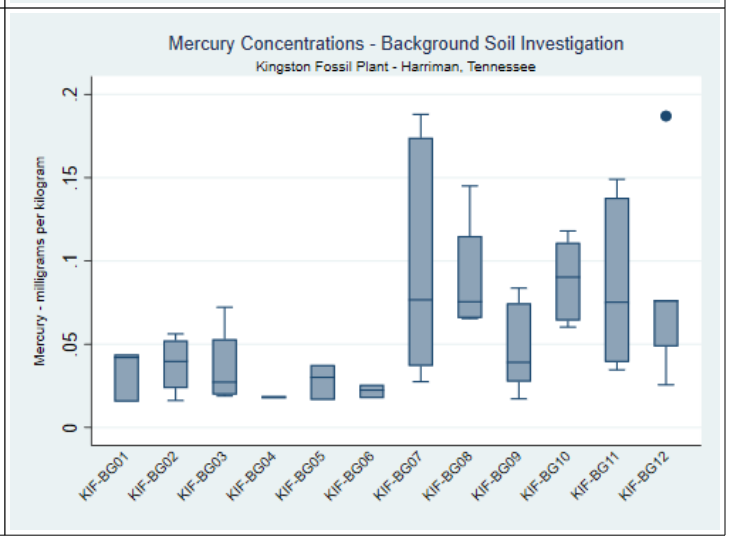
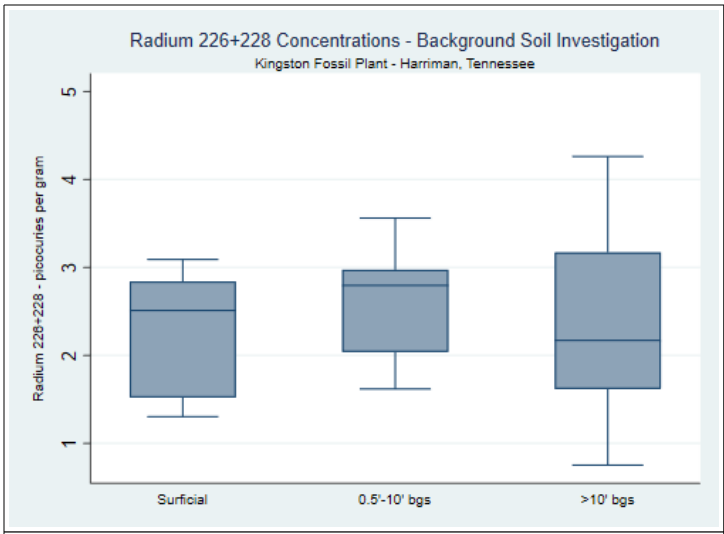
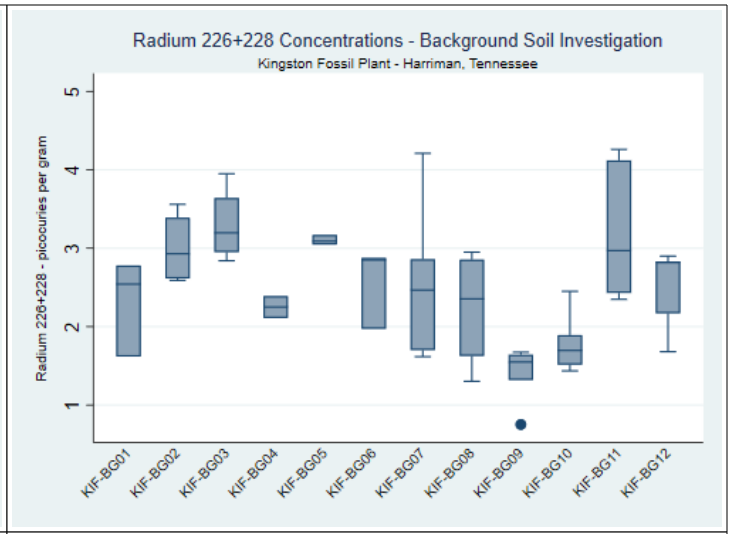
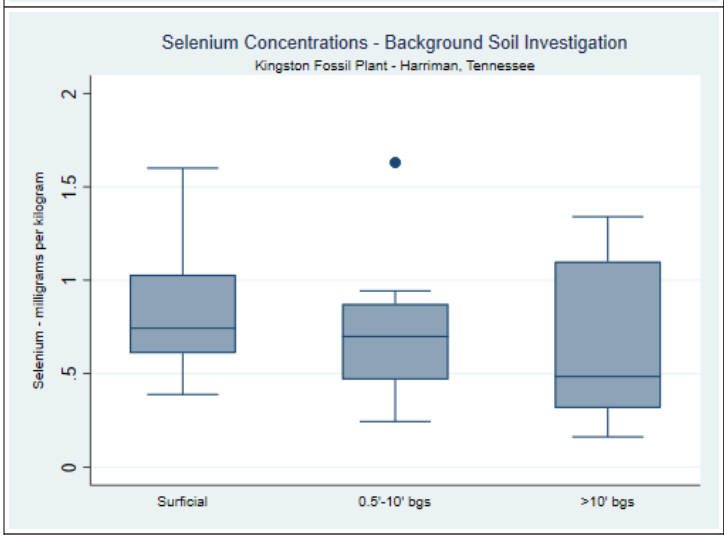
KIF-BG11
KIF-BG12

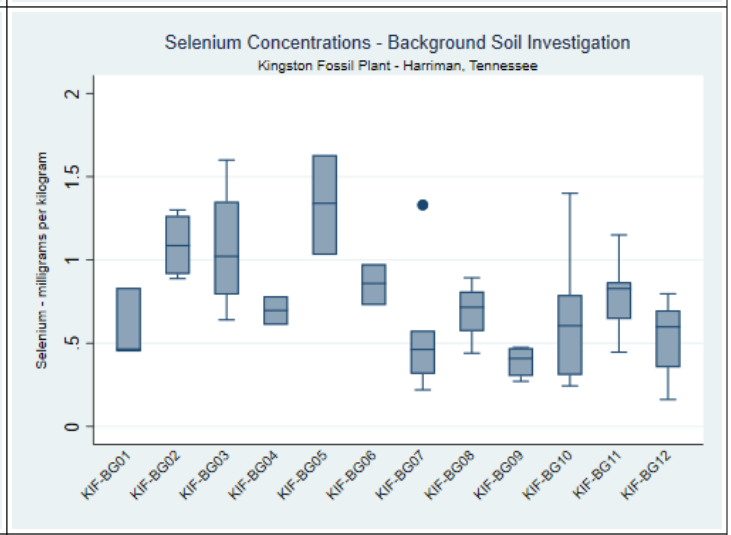

Mercury Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Mercury - milligrams per kilogram
0
.05
.1
.15
.2
Surficial
0.5'-10' bgs
>10' bgs


Mercury Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Mercury - milligrams per kilogram
0
.05
.1
.15
.2
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Radium 226+228 Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Radium 226+228 - picocuries per gram
1
2
3
4
5
Surficial
0.5'-10' bgs
>10' bgs


Radium 226+228 Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Radium 226+228 - picocuries per gram
1
2
3
4
5
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Selenium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Selenium - milligrams per kilogram
0
.5
1
1.5
2
Surficial
0.5'-10' bgs
>10' bgs


Selenium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Selenium - milligrams per kilogram
0
.5
1
1.5
2
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
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KIF-BG09
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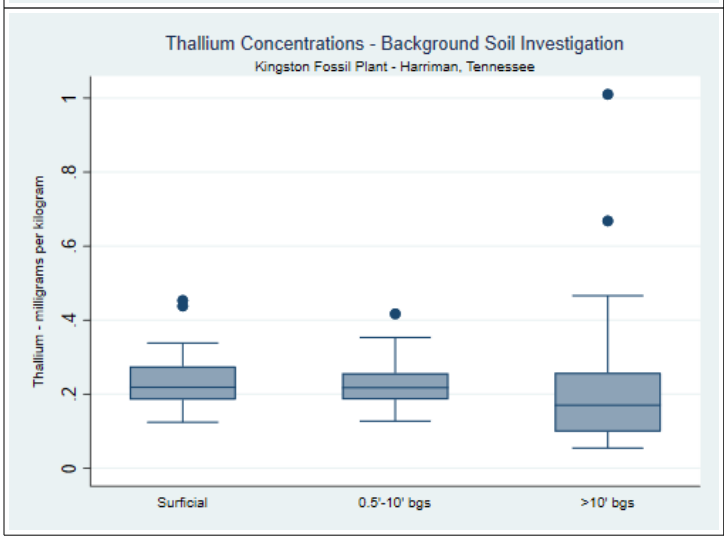
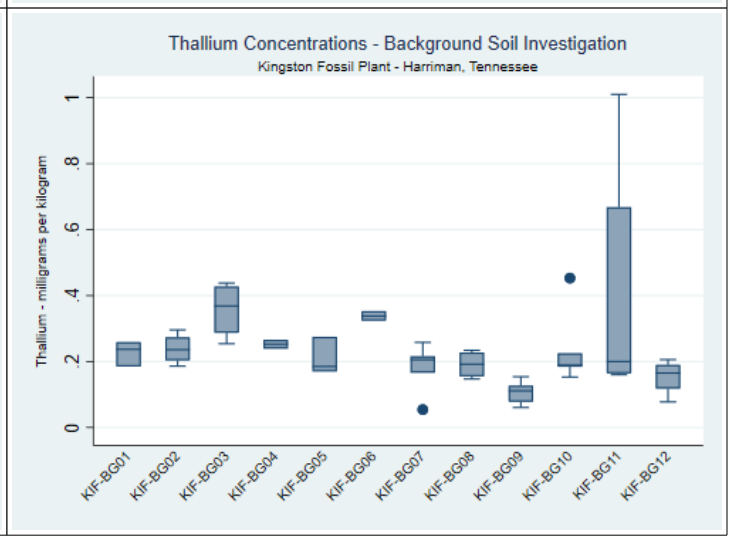
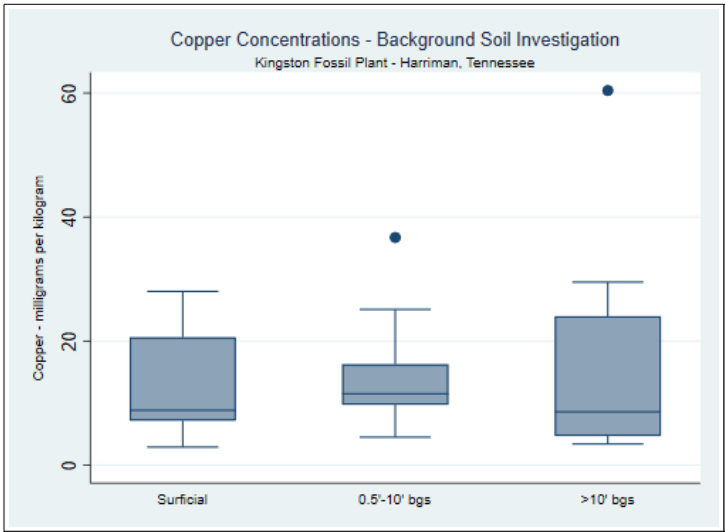
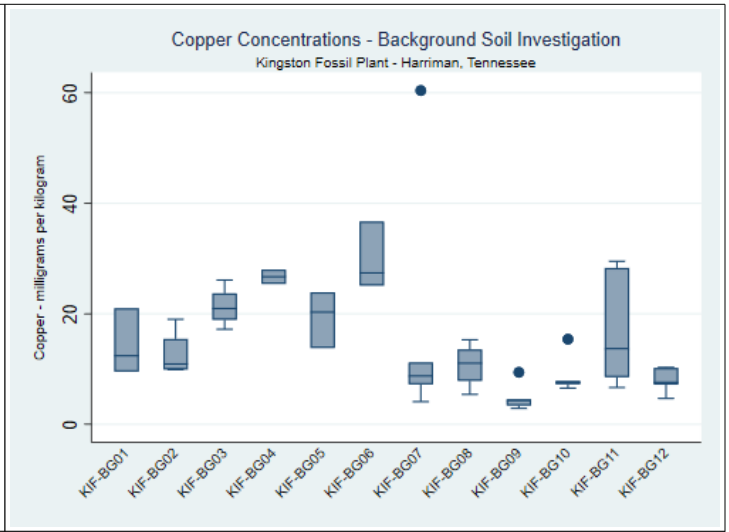
KIF-BG11
KIF-BG12

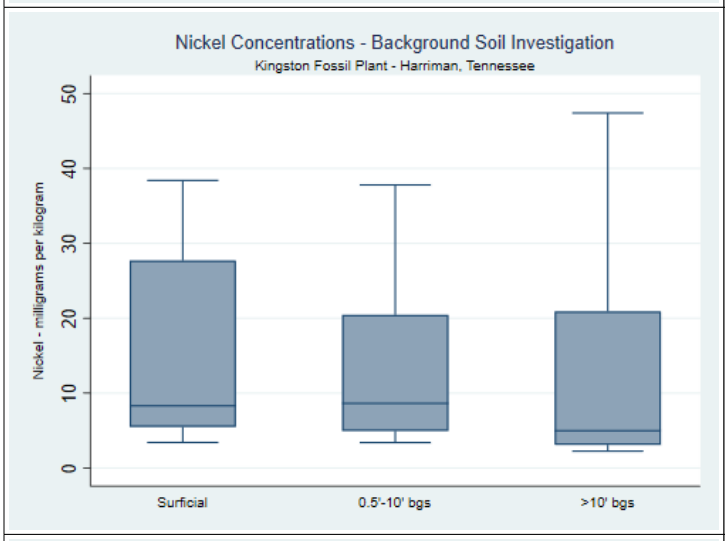

Thallium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Thallium - milligrams per kilogram
0
.2
.4
.6
.8
1
Surficial
0.5'-10' bgs
>10' bgs

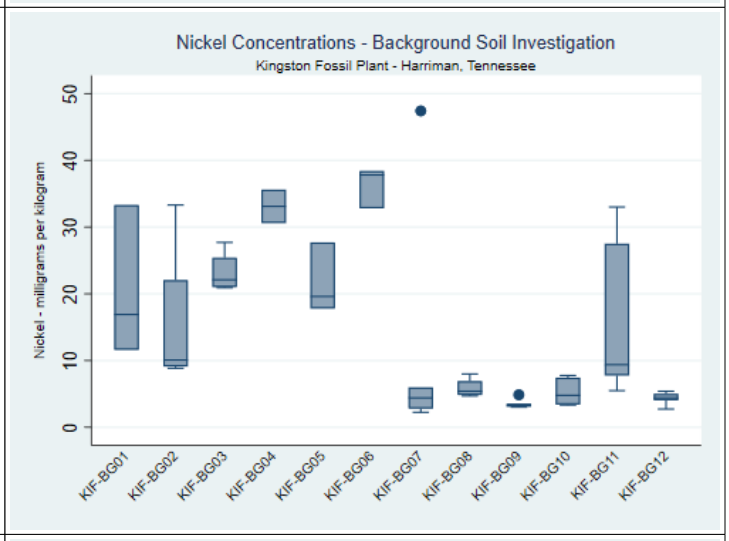

Thallium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Thallium - milligrams per kilogram
0
.2
.4
.6
.8
1
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12

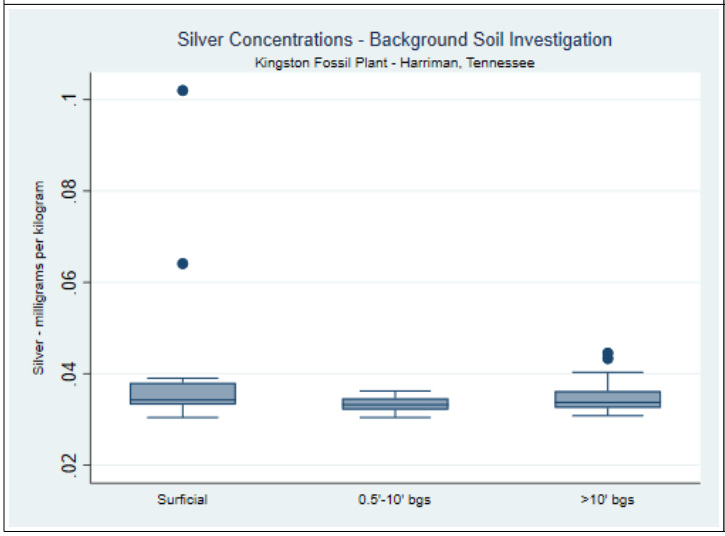
Box Plots
TDEC Appendix I Parameters
Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee

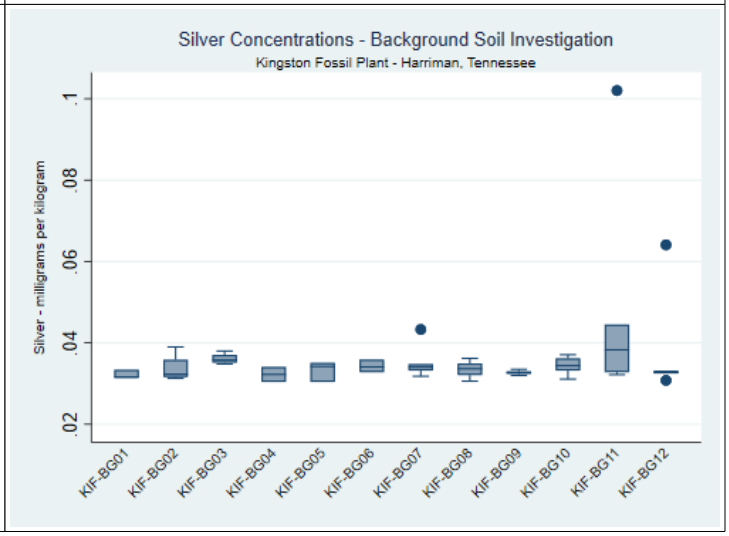


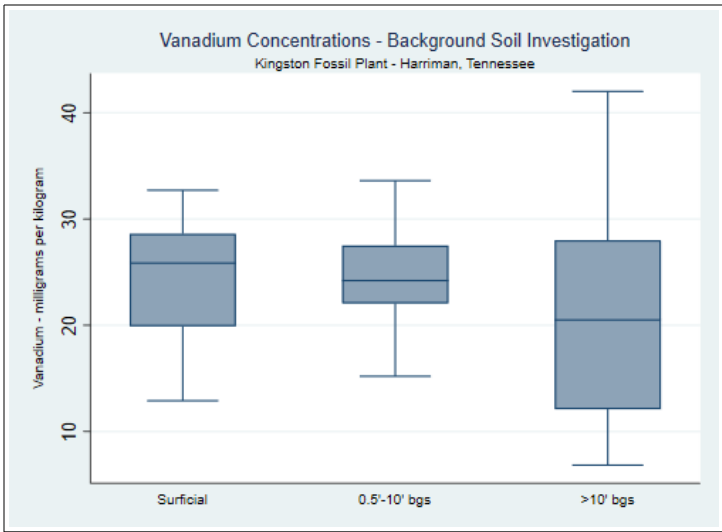


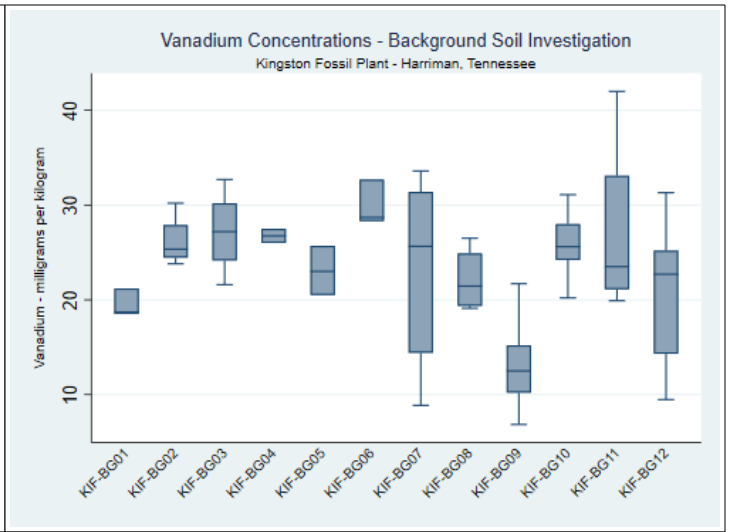


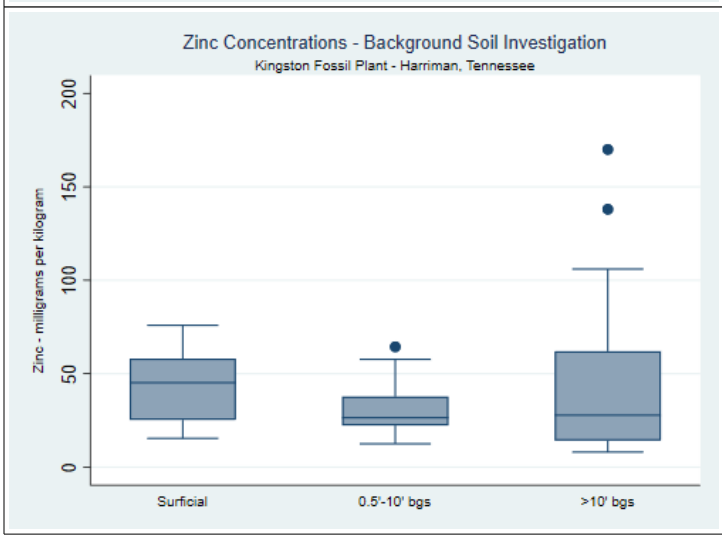


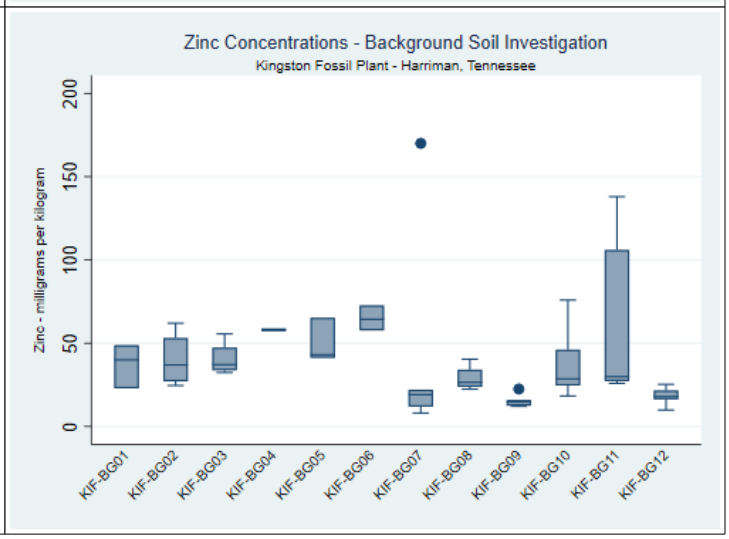





Vanadium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Vanadium - milligrams per kilogram
10
20
30
40
Surficial
0.5'-10' bgs
>10' bgs


Vanadium Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Vanadium - milligrams per kilogram
10
20
30
40
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12


Zinc Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Zinc - milligrams per kilogram
0
50
100
150
200
Surficial
0.5'-10' bgs
>10' bgs


Zinc Concentrations - Background Soil Investigation
Kingston Fossil Plant - Harriman, Tennessee
Zinc - milligrams per kilogram
0
50
100
150
200
KIF-BG01
KIF-BG02
KIF-BG03
KIF-BG04
KIF-BG05
KIF-BG06
KIF-BG07
KIF-BG08
KIF-BG09
KIF-BG10
KIF-BG11
KIF-BG12

APPENDIX E.2

STATISTICAL ANALYSIS OF CCR MATERIAL CHARACTERISTICS DATA

Appendix E.2 - Statistical Analysis of CCR Material Characteristics Data

TDEC Commissioner's Order:
Environmental Assessment Report
Kingston Fossil Plant
Harriman, Tennessee

March 12, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

REVISION LOG

Revision	Description	Date
0	EAR Submittal to TDEC	May 30, 2023
1	Addresses August 16, 2023 TDEC Review Comments and Issued for TDEC	November 14, 2023
2	Addresses January 12, 2024 TDEC Review Comments and Issued for TDEC	March 12, 2024

Sign-off Sheet

This document entitled Appendix E.2 - Statistical Analysis of CCR Material Characteristics Data was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Tennessee Valley Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not consider any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by

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Reviewed by

Melissa Whitfield Aslund, PhD, Environmental Scientist

Approved by

Rebekah Brooks, PG, Senior Principal Hydrogeologist

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Attachment E.2-D Scatter Plots and Regression

Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of 40 CFR 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
EAR	Environmental Assessment Report
IQR	Interquartile Range
KIF Plant	Kingston Fossil Plant
NA	Not Available
NTUs	Nephelometric Turbidity Units
%	Percent
SPLP	Synthetic Precipitate Leaching Procedure
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

APPENDIX E.2 - STATISTICAL ANALYSIS OF CCR MATERIAL CHARACTERISTICS DATA

March 12, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to document the statistical analyses performed on data collected to characterize coal combustion residual (CCR) material in support of evaluations conducted for the Environmental Assessment Report (EAR) at the Kingston Fossil Plant (KIF Plant) located in Harriman, Tennessee. The CCR material characterization samples were collected between November 2018 and December 2019 within the TDEC Order CCR management units[1] at the KIF Plant, which include the Interim Ash Staging Area, Sluice Trench and Area East of Sluice Trench, and Stilling Pond . Further details regarding the CCR material sampling and laboratory data are presented in the KIF Plant *CCR Material Characteristics Sampling and Analysis Report* (Appendix J.2). Additional samples collected in November 2017 from the Stilling Pond were incorporated into this evaluation.

For the Environmental Investigation, CCR material and pore water samples were collected for characterization related to the leachability of constituents listed in Appendices III and IV of 40 CFR 257 and five additional inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) from material within two KIF Plant TDEC Order CCR management units: the Interim Ash Staging Area and Sluice Trench and Area East of Sluice Trench. Additional samples collected in November 2017 from locations in the Stilling Pond were included into this evaluation. The Synthetic Precipitate Leaching Procedure (SPLP) was used to characterize leachability of CCR Parameters in CCR material. Temporary well/boring locations and the number of samples collected in each KIF Plant TDEC Order CCR management unit are presented in Table E.2-1. Table E.2-2 presents the list of CCR parameters evaluated in this statistical evaluation.

Table E.2-1 – CCR Material Characteristics Sample Locations - KIF Plant

KIF Plant TDEC Order CCR Management Unit	Temporary Well/Boring Location	Number of Samples	
		CCR Material/SPLP	Pore Water
Interim Ash Staging Area	KIF-TW01; KIF-TW02; KIF-TW03; KIF-B01; KIF-B02; KIF-B03	33	3
Sluice Trench and Area East of Sluice Trench	KIF-TW04; KIF-TW05; KIF-B04	17	2
Stilling Pond	GP-17-101; GP-17-102; GP-17-103	3	3

[1] The term “CCR management unit” is used in this document generally and is not intended to be a designation under federal or state regulations.

Table E.2-2 – CCR Parameters Evaluated in Statistical Analysis

CCR Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
Total Dissolved Solids	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3 / 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
Additional TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6
Other	
Iron	7439-89-6
Manganese	7439-96-5
Total Organic Carbon	NA

Notes: CASRN: Chemical Abstracts Service Registry Number; CCR Rule - Title 40, Code of Federal Regulations, Part 257; NA – Not Available; TDEC - Tennessee Department of Environment and Conservation

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV CCR parameter. In this table, and in the results figures and tables for this report, fluoride has been grouped with the Appendix III CCR parameters only to avoid duplication.

The following sections present the methods and results used to evaluate the CCR material and pore water data, including: 1) general exploratory data analysis (summary statistics, data plots and outlier screening), 2) a regression analysis to evaluate correlation between SPLP results to CCR Parameter concentrations in CCR material, and 3) a comparison of SPLP results to pore water concentrations.

2.0 METHODS

The statistical evaluation was conducted in three parts: 1) exploratory data analysis, 2) regression analysis, and 3) comparison of SPLP results to CCR Parameter concentrations in pore water.

2.1 EXPLORATORY DATA ANALYSIS

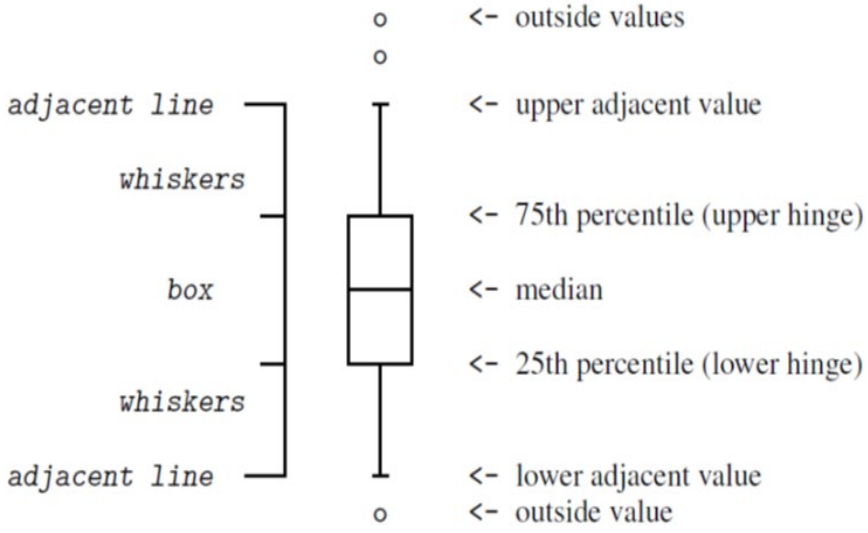
Exploratory data analysis is the initial step of statistical analysis. It utilizes simple summary statistics (e.g. mean, median, standard deviation and percentiles) and graphical representations to identify characteristics of an analytical dataset, such as the center of the data (mean, median), variation, distribution, patterns, presence of outliers, and randomness.

2.1.1 Summary Statistics

Summary statistics were calculated for CCR material, SPLP, and pore water for each CCR Parameter grouped by KIF Plant TDEC Order CCR management unit. Summary statistics include information such as the total numbers of available samples, the frequencies of detection, ranges of reporting limits, minimum and maximum detected concentrations, mean concentrations, standard deviations, median concentrations, and the 95th percentile concentrations. Summary statistics were calculated for total metal and dissolved metal concentrations in pore water. Summary statistics tables are presented in Attachment E.2-A.

2.1.2 Exploratory Data Plots

Box plots were constructed of CCR Parameter concentrations in CCR material to support a visual review of the data. Box plots were used to identify the center of the data, distribution, variability, and to visually identify potential outliers. The diagram below graphically depicts the basics of the construction of the box plots (StataCorp LLC 2017).



The box portion of the plot is the interquartile range (IQR), which represents the middle 50 percent (%) of data, with the bottom of the box being the 25th percentile and the top of the box being the 75th percentile. The line inside the box is the median concentration. The top of the upper “whisker” represents the first observed concentration above the 75th percentile, whereas the bottom of the lower “whisker” represents the first observed concentration below the 25th percentile (upper adjacent value and lower adjacent value,

respectively). Values that lie outside of the adjacent values represent outside (potential outliers) concentrations (i.e. concentrations at the upper and lower ends of the distribution of the data). The method detection limit was used as the reported value in order to construct the box plot when analytical results were reported as non-detects.

Side-by-side box plots were constructed for the CCR material and pore water data and aggregated by temporary well/boring location and KIF Plant TDEC Order CCR management unit. These box plots were useful in identifying differences in CCR Parameter concentrations between each KIF Plant TDEC Order CCR management unit and are especially useful for visually identifying potential outliers. Box plots are presented in Attachment E.2-B for CCR material results and E.2-C for pore water results.

2.1.3 Outlier Screening

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variation of CCR Parameter concentrations in environmental systems. Screening for outliers is a critical step because outliers can bias statistical estimates, statistical testing results, and inferences.

Outlier values were initially screened visually using side-by-side box plots. If suspected visual outliers were identified, then Tukey's procedure was used to identify extreme outliers (Tukey 1977). This method relies on the 25th and 75th percentiles of the data (IQR), which is defined as the 75th percentile value minus the 25th percentile value. Values were identified as potential outliers as follows:

- **Lower extreme outliers** are less than the 25th percentile minus 3 x IQR
- **Upper extreme outliers** are greater than the 75th percentile plus 3 x IQR.

Finally, when the potential outlier(s) were identified visually and by Tukey's procedure, then statistical testing for outliers (Dixon or Rosner's Test) was conducted to determine if the data points were statistically significant outliers.

Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional error). Field forms, data validation reports, and other variables in the dataset that could influence analytical results were also evaluated. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset. The results of the outlier screening for the KIF Plant CCR material dataset are provided in Section 3.1.

2.2 REGRESSION ANALYSIS

The linear relationship between the concentrations of CCR Parameters in SPLP results and concentrations in CCR material was evaluated using regression analysis. Scatter plots were constructed to compare SPLP and CCR material results for the CCR Parameters. Using linear regression, the Pearson's correlation coefficient was estimated, and a regression line was fit to the data and added to the scatter plots. As part of the analysis, the SPLP results for the CCR Parameters were compared to the range of pore water concentrations observed in the respective KIF Plant TDEC Order CCR management units. Analyses were conducted on data where CCR parameters were detected in greater than 50% of the samples in both the SPLP and CCR material datasets. Scatter plots, regression results, and range of pore water concentrations are presented in Attachment E.2-D.

3.0 RESULTS AND DISCUSSION

3.1 SUMMARY STATISTICS, EXPLORATORY DATA PLOTS, AND OUTLIER SCREENING

Summary statistics tables are presented in Attachment E.2-A, and box plots are presented in Attachments E.2-B for CCR material and E.2-C for pore water.

No outliers were identified in the CCR material or SPLP datasets.

Anomalously high CCR parameter concentrations were observed in the pore water sample collected from well GP-17-102, thus the pore water dataset was subsequently screened using outlier screening methods described above for CCR Appendix IV and TDEC Appendix I parameters. Pore water box plots aggregated by KIF Plant TDEC Order CCR management unit are presented as Attachment E.2-C. Multiple CCR parameter concentrations were identified as potential statistical outliers. Turbidity measurements were also anomalously high in sample GP-17-102 (616.3 nephelometric turbidity units [NTUs]), compared to turbidity measurements across the KIF Plant TDEC Order CCR management unit areas, which ranged from 1.17 to 99 NTUs. Using the outlier screening methods described above, turbidity in sample GP-17-102 was found to be a statistically significant outlier. A box plot for turbidity is provided in Attachment E.2-C. Since turbidity was an outlier and could be the cause of other anomalously high CCR parameter concentrations observed in sample GP-17-102, sample results from GP-17-102 were excluded from further statistical analyses.

3.2 REGRESSION ANALYSIS

The purpose of the regression analysis was to evaluate whether the total concentrations of metals in CCR material could be used as a reliable predictor of leachable concentrations as represented by SPLP concentrations. Scatter plots, regression results, and range of pore water concentrations are presented in Attachment E.2-D. The correlation coefficient is a numerical measure that measures the strength of association between two variables (in this case, between total concentration and SPLP results for CCR material), with values ranging from zero to one. A high correlation coefficient (closer to one) demonstrates

a strong relationship between the two variables, whereas a low correlation coefficient (closer to zero) demonstrates a weak relationship. The slope of the regression line indicates the direction of correlation. A positive slope indicates that SPLP concentrations increased as CCR Parameter concentrations in CCR material increased. Conversely, a negative slope indicates that as CCR Parameter concentrations in CCR material increased, the SPLP concentrations decreased.

The statistical relationships between SPLP concentrations and CCR material concentrations were inconsistent and highly variable. One would expect SPLP concentrations to increase with increasing CCR parameter concentrations in CCR material (e.g. regression line with a positive slope). However, this relationship was inconsistent between different CCR parameters and between KIF Plant TDEC Order CCR management units (e.g. boron). In some cases, even when there was a statistically significant correlation (e.g., vanadium), the wide range of variability around the regression line limits the predictive value of the relationship. The results indicate that the total concentrations of metals in CCR material are not a reliable predictor of the magnitude of the potentially leached concentrations measured using SPLP.

In addition, the CCR parameter concentrations in SPLP generally underestimated CCR parameter concentrations measured in pore water.

The results indicate that direct measurement of pore water concentrations is the most accurate way of characterizing potential leachability from CCR materials.

4.0 REFERENCES

StataCorp LLC. (2017). Stata Graphics Reference Manual Stata: Release 15. Statistical Software. College Station, Texas: StataCorp LLC.

Tukey, J.W. (1977). Exploratory Data Analysis. Reading, Massachusetts: Addison-Wesley. 1977.

ATTACHMENT E.2–A
SUMMARY STATISTICS

Summary Statistics - CCR Material Characteristics
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Interim Ash Staging Area	33/33	--	0%	9.67	57.6	29.0	13.59	26.4	50.7
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	3.92	211	62.0	70.62	31.7	202.2
	Interim Ash Staging Area	3/3	--	0%	28.3	58.7	39.3	16.83	31	55.93
Calcium	Interim Ash Staging Area	33/33	--	0%	1,060	24,500	5,828	5,914	3,680	19,480
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	770	51,100	13,495	15,054	4,530	36,300
	Interim Ash Staging Area	3/3	--	0%	2,250	6,400	3,753	2,299	2,610	6,021
Chloride	Interim Ash Staging Area	23/33	(4.62-5.79)	30.3%	5.48	104	10.19	16.78	6.83	13.52
	Sluice Trench and Ballfield East of Sluice Trench	2/17	(5.07-10.2)	88.2%	6.04	9.88	5.484	1.177	6.07	9.944
	Interim Ash Staging Area	1/3	(3.79-3.86)	66.7%	4.36	4.36	3.98	0.269	3.86	4.31
Fluoride	Interim Ash Staging Area	17/33	(0.756-1.05)	48.5%	1.13	4.29	1.671	1.163	1.13	3.752
	Sluice Trench and Ballfield East of Sluice Trench	7/17	(0.848-1.37)	58.8%	1.07	2.37	1.10	0.403	1.07	1.794
	Interim Ash Staging Area	3/3	--	0.0%	1.15	6.13	3.44	2.515	3.03	5.82
pH (lab)	Interim Ash Staging Area	33/33	--	0%	4.90	8.70	7.345	0.896	7.60	8.30
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	3.90	11.0	8.165	2.166	8.20	10.92
	Interim Ash Staging Area	3/3	--	0%	7.80	8.0	7.9	0.1	7.90	7.99
Sulfate	Interim Ash Staging Area	33/33	--	0%	111	16,400	1,157	2,788	531	2,252
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	49.7	1,460	434	434	258	1,196
	Interim Ash Staging Area	3/3	--	0%	31.9	94	65	31	70	91
CCR Rule Appendix IV Parameters										
Antimony	Interim Ash Staging Area	33/33	--	0%	0.292	1.15	0.659	0.281	0.623	1.108
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.225	2.01	0.808	0.616	0.538	1.866
	Stilling Pond	3/3	--	0%	0.432	0.926	0.761	0.285	0.924	0.926
Arsenic	Interim Ash Staging Area	33/33	--	0%	18.1	119	49.12	24.09	43.6	92.6
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	15.9	115	38.82	24.0	33.5	77.64
	Stilling Pond	3/3	--	0%	32.6	80.8	60.5	25.0	68.1	79.53
Barium	Interim Ash Staging Area	33/33	--	0%	105	428	248	95.56	243	410.2
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	79.7	1520	475.6	515	218	1448
	Stilling Pond	3/3	--	0%	137	225	185	44.54	193	221.8
Beryllium	Interim Ash Staging Area	33/33	--	0%	0.596	3.86	1.673	0.822	1.50	3.116
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.321	5.49	2.249	1.823	1.54	5.434
	Stilling Pond	3/3	--	0%	1.28	2.44	1.853	0.58	1.84	2.38
Cadmium	Interim Ash Staging Area	33/33	--	0%	0.0664	0.879	0.262	0.179	0.230	0.554
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.0520	0.594	0.233	0.204	0.153	0.580
	Stilling Pond	3/3	--	0%	0.2460	0.571	0.413	0.163	0.423	0.556

Summary Statistics - CCR Material Characteristics
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Chromium	Interim Ash Staging Area	33/33	--	0%	8.78	35.3	21.29	7.778	19.3	34.0
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	8.73	41.0	23.63	11.0	22.7	38.84
	Stilling Pond	3/3	--	0%	13.5	20.3	17.87	3.8	19.8	20.25
Cobalt	Interim Ash Staging Area	33/33	--	0%	3.88	35.6	9.018	5.819	7.48	14.9
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	3.15	22.1	10.88	6.257	8.76	21.22
	Stilling Pond	3/3	--	0%	4.42	7.97	6.097	1.783	5.9	7.763
Fluoride	Interim Ash Staging Area	17/33	(0.756-1.05)	48.5%	1.13	4.29	1.671	1.163	1.13	3.752
	Sluice Trench and Ballfield East of Sluice Trench	7/17	(0.848-1.37)	58.8%	1.07	2.37	1.10	0.403	1.07	1.794
	Stilling Pond	3/3	--	0.0%	1.15	6.13	3.44	2.515	3.03	5.82
Lead	Interim Ash Staging Area	33/33	--	0%	2.83	27.4	11.77	6.993	9.62	24.3
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	2.82	27.4	11.79	8.949	8.12	26.6
	Stilling Pond	3/3	--	0%	11.6	19.9	16.37	4.285	17.6	19.67
Lithium	Interim Ash Staging Area	33/33	--	0%	10.2	38.8	20.0	8.60	17.7	36.0
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	5.75	23.1	14.56	5.831	13.1	22.94
	Stilling Pond	3/3	--	0%	15.4	25.2	20.1	4.912	19.7	24.65
Mercury	Interim Ash Staging Area	31/33	(0.0148-0.0305)	6.06%	0.0307	1.22	0.125	0.212	0.0786	0.305
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.0351	0.611	0.166	0.153	0.120	0.489
	Stilling Pond	3/3	--	0%	0.0451	0.101	0.0682	0.0292	0.058	0.0967
Molybdenum	Interim Ash Staging Area	33/33	--	0%	1.82	9.31	3.538	1.891	2.91	8.078
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.990	6.84	4.20	1.894	3.74	6.688
	Stilling Pond	3/3	--	0%	1.880	16	8.05	7.228	6.26	15.03
Radium-226+228	Interim Ash Staging Area	33/33	--	0%	2.95	8.52	6.38	1.37	6.62	8.18
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	2.87	7.61	5.55	1.41	5.57	7.49
	Stilling Pond	3/3	--	0%	6.57	7.78	7.113	0.61	6.99	7.701
Selenium	Interim Ash Staging Area	33/33	--	0%	1.00	8.88	2.967	1.764	2.51	6.434
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	1.32	13.5	4.046	2.917	3.45	7.60
	Stilling Pond	3/3	--	0%	1.91	4.21	3.367	1.267	3.98	4.19
Thallium	Interim Ash Staging Area	33/33	--	0%	0.395	7.31	1.208	1.172	1.03	1.838
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.353	1.75	1.027	0.368	1.05	1.694
	Stilling Pond	3/3	--	0%	1.05	1.51	1.24	0.24	1.16	1.475

Summary Statistics - CCR Material Characteristics
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
TDEC Appendix I Parameters										
Copper	Interim Ash Staging Area	33/33	--	0%	13.4	47.7	28.27	9.73	26.1	42.44
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	12.3	79.3	35.41	24.23	25.2	77.3
	Stilling Pond	3/3	--	0%	19.3	36.9	28.2	8.802	28.4	36.05
Nickel	Interim Ash Staging Area	33/33	--	0%	10.3	37.5	20.67	7.285	18.5	32.8
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	10.2	40.0	22.93	10.38	20.0	39.28
	Stilling Pond	3/3	--	0%	11.1	18.3	14.87	3.612	15.2	17.99
Silver	Interim Ash Staging Area	25/33	(0.0324-0.0424)	24.2%	0.0235	0.116	0.0559	0.0277	0.0443	0.107
	Sluice Trench and Ballfield East of Sluice Trench	9/17	(0.0376-0.333)	47.1%	0.0202	0.355	0.0737	0.0955	0.122	0.337
	Stilling Pond	3/3	--	0.0%	0.0447	0.0663	0.0591	0.0124	0.0662	0.0663
Vanadium	Interim Ash Staging Area	33/33	--	0%	15.5	76.7	42.23	17.28	38.0	73.32
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	11.1	121	54.25	38.58	38.3	119.4
	Stilling Pond	3/3	--	0%	25.1	46.1	37.07	10.8	40	45.49
Zinc	Interim Ash Staging Area	33/33	--	0%	10.8	43.2	25.56	10.86	23.1	41.74
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	5.43	61.5	27.69	18.32	23.0	58.14
	Stilling Pond	3/3	--	0%	18.1	37	27.33	9.457	26.9	35.99
Additional Parameters										
Iron	Interim Ash Staging Area	33/33	--	0%	9,950	110,000	34,959	21,896	30,700	68,240
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	8,810	107,000	38,042	25,389	38,800	74,280
	Stilling Pond	3/3	--	0%	10,400	14,000	11,967	1,845	11,500	13,750
Manganese	Interim Ash Staging Area	33/33	--	0%	37.9	242	85.76	44.6	73.6	164.2
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	26.1	216	97.88	52.66	88.2	188
	Stilling Pond	3/3	--	0%	39.9	153	81.43	62.24	51.4	142.8
TOC	Interim Ash Staging Area	33/33	--	0%	6,810	45,600	23,231	10,529	22,500	41,880
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	11,400	93,900	36,900	22,927	31,800	81,900
	Stilling Pond	3/3	--	0%	17,900	19,800	19,133	1,069	19,700	19,790

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

TDEC - Tennessee Department of Environment and Conservation

% - percent

"--" - Not Applicable

TOC - Total Organic Carbon

Except for pH & Radium 226 + 228, all units are milligrams per kilogram (mg/kg).

Units for pH are Standard Units (S.U.).

Units for Radium 226+228 are picocuries per gram (pCi/g).

All non-detects reported at the method detection limit.

For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM)

Summary Statistics - CCR Material Characteristics - Synthetic Precipitate Leaching Procedure (SPLP)
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Interim Ash Staging Area	30/33	(62.5 - 76.6)	9.09%	45.1	1,020	422.3	393.1	160	987.8
	Sluice Trench and Ballfield East of Sluice Trench	12/17	(38.6 - 291)	29.4%	40.0	1,180	305.7	419.5	111	1,156
	Stilling Pond	3/3	--	0.0%	360.0	598	474.7	119.2	466	585
Calcium	Interim Ash Staging Area	33/33	--	0%	4,580	385,000	26,818	64,925	13,400	37,340
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	3,570	42,000	20,640	13,646	17,100	38,880
	Stilling Pond	3/3	--	0%	8,000	21,700	13,500	7,238	10,800	20,610
CCR Rule Appendix IV Parameters										
Antimony	Interim Ash Staging Area	24/33	(0.378 - 1.12)	27.3%	0.460	6.19	1.246	1.391	0.847	4.376
	Sluice Trench and Ballfield East of Sluice Trench	7/17	(0.879 - 1.75)	58.8%	1.18	5.67	1.627	1.235	1.35	3.502
	Stilling Pond	3/3	--	0.0%	4.56	12.6	7.5	4.434	5.34	11.87
Arsenic	Interim Ash Staging Area	33/33	--	0%	0.917	143	26.0	33.0	15.3	93.3
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.351	40.7	12.72	11.53	6.53	34.06
	Stilling Pond	3/3	--	0%	90.4	190	124.8	56.52	93.9	180.4
Barium	Interim Ash Staging Area	33/33	--	0%	10.4	199	72.47	39.38	73.5	129.8
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	6.55	377	105.8	102.1	87.5	283.4
	Stilling Pond	3/3	--	0%	160	327	222.7	90.96	181	312.4
Beryllium	Interim Ash Staging Area	4/33	(0.057 - 0.182)	87.9%	0.202	0.433	0.0864	0.0857	0.155	0.268
	Sluice Trench and Ballfield East of Sluice Trench	5/17	(0.057 - 0.155)	70.6%	0.0600	3.31	0.346	0.808	0.155	1.806
	Stilling Pond	0/3	(0.131 - 0.131)	100.0%	--	--	--	--	0.131	0.131
Cadmium	Interim Ash Staging Area	4/33	(0.125 - 0.125)	87.9%	0.133	0.396	0.145	0.0646	0.125	0.295
	Sluice Trench and Ballfield East of Sluice Trench	3/17	(0.125 - 0.125)	82.4%	0.192	1.88	0.288	0.456	0.125	1.232
	Stilling Pond	2/3	(0.0781 - 0.0781)	33.3%	0.086	0.089	0.0844	0.0046	0.086	0.0887
Chromium	Interim Ash Staging Area	10/33	(0.631 - 1.53)	69.7%	0.804	6.88	1.20	1.159	1.53	2.684
	Sluice Trench and Ballfield East of Sluice Trench	15/17	(1.53 - 1.53)	11.8%	1.06	22.7	4.344	5.60	1.95	14.14
	Stilling Pond	0/3	(1.17 - 2.9)	100.0%	--	--	--	--	2.46	2.856
Cobalt	Interim Ash Staging Area	17/33	(0.075 - 0.075)	48.5%	0.091	12.2	1.20	2.465	0.091	5.79
	Sluice Trench and Ballfield East of Sluice Trench	5/17	(0.075 - 0.245)	70.6%	0.100	54.5	4.854	13.15	0.100	24.66
	Stilling Pond	3/3	--	0.0%	0.116	0.513	0.284	0.205	0.223	0.484
Lead	Interim Ash Staging Area	9/33	(0.094 - 0.128)	72.7%	0.130	1.09	0.157	0.183	0.128	0.406
	Sluice Trench and Ballfield East of Sluice Trench	3/17	(0.094 - 0.516)	82.4%	0.161	6.62	0.54	1.537	0.128	2.172
	Stilling Pond	2/3	(0.318 - 0.318)	33.3%	0.964	1.17	0.817	0.363	0.964	1.149
Lithium	Interim Ash Staging Area	29/33	(2.56 - 3.14)	12.1%	3.15	19.9	9.565	5.044	9.22	17.0
	Sluice Trench and Ballfield East of Sluice Trench	15/17	(2.56 - 3.14)	11.8%	3.13	30.7	7.057	6.725	4.54	16.94
	Stilling Pond	3/3	--	0.0%	4.95	7.7	6.083	1.437	5.6	7.49

Summary Statistics - CCR Material Characteristics - Synthetic Precipitate Leaching Procedure (SPLP)
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Mercury	Interim Ash Staging Area	1/33	(0.101 - 0.101)	97.0%	0.114	0.114	0.101	0.00223	0.101	0.101
	Sluice Trench and Ballfield East of Sluice Trench	0/17	(0.1 - 0.101)	100%	--	--	--	--	0.101	0.101
	Stilling Pond	0/3	(0.0653 - 0.0653)	100%	--	--	--	--	0.0653	0.0653
Molybdenum	Interim Ash Staging Area	30/33	(0.61 - 0.61)	9.09%	0.759	203	26.69	44.19	9.97	134.2
	Sluice Trench and Ballfield East of Sluice Trench	11/17	(0.474 - 3.81)	35.3%	1.34	49.2	10.79	12.7	6.11	29.36
	Stilling Pond	3/3	--	0.0%	25.3	88	60.87	32.19	69.3	86.13
Radium-226+228	Interim Ash Staging Area	11/33	(0.0233 - 0.59)	66.7%	0.0645	0.594	0.128	0.151	0.207	0.534
	Sluice Trench and Ballfield East of Sluice Trench	9/17	(0 - 0.338)	47.1%	0.245	1.062	0.348	0.354	0.338	0.824
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
Selenium	Interim Ash Staging Area	26/33	(2.62 - 2.62)	21.2%	1.28	10.6	5.092	3.049	3.97	10.3
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	1.04	42.3	11.0	12.14	6.71	36.46
	Stilling Pond	3/3	--	0%	13	32.2	21.4	9.835	18.9	30.87
Thallium	Interim Ash Staging Area	15/33	(0.063 - 0.148)	54.6%	0.152	1.23	0.221	0.259	0.148	0.751
	Sluice Trench and Ballfield East of Sluice Trench	4/17	(0.063 - 0.148)	76.5%	0.174	4.45	0.527	1.20	0.128	3.30
	Stilling Pond	1/3	(0.0531 - 0.0531)	66.7%	0.09	0.09	0.0654	0.02	0.0531	0.09
TDEC Appendix I Parameters										
Copper	Interim Ash Staging Area	14/33	(0.627 - 1.3)	57.6%	0.685	9.03	1.60	2.02	0.962	6.658
	Sluice Trench and Ballfield East of Sluice Trench	7/17	(0.627 - 9.17)	58.8%	5.97	21.7	6.491	7.545	5.99	19.86
	Stilling Pond	2/3	(1.04 - 1.04)	33.3%	2.61	2.69	2.113	0.76	2.61	2.682
Nickel	Interim Ash Staging Area	16/33	(0.312 - 1.32)	51.5%	0.382	23.3	2.863	4.707	1.02	10.3
	Sluice Trench and Ballfield East of Sluice Trench	12/17	(0.312 - 0.573)	29.4%	0.467	111	11.52	27.63	0.866	62.76
	Stilling Pond	3/3	--	0.0%	0.643	2.35	1.311	0.912	0.941	2.209
Silver	Interim Ash Staging Area	4/33	(0.121 - 0.177)	87.9%	0.128	0.215	0.127	0.0193	0.121	0.177
	Sluice Trench and Ballfield East of Sluice Trench	0/17	(0.121 - 0.177)	100%	--	--	--	--	0.121	0.177
	Stilling Pond	0/3	(0.2 - 0.2)	100%	--	--	--	--	0.2	0.2
Vanadium	Interim Ash Staging Area	26/33	(0.899 - 0.899)	21.2%	1.03	100	13.09	19.76	5.62	42.22
	Sluice Trench and Ballfield East of Sluice Trench	17/17	--	0%	0.926	187	42.05	54.46	12.8	135.8
	Stilling Pond	3/3	--	0%	48	96.3	69.1	24.72	63	92.97
Zinc	Interim Ash Staging Area	10/33	(2.42 - 3.22)	69.7%	3.65	26.1	4.285	5.449	3.22	13.21
	Sluice Trench and Ballfield East of Sluice Trench	7/17	(2.42 - 6.29)	58.8%	3.66	69.3	12.29	20.0	5.29	60.74
	Stilling Pond	3/3	--	0.0%	49.6	137	86.53	45.2	73	130.6

Summary Statistics - CCR Material Characteristics - Synthetic Precipitate Leaching Procedure (SPLP) Kingston Fossil Plant - Harriman, Tennessee										
Parameter	**CCR Management Unit**	**Frequency of Detection**	**Range of Reporting Limits**	**% Non Detect**	**Statistics using Detected Data Only**		**Statistics using Detects & Non-Detects**			
					Minimum Detect	**Maximum Detect**	**Mean**	**Standard Deviation**	**50th Percentile**	**95th Percentile**
Additional Parameters										
Iron	Interim Ash Staging Area	17/33	(14.1 - 19.5)	48.5%	14.8	8,940	426	1,572	19.5	1,714
	Sluice Trench and Ballfield East of Sluice Trench	10/17	(14.1 - 19.5)	41.2%	15.7	21,700	2,417	6,464	19.5	19,060
	Stilling Pond	3/3	--	0.0%	107	606	365	250	382	584
Manganese	Interim Ash Staging Area	31/33	(1.35 - 1.35)	6.06%	1.47	2,090	121	388.9	9.13	601.4
	Sluice Trench and Ballfield East of Sluice Trench	12/17	(1.35 - 1.35)	29.4%	1.43	138	17.46	34.0	2.88	70.16
	Stilling Pond	3/3	--	0.0%	4.62	20.2	10.76	8.3	7.45	18.93

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

TDEC - Tennessee Department of Environment and Conservation

% - percent

"--" - Not Applicable

Except for pH & Radium 226 + 228, all units are micrograms per liter (µg/L).

Units for pH are Standard Units (S.U.).

Units for Radium 226+228 are picocuries per liter (pCi/L).

All non-detects reported at the method detection limit.

For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

Summary Statistics - CCR Material Characteristics - Pore Water - Total Metals
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Interim Ash Staging Area	3/3	--	0%	797	3,830	2,646	1,622	3,310	3,778
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	2,160	2,600	2,380	311	2,380	2,578
	Stilling Pond	2/2	--	0%	1,080	11,000	6,040	7,014	6,040	10,504
Calcium	Interim Ash Staging Area	3/3	--	0%	174,000	521,000	349,667	173,541	354,000	504,300
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	136,000	288,000	212,000	107,480	212,000	280,400
	Stilling Pond	2/2	--	0%	85,700	189,000	137,350	73,044	137,350	183,835
Chloride	Interim Ash Staging Area	3/3	--	0%	9,400	34,200	18,833	13,422	12,900	32,070
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	6,990	12,200	9,595	3,684	9,595	11,940
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
Fluoride	Interim Ash Staging Area	3/3	--	0%	268	463	351	100.7	322	448.9
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	192	325	258.5	94.05	258.5	318.4
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
pH (field)	Interim Ash Staging Area	3/3	--	0%	6.84	6.93	6.873	0.0493	6.85	6.922
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	6.53	8.86	7.695	1.648	7.695	8.744
	Stilling Pond	2/2	--	0%	6.73	7.16	6.945	0.304	6.945	7.044
Sulfate	Interim Ash Staging Area	3/3	--	0%	376,000	1,420,000	887,333	522,327	866,000	1,364,600
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	300,000	902,000	601,000	425,678	601,000	871,900
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
TDS	Interim Ash Staging Area	3/3	--	0%	850,000	2,580,000	1,703,333	865,236	1,680,000	2,490,000
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	659,000	1,670,000	1,164,500	714,885	1,164,500	1,619,450
	Stilling Pond	2/2	--	0%	345,000	882,000	613,500	379,716	613,500	855,150
CCR Rule Appendix IV Parameters										
Antimony	Interim Ash Staging Area	0/3	(0.378 - 0.378)	100%	--	--	--	--	0.378	0.378
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(0.378 - 0.378)	50.0%	0.707	0.707	0.543	0.165	0.543	0.691
	Stilling Pond	0/2	(2.1 - 4.25)	100.0%	--	--	--	--	3.175	4.143
Arsenic	Interim Ash Staging Area	3/3	--	0%	229	382	304	76.54	301	373.9
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	79.4	365	222.2	201.9	222.2	350.7
	Stilling Pond	2/2	--	0%	676	1770	1223	773.6	1223	1715
Barium	Interim Ash Staging Area	3/3	--	0%	36.2	76.2	50.5	22.3	39.1	72.49
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	32.0	242	137	148.5	137	231.5
	Stilling Pond	2/2	--	0%	216.0	265	240.5	34.65	240.5	262.6
Beryllium	Interim Ash Staging Area	0/3	(0.155 - 0.155)	100%	--	--	--	--	0.155	0.155
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.155 - 0.155)	100%	--	--	--	--	0.155	0.155
	Stilling Pond	1/2	(0.131 - 0.131)	50%	0.346	0.346	0.239	0.108	0.239	0.335
Cadmium	Interim Ash Staging Area	1/3	(0.125 - 0.125)	66.7%	0.127	0.127	0.126	0.000943	0.125	0.127
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.125 - 0.125)	100%	--	--	--	--	0.125	0.125
	Stilling Pond	1/2	(0.0781 - 0.0781)	50%	0.589	0.59	0.334	0.255	0.334	0.563

Summary Statistics - CCR Material Characteristics - Pore Water - Total Metals
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Chromium	Interim Ash Staging Area	0/3	(2.79 - 4.74)	100%	--	--	--	--	4.13	4.679
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(1.96 - 3.72)	100%	--	--	--	--	2.84	3.632
	Stilling Pond	0/2	(2.05 - 4.73)	100%	--	--	--	--	3.39	4.596
Cobalt	Interim Ash Staging Area	3/3	--	0%	0.393	3.10	1.39	1.489	0.673	2.86
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	0.257	0.350	0.304	0.0658	0.304	0.345
	Stilling Pond	2/2	--	0%	1.39	2.190	1.79	0.566	1.79	2.150
Fluoride	Interim Ash Staging Area	3/3	--	0%	268	463	351	100.7	322	448.9
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	192	325	258.5	94.05	258.5	318.4
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
Lead	Interim Ash Staging Area	1/3	(0.128 - 0.128)	66.7%	0.671	0.671	0.309	0.256	0.128	0.617
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(0.128 - 0.128)	50.0%	0.135	0.135	0.132	0.00350	0.132	0.135
	Stilling Pond	2/2	--	0.0%	1.21	4.51	2.86	2.33300	2.86	4.345
Lithium	Interim Ash Staging Area	3/3	--	0%	192	528	335.7	173.2	287	503.9
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	47.8	308	177.9	184	177.9	295
	Stilling Pond	1/2	(14.5 - 14.5)	50%	159	159	86.75	72.25	86.75	151.8
Mercury	Interim Ash Staging Area	0/3	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
	Stilling Pond	0/2	(0.0653 - 0.0653)	100%	--	--	--	--	0.0653	0.0653
Molybdenum	Interim Ash Staging Area	3/3	--	0%	120	450	320.3	176	391	444.1
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	193	195	194	1.414	194	194.9
	Stilling Pond	2/2	--	0%	74.2	3310	1692	2288	1692	3148
Radium-226+228	Interim Ash Staging Area	2/2	--	0.0%	0.359	0.620	0.49	0.185	0.490	0.607
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	0.257	0.544	0.401	0.203	0.401	0.530
	Stilling Pond	0/0	--	--	--	--	--	--	--	--
Selenium	Interim Ash Staging Area	0/3	(2.62 - 2.62)	100%	--	--	--	--	2.62	2.62
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(2.62 - 2.62)	100%	--	--	--	--	2.62	2.62
	Stilling Pond	1/2	(1.27 - 1.27)	50%	1.38	1.38	1.325	0.055	1.325	1.375
Thallium	Interim Ash Staging Area	2/3	(0.128 - 0.128)	33.3%	0.149	0.491	0.256	0.166	0.149	0.457
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.128 - 0.128)	100%	--	--	--	--	0.128	0.128
	Stilling Pond	2/2	--	0%	0.198	0.768	0.483	0.403	0.483	0.74
TDEC Appendix I Parameters										
Copper	Interim Ash Staging Area	3/3	--	0%	0.758	1.60	1.136	0.428	1.05	1.545
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(0.627 - 0.627)	50.0%	0.667	0.667	0.647	0.0200	0.647	0.67
	Stilling Pond	1/2	(3.45 - 3.45)	50.0%	8.49	8.49	5.97	2.5200	5.97	8.24
Nickel	Interim Ash Staging Area	3/3	--	0%	0.998	3.91	2.44	1.456	2.42	3.761
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	0.866	1.94	1.40	0.759	1.40	1.886
	Stilling Pond	2/2	--	0%	2.66	6.46	4.56	2.687	4.56	6.27
Silver	Interim Ash Staging Area	0/3	(0.121 - 0.121)	100%	--	--	--	--	0.121	0.121
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.121 - 0.121)	100%	--	--	--	--	0.121	0.121
	Stilling Pond	0/2	(0.2 - 0.2)	100%	--	--	--	--	0.2	0.2

Summary Statistics - CCR Material Characteristics - Pore Water - Total Metals
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Vanadium	Interim Ash Staging Area	0/3	(1.73 - 3.9)	100%	--	--	--	--	2.59	3.769
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(2.37 - 13.4)	100%	--	--	--	--	7.885	12.85
	Stilling Pond	2/2	--	0%	6.03	14.8	10.42	6.201	10.42	14.36
Zinc	Interim Ash Staging Area	3/3	--	0%	5.41	10.3	7.407	2.57	6.51	9.921
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(3.22 - 3.22)	50.0%	45.3	45.3	24.26	21.0	24.26	43.2
	Stilling Pond	2/2	--	0.0%	5.37	12.1	8.735	4.8	8.735	11.76
Additional Water Quality Parameters										
Iron	Interim Ash Staging Area	3/3	--	0%	36,700	73,300	51,167	19,467	43,500	70,320
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	608	108,000	54,304	75,938	54,304	102,630
	Stilling Pond	2/2	--	0%	2,370	5,410	3,890	2,150	3,890	5,258
Manganese	Interim Ash Staging Area	3/3	--	0%	1,750	5,820	3,537	2,080	3,040	5,542
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	151	2,410	1,281	1,597	1,281	2,297
	Stilling Pond	2/2	--	0%	322	851	587	374	587	825
TOC	Interim Ash Staging Area	3/3	--	0%	916	2,120	1,344	673	996	2,008
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	1,190	4,290	2,740	2,192	2,740	4,135
	Stilling Pond	2/2	--	0%	2,070	3,810	2,940	1,230	2,940	3,723

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

TDEC - Tennessee Department of Environment and Conservation

% - percent

"--" : Not Applicable

TDS - Total Dissolved Solids

TOC - Total Organic Carbon

Sample results collected from GP-17-102 at the Stilling Pond were excluded from the analysis due to elevated Turbidity (616.3 Nephelometric Turbidity Units).

Except for pH & Radium 226 + 228, all units micrograms per liter (µg/L).

Units for pH are Standard Units (S.U.).

Units for Radium 226+228 are picocuries per liter (pCi/L).

All non-detects reported at the laboratory detection limit.

For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

Summary Statistics - CCR Material Characteristics - Pore Water - Dissolved Metals
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
CCR Rule Appendix III Parameters										
Boron	Interim Ash Staging Area	3/3	--	0%	762	3,550	2,534	1,540	3,290	3,524
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	2,080	2,610	2,345	375	2,345	2,584
	Stilling Pond	2/2	--	0%	1,170	10,000	5,585	6,244	5,585	9,559
Calcium	Interim Ash Staging Area	3/3	--	0%	163,000	517,000	343,333	177,094	350,000	500,300
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	134,000	298,000	216,000	115,966	216,000	289,800
	Stilling Pond	2/2	--	0%	75,300	185,000	130,150	77,570	130,150	179,515
CCR Rule Appendix IV Parameters										
Antimony	Interim Ash Staging Area	0/3	(0.378 - 0.378)	100%	--	--	--	--	0.378	0.378
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(0.378 - 0.378)	50.0%	0.681	0.681	0.530	0.152	0.530	0.666
	Stilling Pond	1/2	(1.84 - 1.84)	50.0%	4.05	4.05	2.945	1.105	2.945	3.94
Arsenic	Interim Ash Staging Area	3/3	--	0%	180	372	280	96.25	288	363.6
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	78.4	349	214	191.3	213.7	335.5
	Stilling Pond	2/2	--	0%	598.0	1820	1209	864.1	1209	1759
Barium	Interim Ash Staging Area	3/3	--	0%	34.4	60.5	44.07	14.31	37.3	58.18
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	31.1	240	135.6	147.7	135.6	229.6
	Stilling Pond	2/2	--	0%	219	231	225	8.485	225	230.4
Beryllium	Interim Ash Staging Area	0/3	(0.155 - 0.155)	100%	--	--	--	--	0.155	0.155
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.155 - 0.155)	100%	--	--	--	--	0.155	0.155
	Stilling Pond	1/2	(0.131 - 0.131)	50%	0.391	0.391	0.261	0.13	0.261	0.378
Cadmium	Interim Ash Staging Area	0/3	(0.125 - 0.125)	100%	--	--	--	--	0.125	0.125
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.125 - 0.125)	100%	--	--	--	--	0.125	0.125
	Stilling Pond	2/2	--	0%	0.171	0.566	0.369	0.28	0.369	0.546
Chromium	Interim Ash Staging Area	0/3	(2.24 - 3.53)	100%	--	--	--	--	3.13	3.49
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(1.53 - 2.96)	100%	--	--	--	--	2.245	2.89
	Stilling Pond	1/2	(0.85 - 0.85)	50%	5.76	5.76	3.305	2.455	3.305	5.52
Cobalt	Interim Ash Staging Area	3/3	--	0%	0.369	2.88	1.228	1.431	0.436	2.636
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	0.243	0.313	0.278	0.0495	0.278	0.310
	Stilling Pond	2/2	--	0%	0.658	2.79	1.724	1.508	1.724	2.683
Lead	Interim Ash Staging Area	0/3	(0.128 - 0.128)	100%	--	--	--	--	0.128	0.128
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.128 - 0.128)	100%	--	--	--	--	0.128	0.128
	Stilling Pond	1/2	(0.318 - 0.318)	50%	4.6	4.6	2.459	2.141	2.459	4.386
Lithium	Interim Ash Staging Area	3/3	--	0%	181	555	338.7	193.8	280	527.5
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	48.6	317	182.8	189.8	182.8	303.6
	Stilling Pond	2/2	--	0%	19.7	173	96.35	108.4	96.35	165.3

Summary Statistics - CCR Material Characteristics - Pore Water - Dissolved Metals
Kingston Fossil Plant - Harriman, Tennessee

Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Mercury	Interim Ash Staging Area	0/3	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.101 - 0.101)	100%	--	--	--	--	0.101	0.101
	Stilling Pond	0/2	(0.0653 - 0.0653)	100%	--	--	--	--	0.0653	0.0653
Molybdenum	Interim Ash Staging Area	3/3	--	0%	115	443	314.3	175	385	437.2
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	195	196	195.5	0.707	195.5	196
	Stilling Pond	2/2	--	0%	67.5	3520	1794	2441	1794	3347
Selenium	Interim Ash Staging Area	0/3	(2.62 - 2.62)	100%	--	--	--	--	2.62	2.62
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(2.62 - 2.62)	100%	--	--	--	--	2.62	2.62
	Stilling Pond	0/2	(1.27 - 1.27)	100%	--	--	--	--	1.27	1.27
Thallium	Interim Ash Staging Area	1/3	(0.128 - 0.128)	66.7%	0.442	0.442	0.233	0.148	0.128	0.411
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.128 - 0.128)	100%	--	--	--	--	0.128	0.128
	Stilling Pond	2/2	--	0%	0.399	0.425	0.412	0.0184	0.412	0.424
TDEC Appendix I Parameters										
Copper	Interim Ash Staging Area	1/3	(0.627 - 0.627)	66.7%	0.905	0.905	0.720	0.131	0.627	0.877
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.627 - 0.627)	100%	--	--	--	--	0.627	0.63
	Stilling Pond	1/2	(1.04 - 1.04)	50%	10.1	10.1	5.57	4.53	5.57	9.65
Nickel	Interim Ash Staging Area	1/3	(0.809 - 1.68)	66.7%	3.96	3.96	1.859	1.485	1.68	3.732
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(0.912 - 0.912)	50.0%	1.90	1.90	1.406	0.494	1.406	1.85
	Stilling Pond	2/2	--	0.0%	1.89	6.10	3.995	2.977	3.995	5.89
Silver	Interim Ash Staging Area	0/3	(0.121 - 0.121)	100%	--	--	--	--	0.121	0.121
	Sluice Trench and Ballfield East of Sluice Trench	0/2	(0.121 - 0.121)	100%	--	--	--	--	0.121	0.121
	Stilling Pond	0/2	(0.2 - 0.2)	100%	--	--	--	--	0.2	0.2
Vanadium	Interim Ash Staging Area	0/3	(1.4 - 2.12)	100%	--	--	--	--	1.87	2.10
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(1.64 - 1.64)	50.0%	11.3	11.3	6.47	4.83	6.47	10.82
	Stilling Pond	1/2	(4.45 - 4.45)	50.0%	16.6	16.6	10.53	6.075	10.53	15.99
Zinc	Interim Ash Staging Area	3/3	--	0%	4.41	9.65	6.677	2.691	5.97	9.282
	Sluice Trench and Ballfield East of Sluice Trench	1/2	(3.22 - 3.22)	50.0%	44.7	44.7	24.0	20.74	24.0	42.63
	Stilling Pond	1/2	(2.65 - 2.65)	50.0%	9.86	9.86	6.3	3.605	6.3	9.5

Summary Statistics - CCR Material Characteristics - Pore Water - Dissolved Metals Kingston Fossil Plant - Harriman, Tennessee										
Parameter	CCR Management Unit	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
					Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Additional Water Quality Parameters										
Iron	Interim Ash Staging Area	3/3	--	0%	31,900	73,300	49,333	21,459	42,800	70,250
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	188	107,000	53,594	75,527	53,594	101,659
	Stilling Pond	2/2	--	0%	3,190	3,370	3,280	127	3,280	3,361
Manganese	Interim Ash Staging Area	3/3	--	0%	1,680	5,770	3,473	2,091	2,970	5,490
	Sluice Trench and Ballfield East of Sluice Trench	2/2	--	0%	155	2,430	1,293	1,609	1,293	2,316
	Stilling Pond	2/2	--	0%	272	748	510	337	510	724

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

TDEC - Tennessee Department of Environment and Conservation

% - percent

"--" : Not Applicable

Sample results collected from GP-17-102 at the Stilling Pond were excluded from the analysis due to elevated Turbidity (616.3 Nephelometric Turbidity Units).

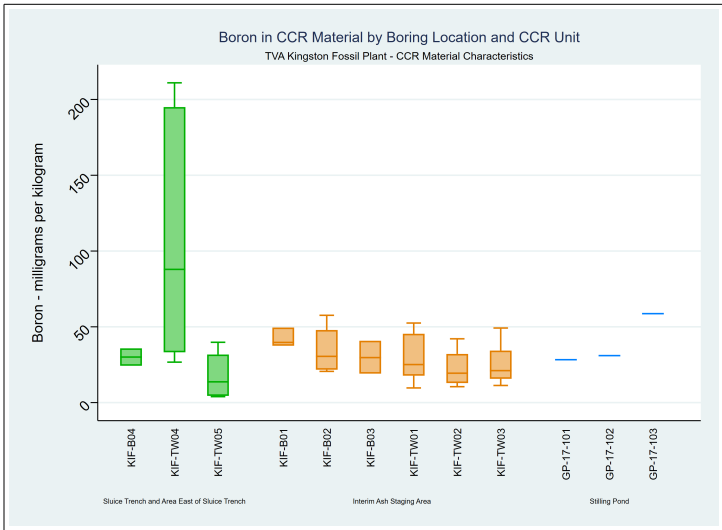
All units in micrograms per liter (µg/L)

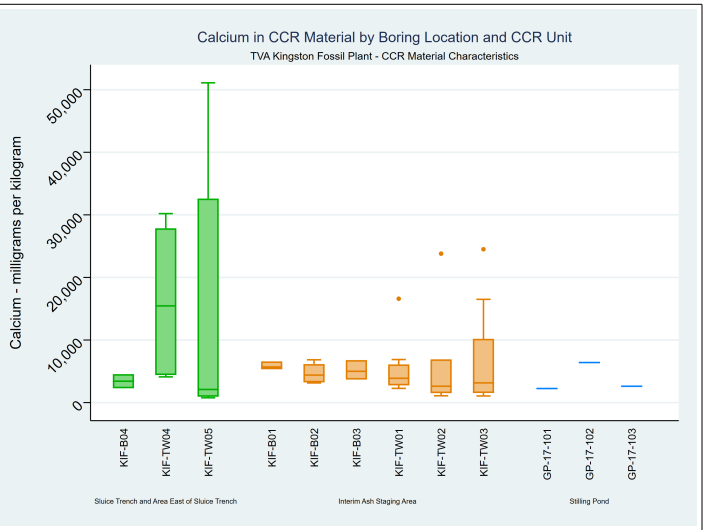
All non-detects reported at the laboratory detection limit

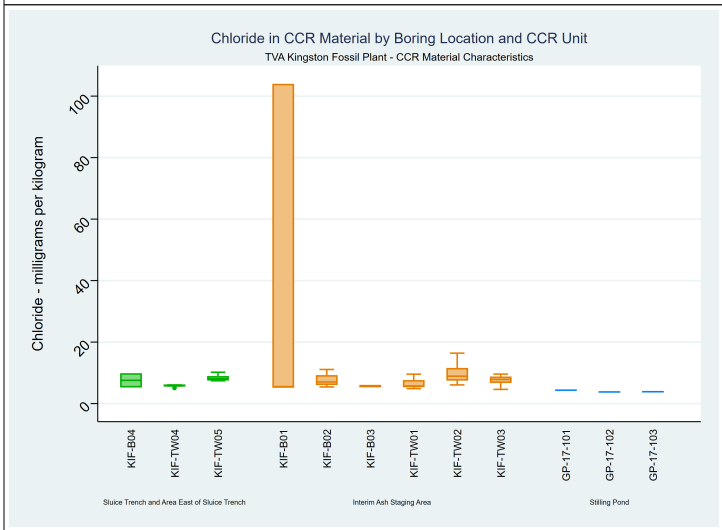
For Parameters with non-detects reported at the method detection limit, the mean and standard deviation were calculated using Kaplan-Meier methods (KM).

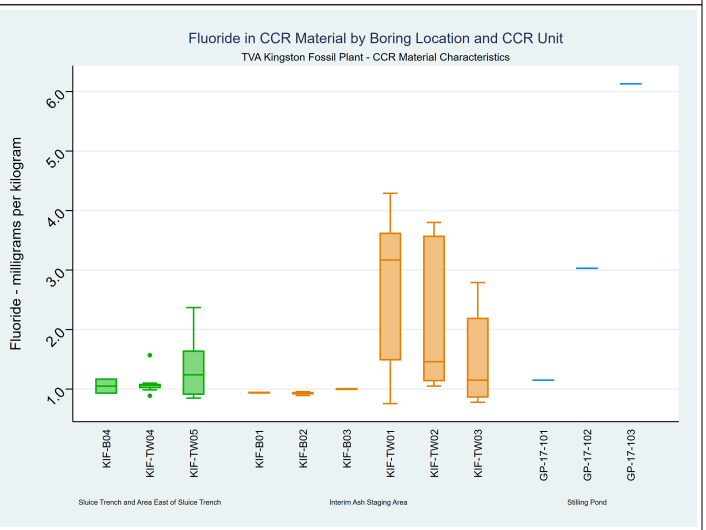
ATTACHMENT E.2-B
BOX PLOTS – CCR MATERIAL

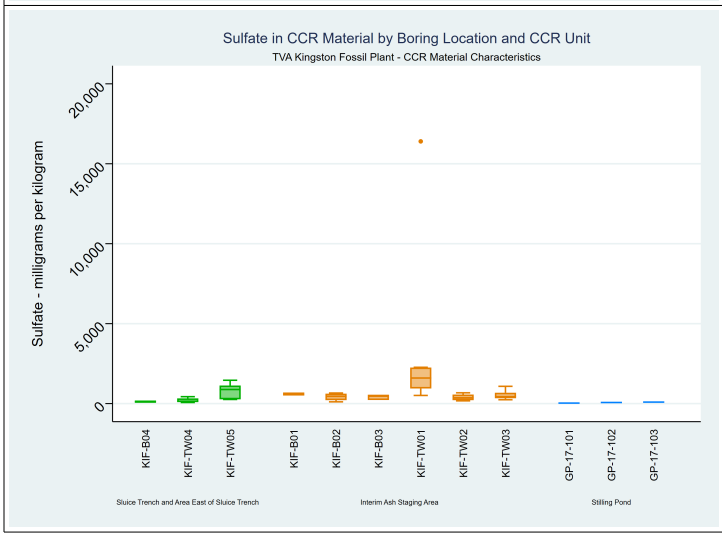
Box Plots
CCR Rule Appendix III Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee

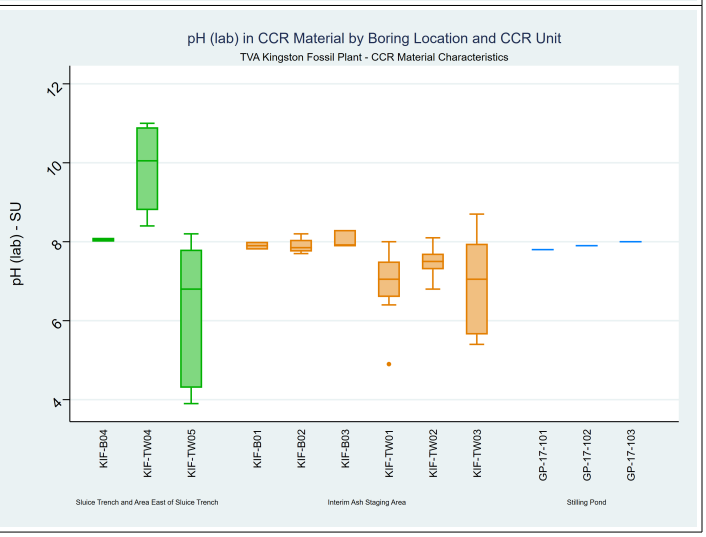




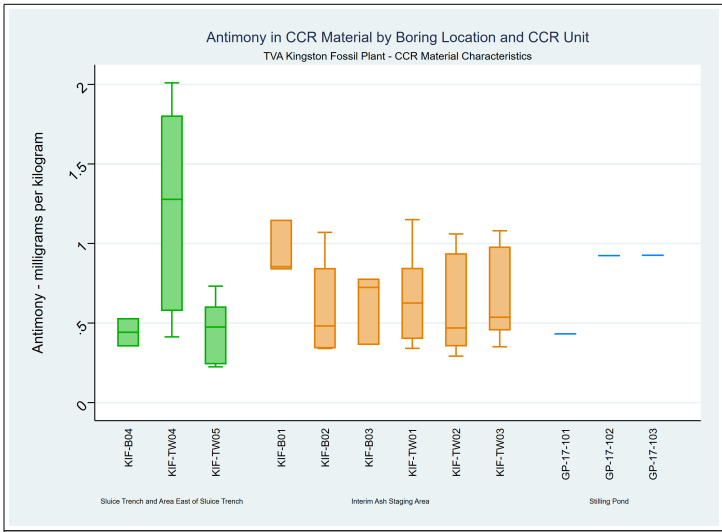


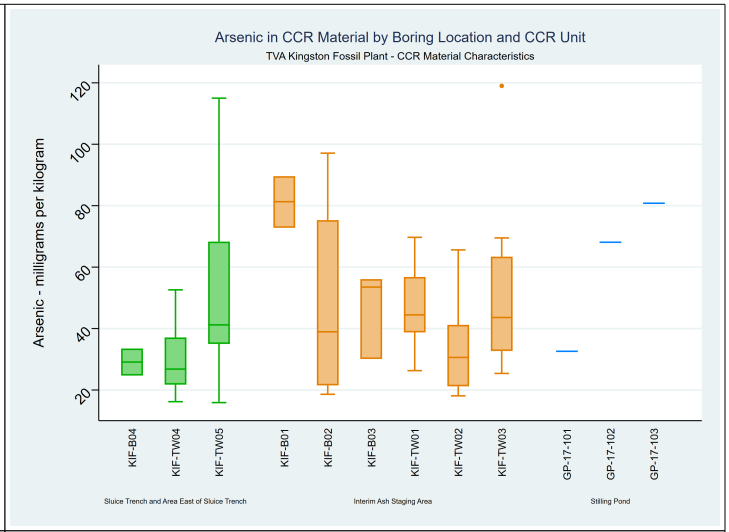


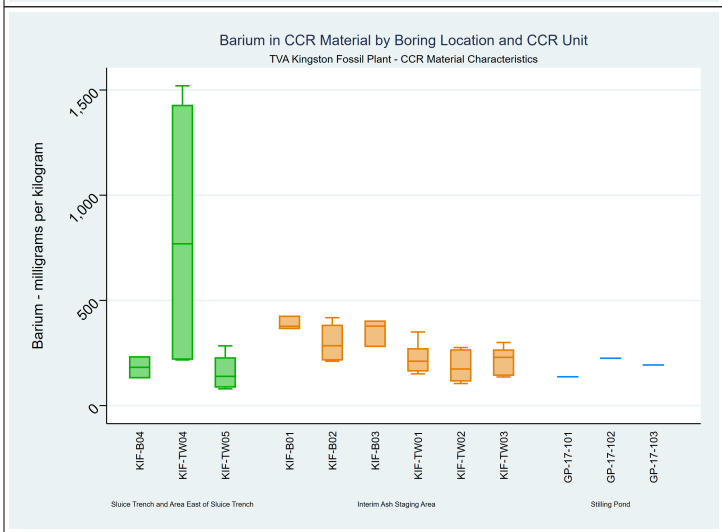


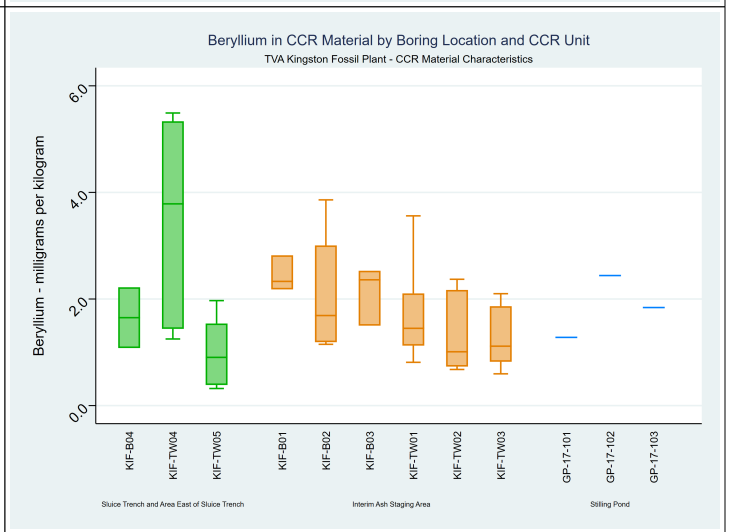


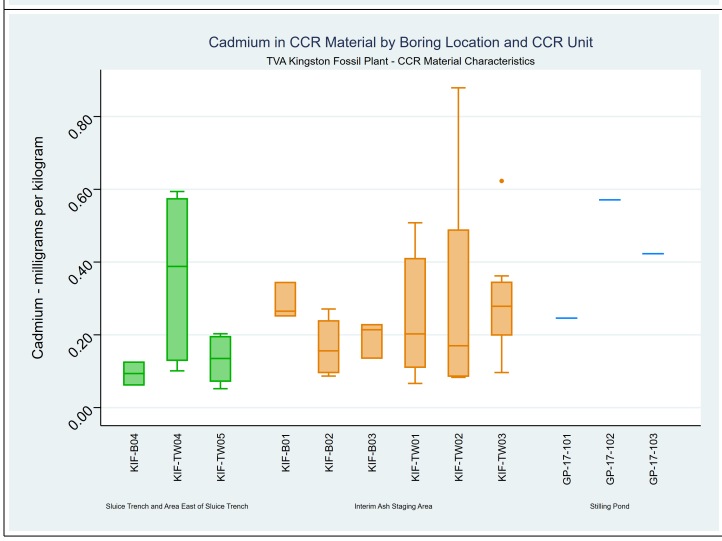
Box Plots
CCR Rule Appendix IV Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee

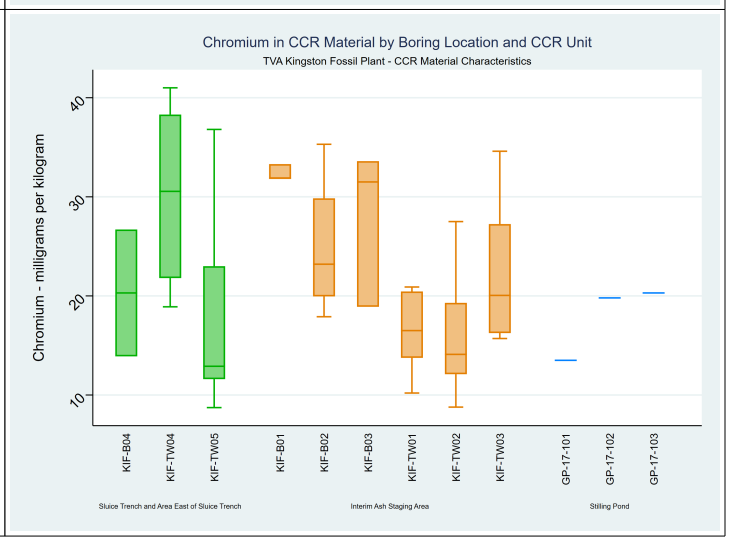


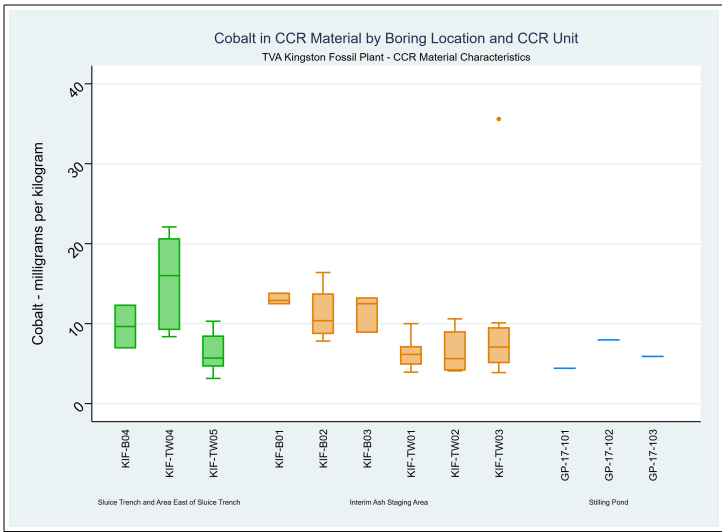


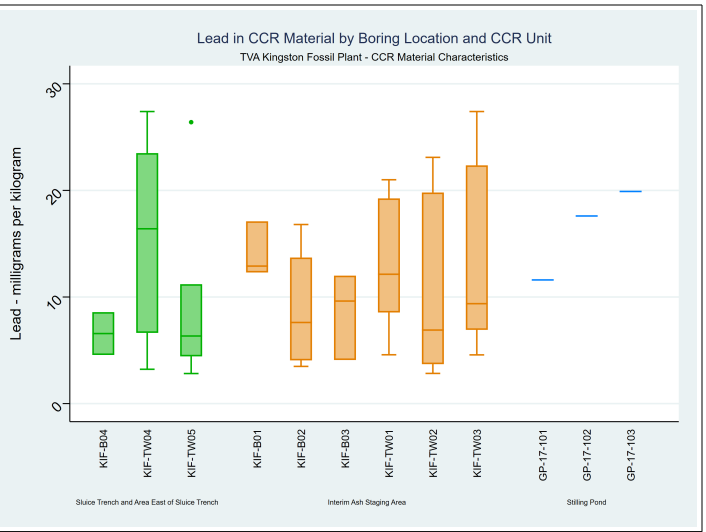


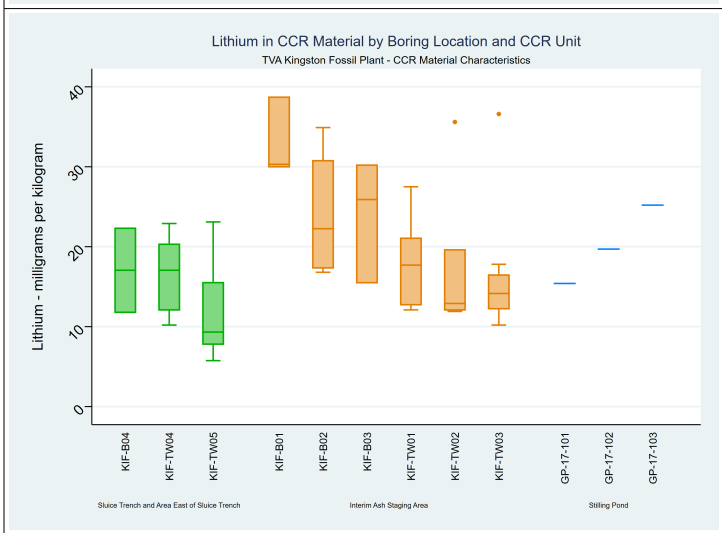


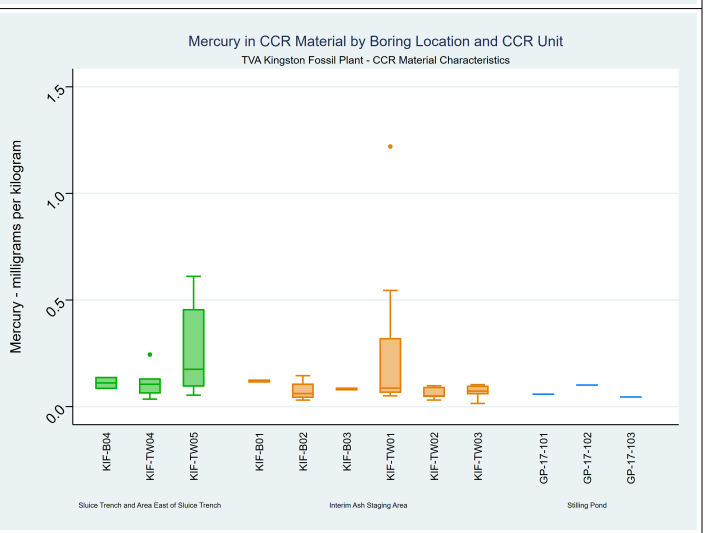


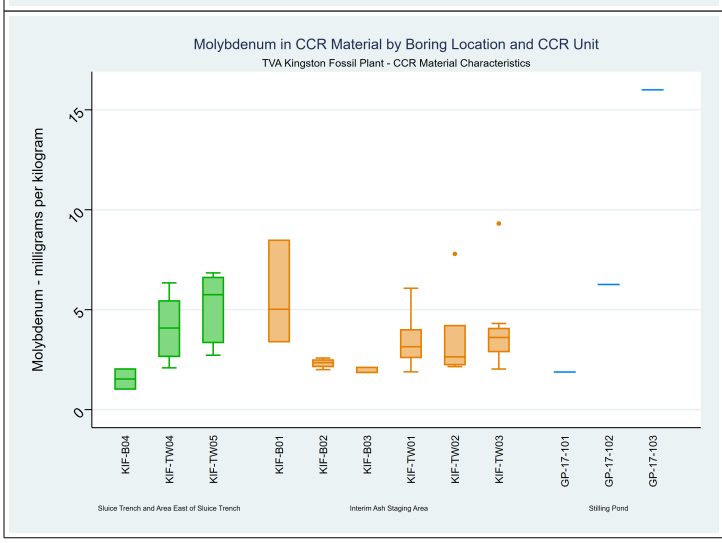


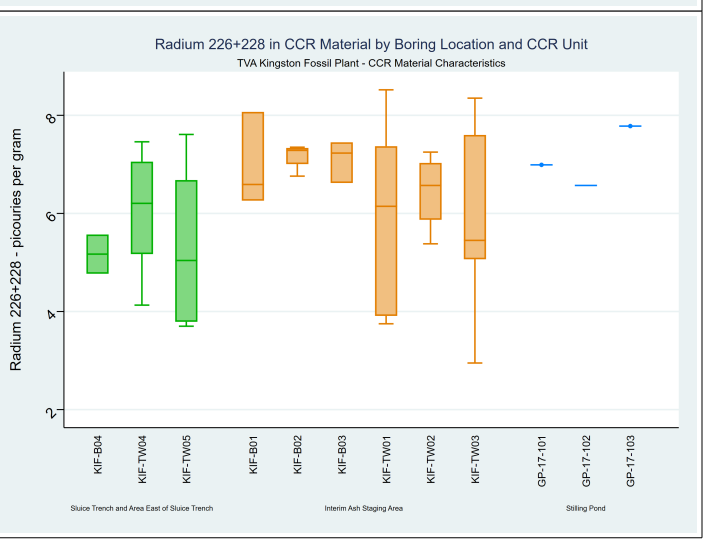

Cobalt in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Cobalt - milligrams per kilogram
0
10
20
30
40
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

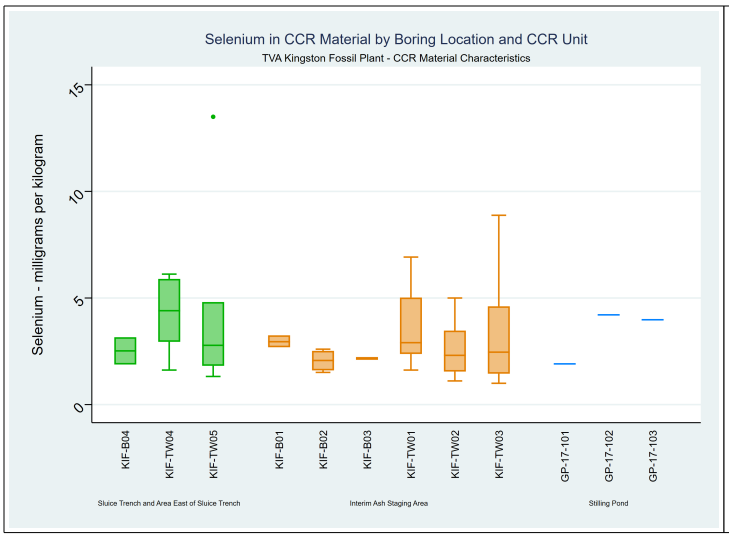

Lead in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Lead - milligrams per kilogram
0
10
20
30
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

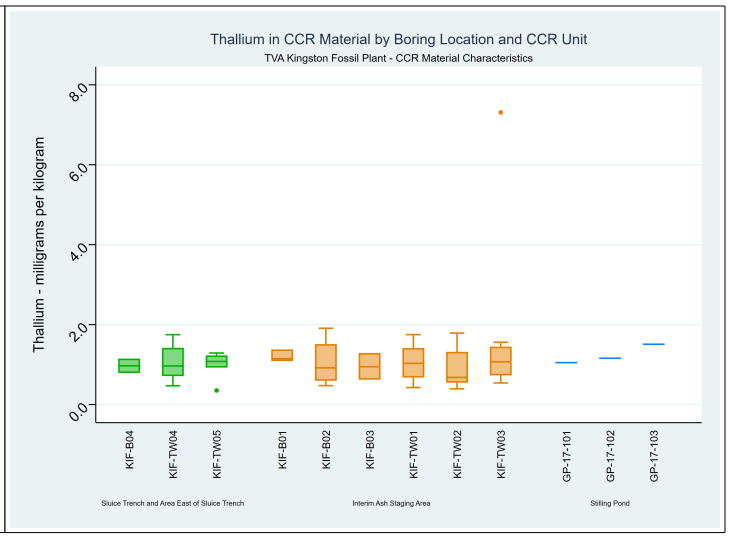

Lithium in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Lithium - milligrams per kilogram
0
10
20
30
40
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond


Mercury in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Mercury - milligrams per kilogram
0.0
0.5
1.0
1.5
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

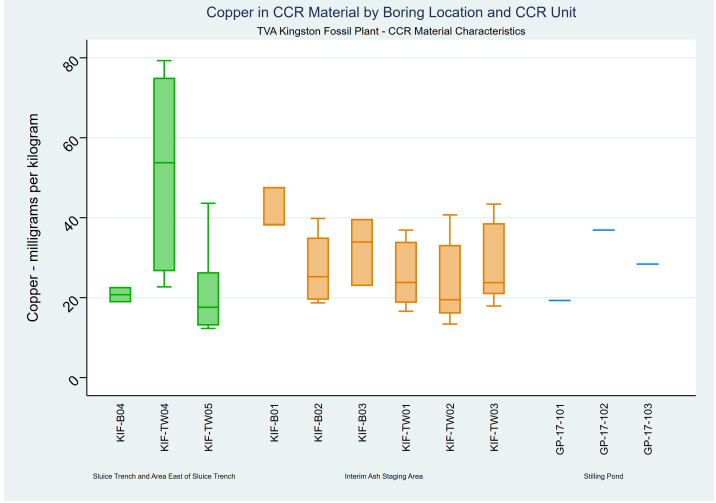

Molybdenum in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Molybdenum - milligrams per kilogram
0
5
10
15
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

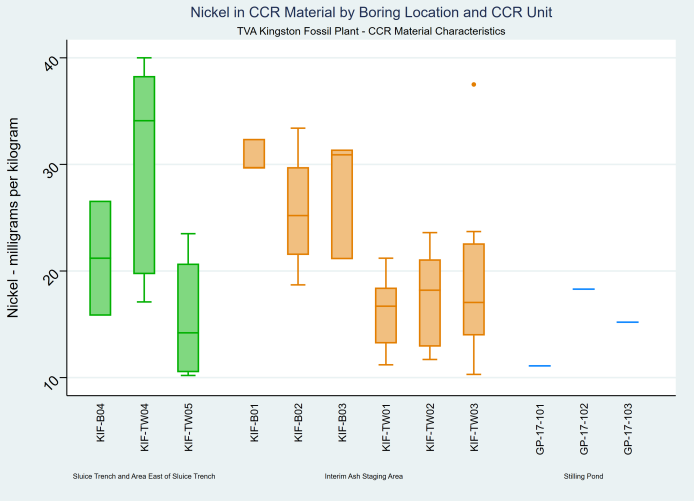

Radium 226+228 in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Radium 226+228 - picocuries per gram
2
4
6
8
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

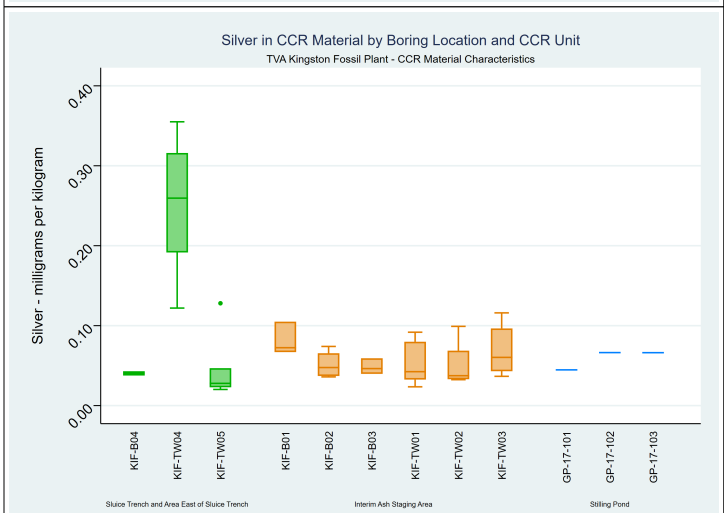

Selenium in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Selenium - milligrams per kilogram
0
5
10
15
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

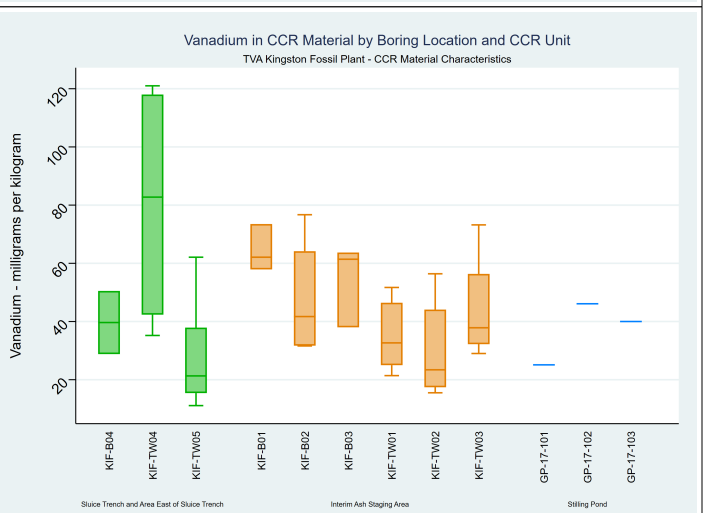

Thallium in CCR Material by Boring Location and CCR Unit
TVA Kingston Fossil Plant - CCR Material Characteristics
Thallium - milligrams per kilogram
0.0
2.0
4.0
6.0
8.0
KIF-B04
KIF-TW04
KIF-TW05
KIF-B01
KIF-B02
KIF-B03
KIF-TW01
KIF-TW02
KIF-TW03
GP-17-101
GP-17-102
GP-17-103
Sluice Trench and Area East of Sluice Trench
Interim Ash Staging Area
Stilling Pond

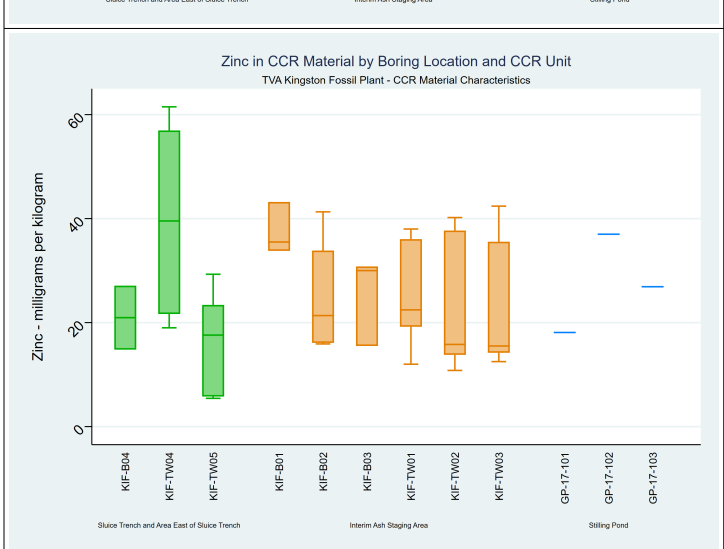
Box Plots
TDEC Appendix I Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee











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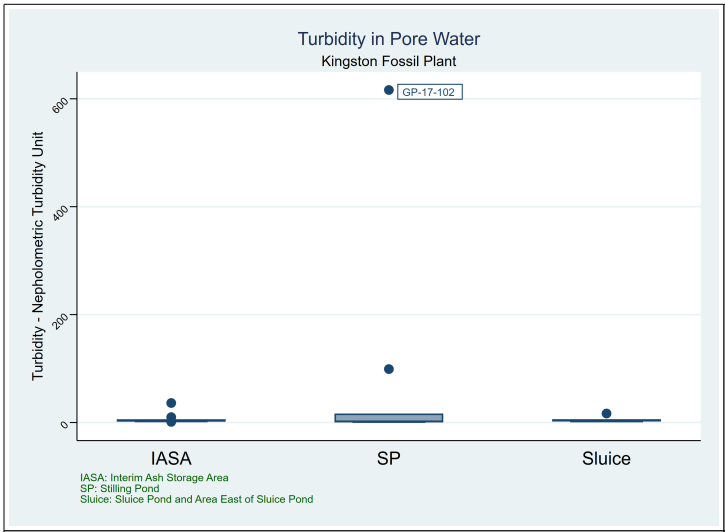
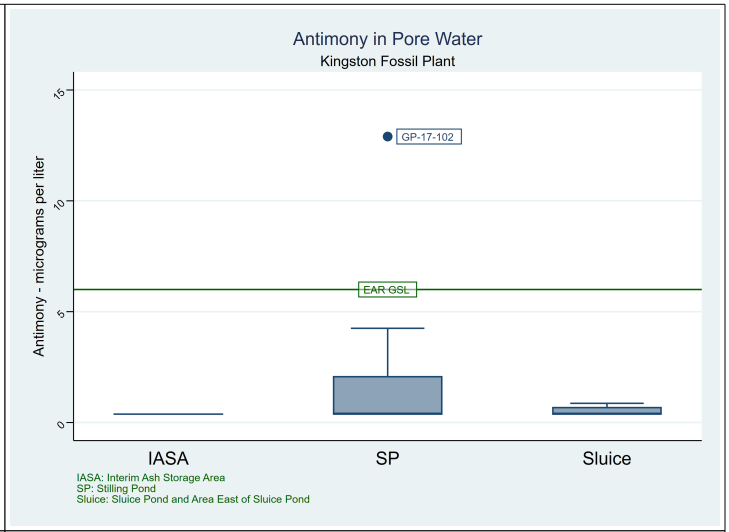
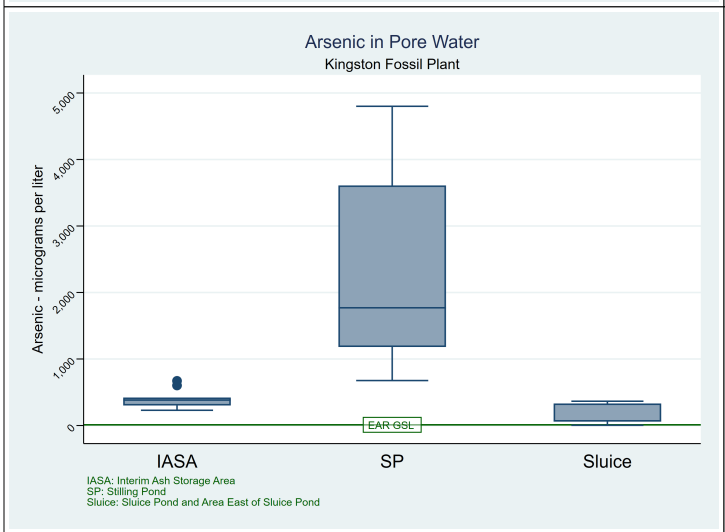
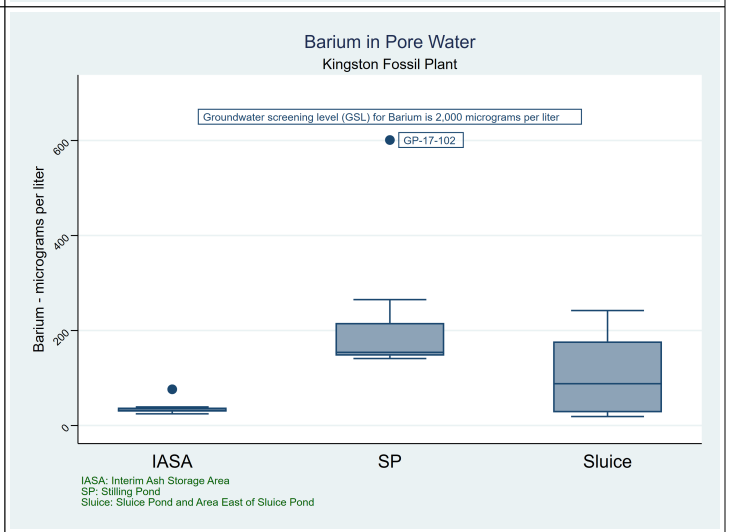
ATTACHMENT E.2-C
BOX PLOTS – PORE WATER OUTLIER ANALYSIS

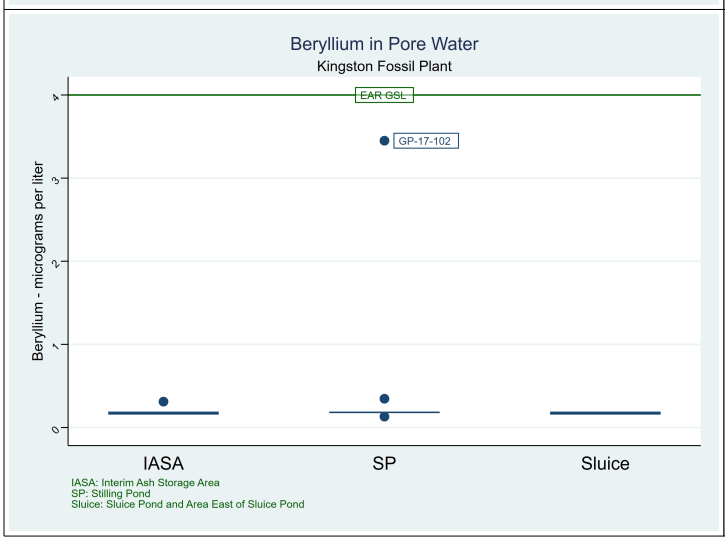
Box Plots - Pore Water Outlier Analysis
CCR Rule Appendix IV Parameters
Pore Water Investigation
Kingston Fossil Plant - Harriman, Tennessee

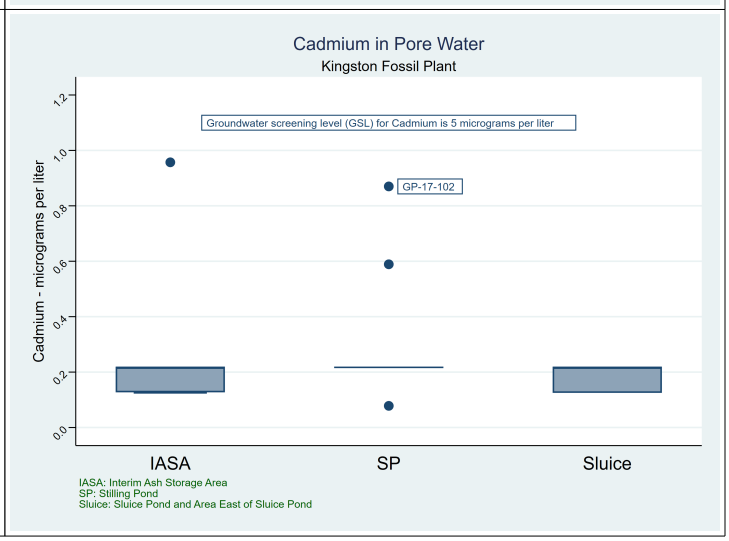


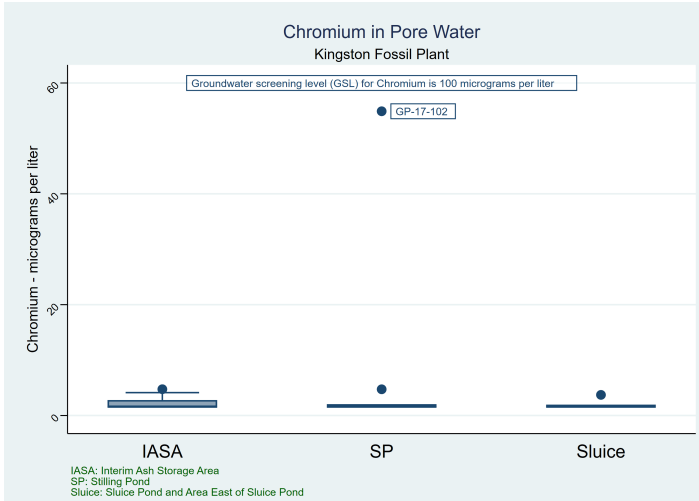


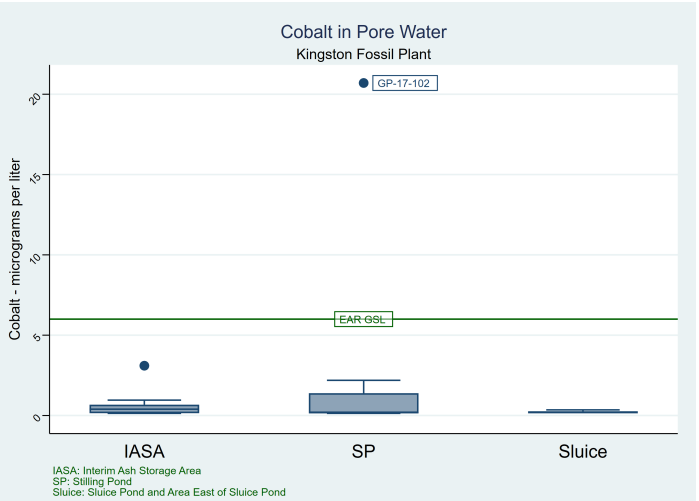


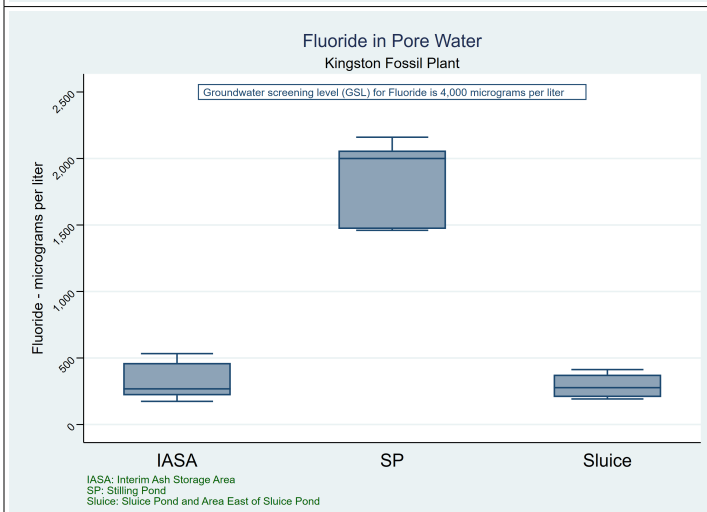


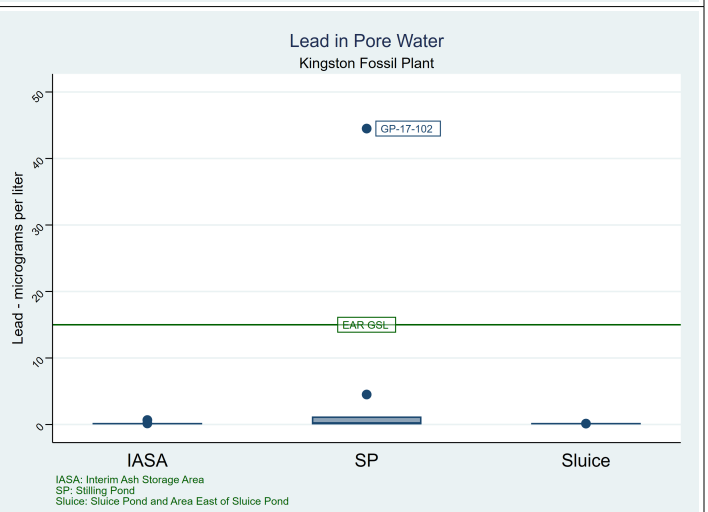


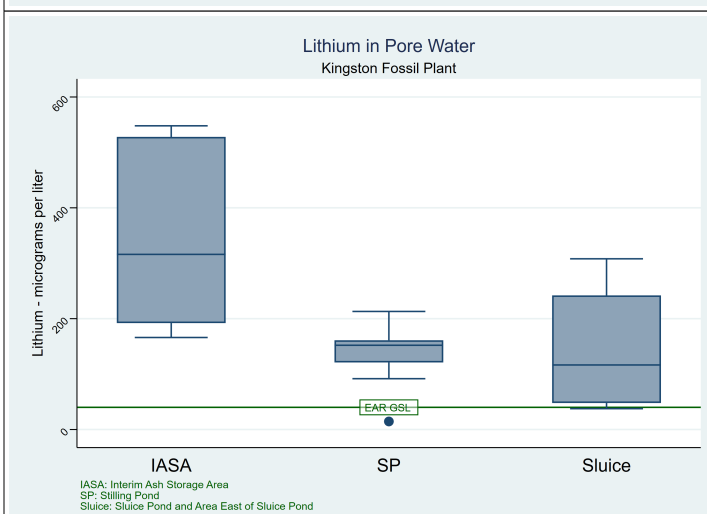


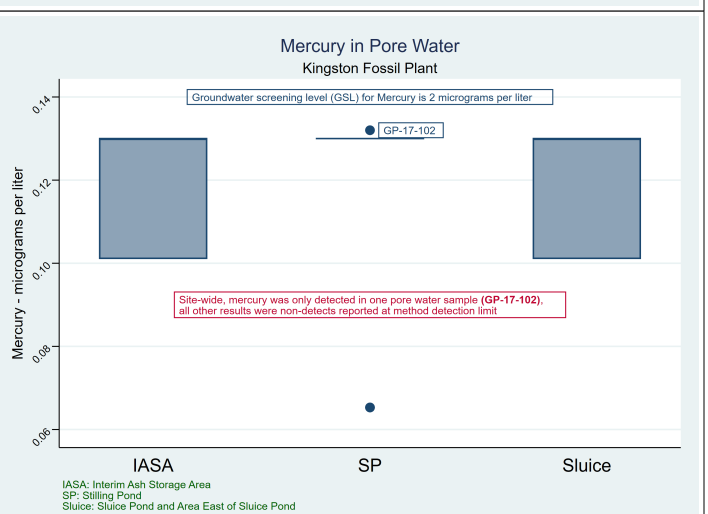

Chromium in Pore Water
Kingston Fossil Plant
Groundwater screening level (GSL) for Chromium is 100 micrograms per liter
GP-17-102
Chromium - micrograms per liter
0
20
40
60
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond

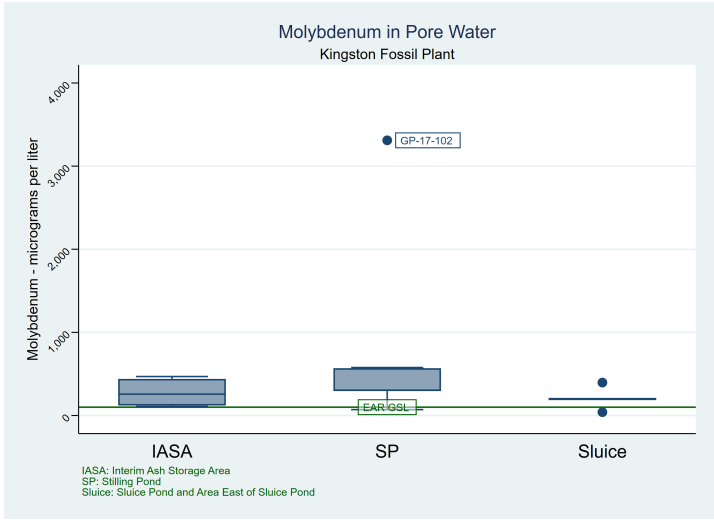

Cobalt in Pore Water
Kingston Fossil Plant
GP-17-102
EAR GSL
Cobalt - micrograms per liter
0
5
10
15
20
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond


Fluoride in Pore Water
Kingston Fossil Plant
Groundwater screening level (GSL) for Fluoride is 4,000 micrograms per liter
Fluoride - micrograms per liter
0
500
1,000
1,500
2,000
2,500
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond

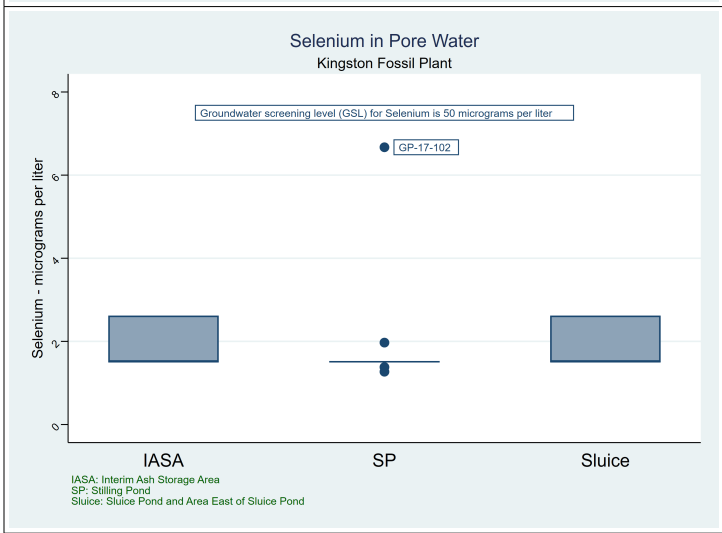

Lead in Pore Water
Kingston Fossil Plant
GP-17-102
EAR GSL
Lead - micrograms per liter
0
10
20
30
40
50
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond

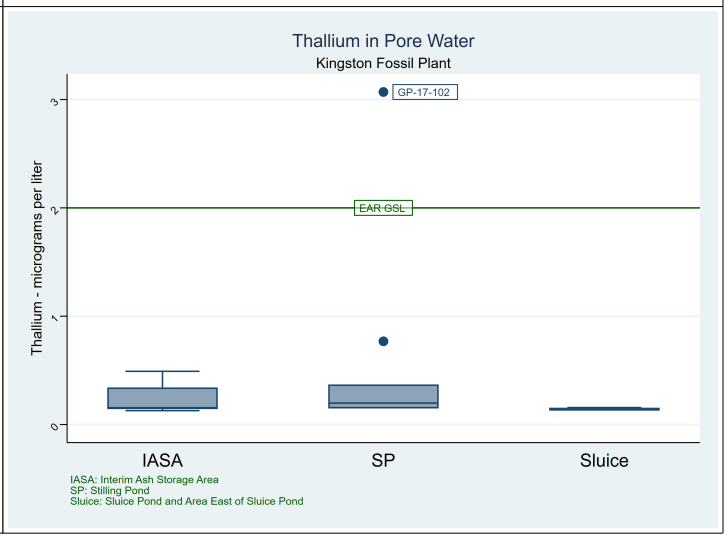

Lithium in Pore Water
Kingston Fossil Plant
Lithium - micrograms per liter
0
200
400
600
EAR GSL
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond


Mercury in Pore Water
Kingston Fossil Plant
Groundwater screening level (GSL) for Mercury is 2 micrograms per liter
GP-17-102
Site-wide, mercury was only detected in one pore water sample (GP-17-102), all other results were non-detects reported at method detection limit
Mercury - micrograms per liter
0.06
0.08
0.10
0.12
0.14
IASA
SP
Sluice
IASA: Interim Ash Storage Area
SP: Stilling Pond
Sluice: Sluice Pond and Area East of Sluice Pond

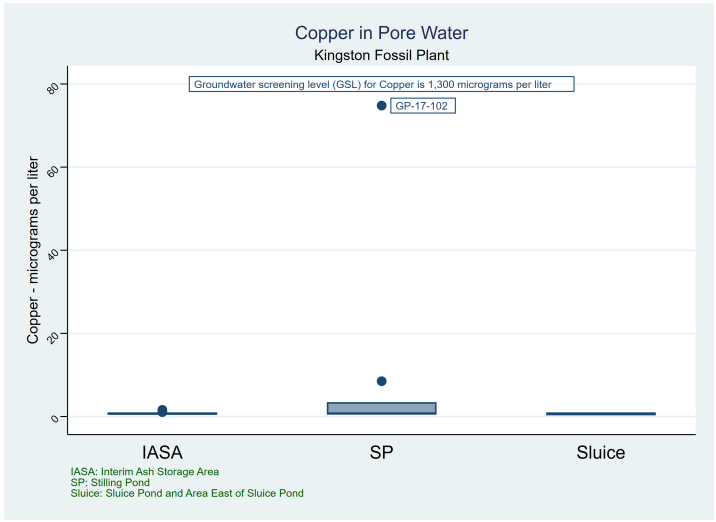


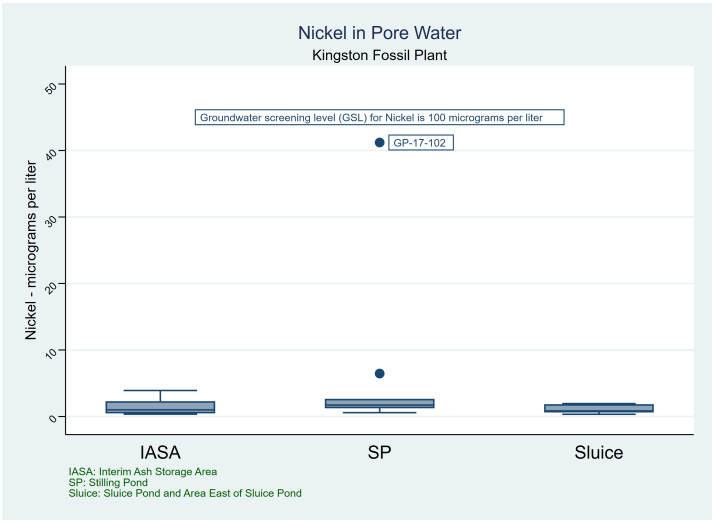
Results for Radium 226+228 were not Reported for GP-17-101, GP-17-102, or GP-17-103



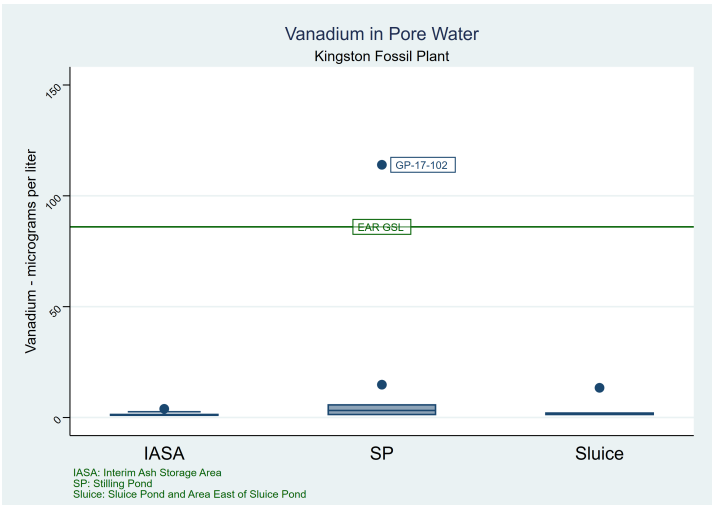


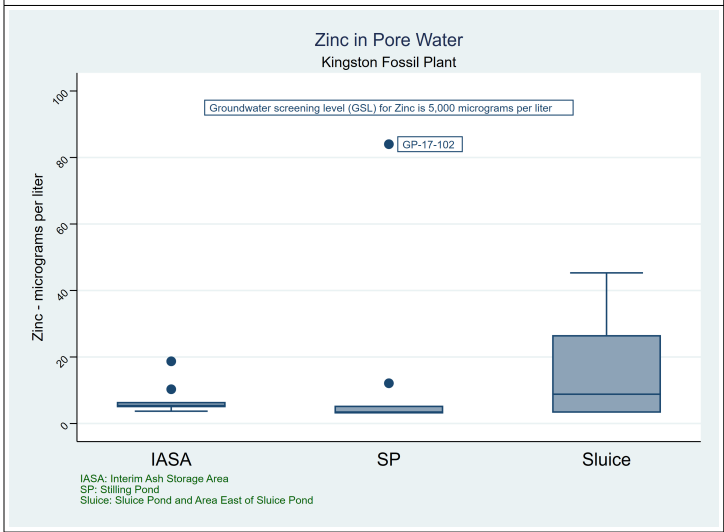
Box Plots - Pore Water Outlier Analysis
TDEC Appendix I Parameters
Pore Water Investigation
Kingston Fossil Plant - Harriman, Tennessee





Silver was not detected above the method detection limit in any pore water sample





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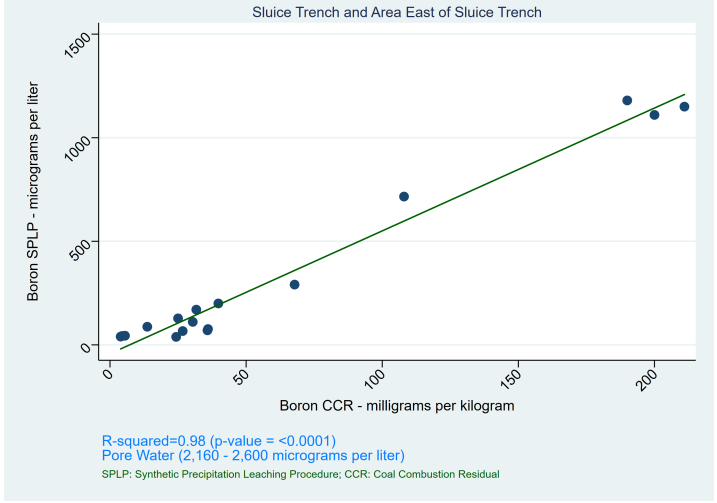
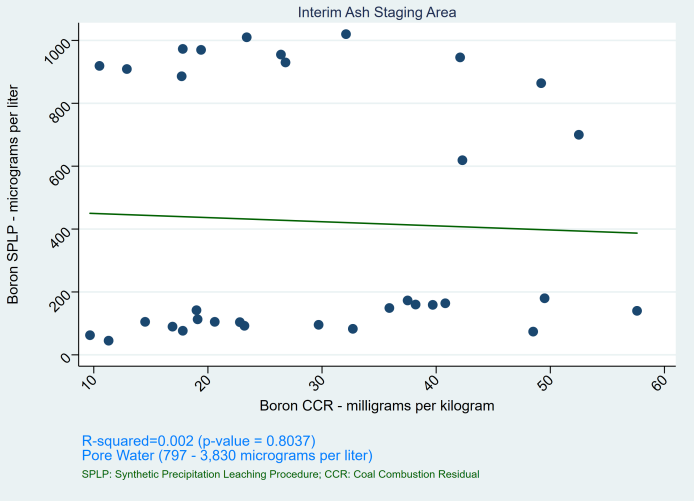
ATTACHMENT E.2-D
SCATTER PLOTS AND REGRESSION

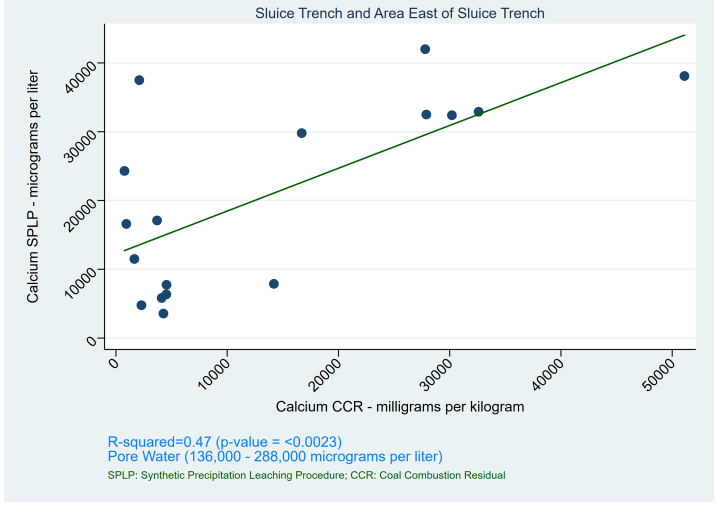
Scatter Plots (SPLP and CCR Material)
CCR Rule Appendix III Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee



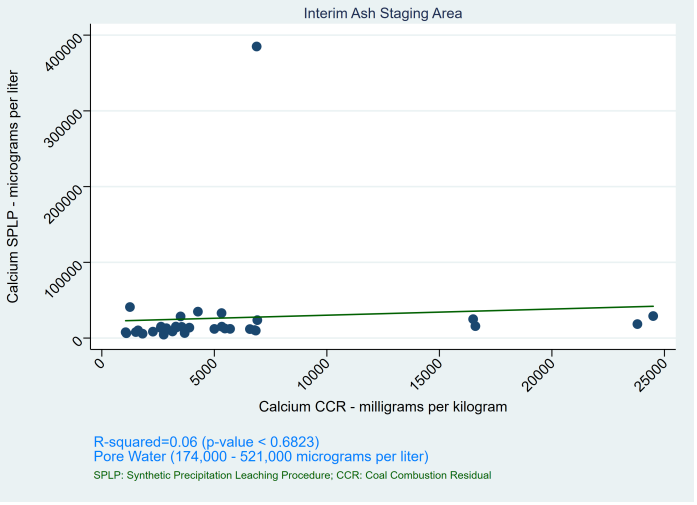
R-squared=0.98 (p-value = <0.0001)
Pore Water (2,160 - 2,600 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



R-squared=0.002 (p-value = 0.8037)
Pore Water (797 - 3,830 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual



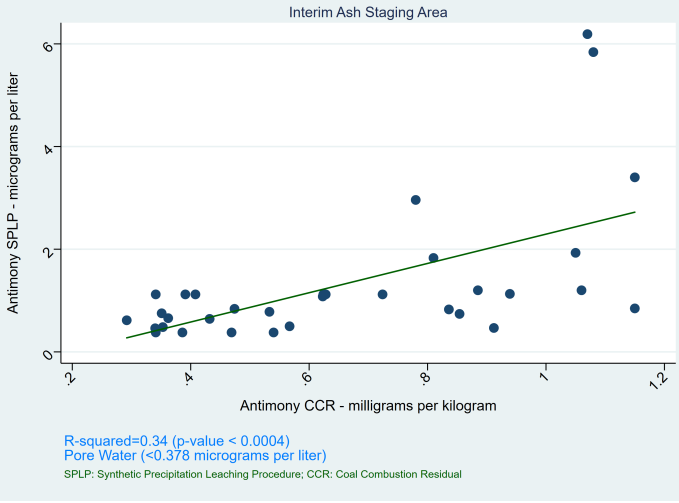
R-squared=0.47 (p-value = <0.0023)
Pore Water (136,000 - 288,000 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual

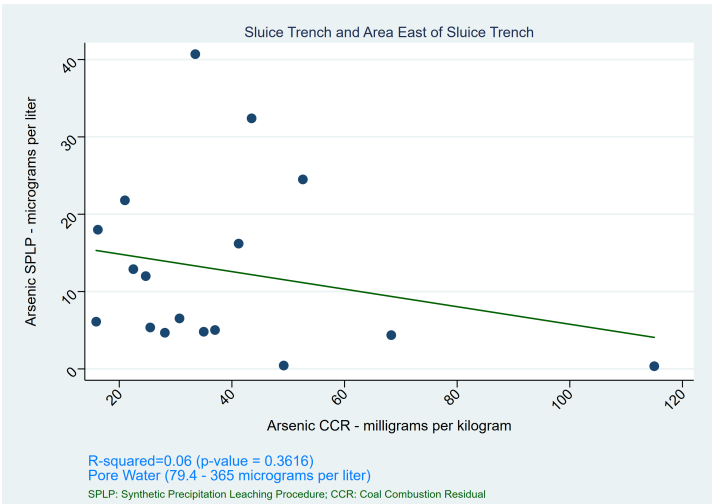


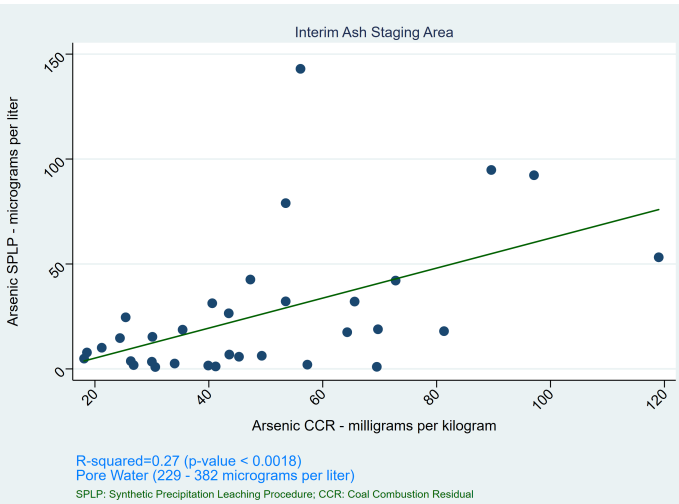
R-squared=0.06 (p-value < 0.6823)
Pore Water (174,000 - 521,000 micrograms per liter)
SPLP: Synthetic Precipitation Leaching Procedure; CCR: Coal Combustion Residual

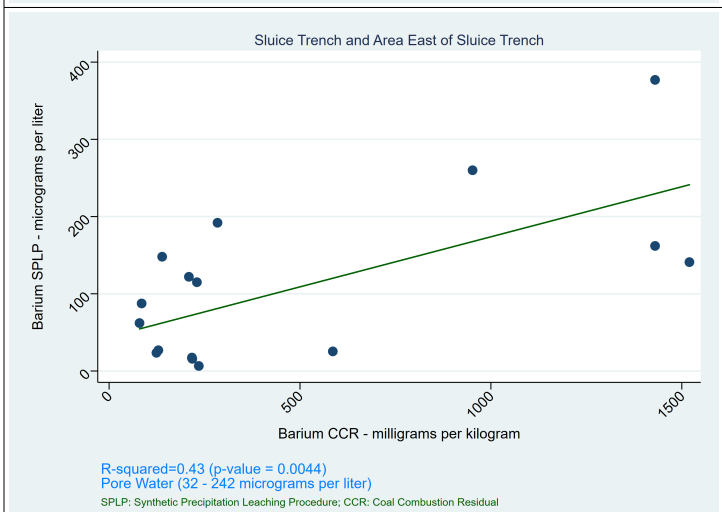
Scatter Plots (SPLP and CCR Material)
CCR Rule Appendix IV Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee

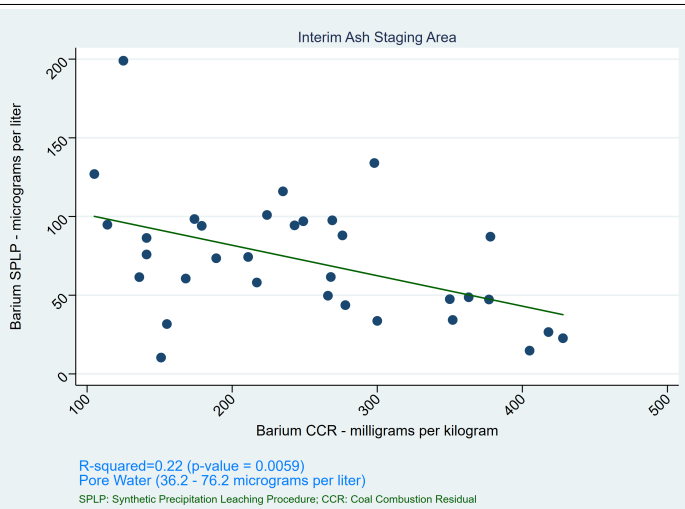
Antimony/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets





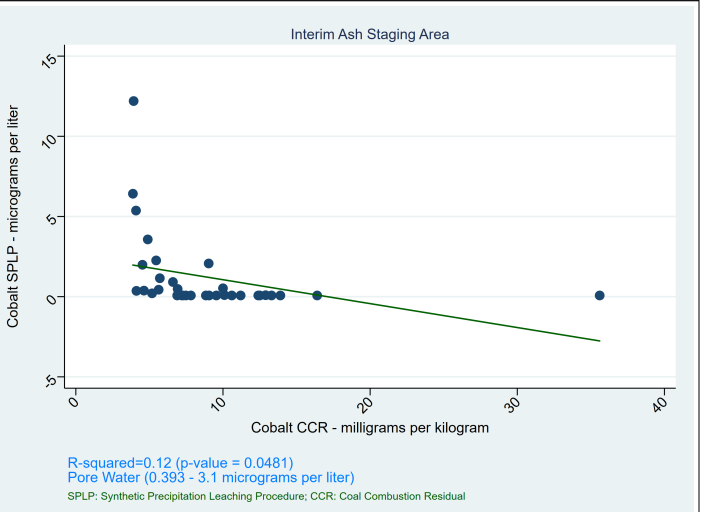
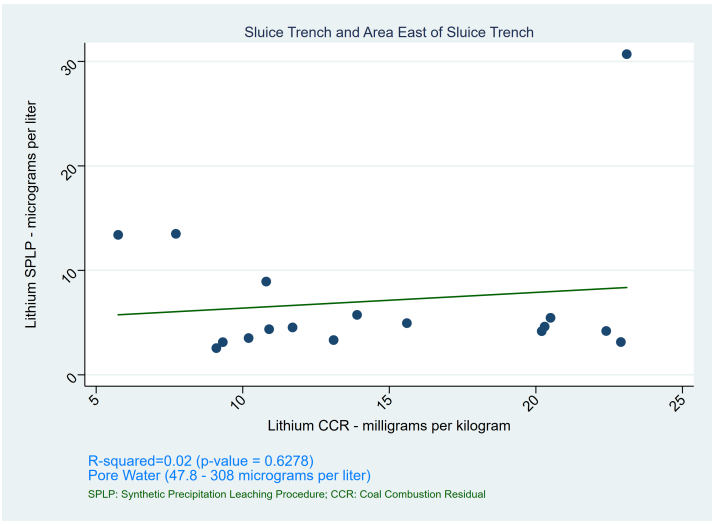
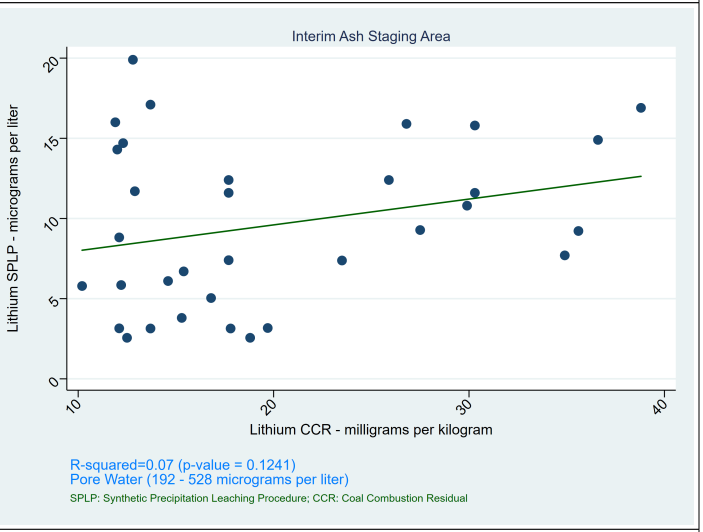


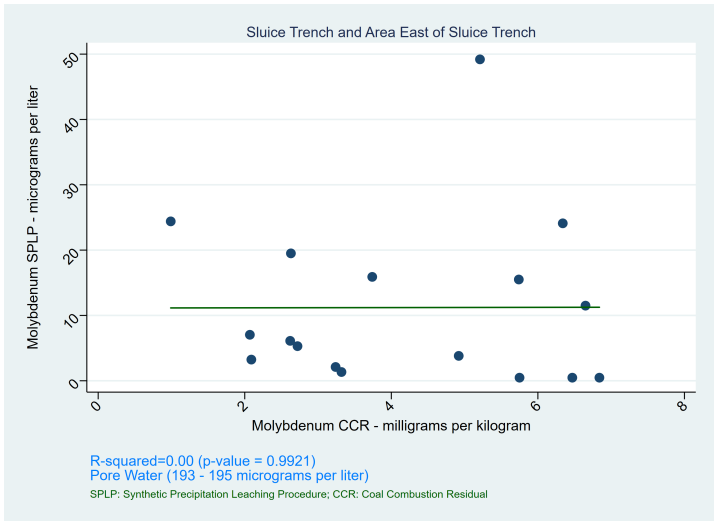


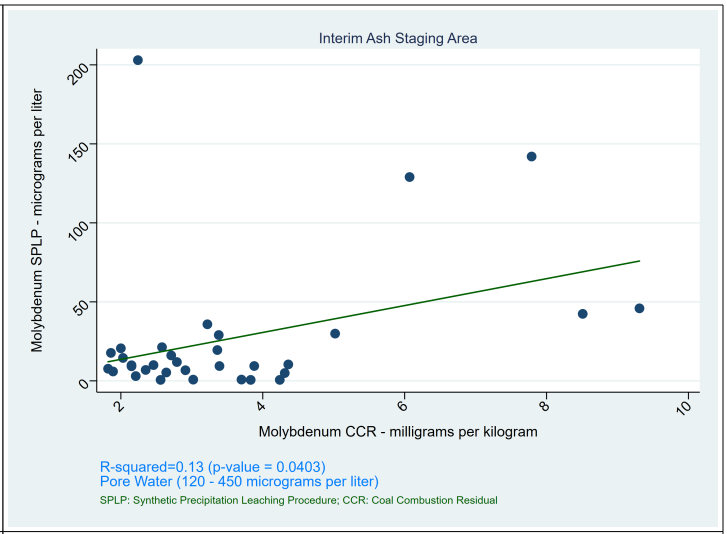


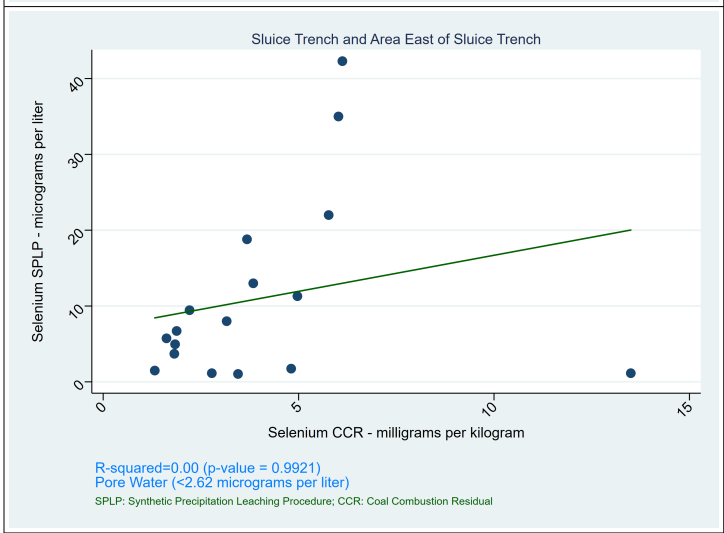
Beryllium/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

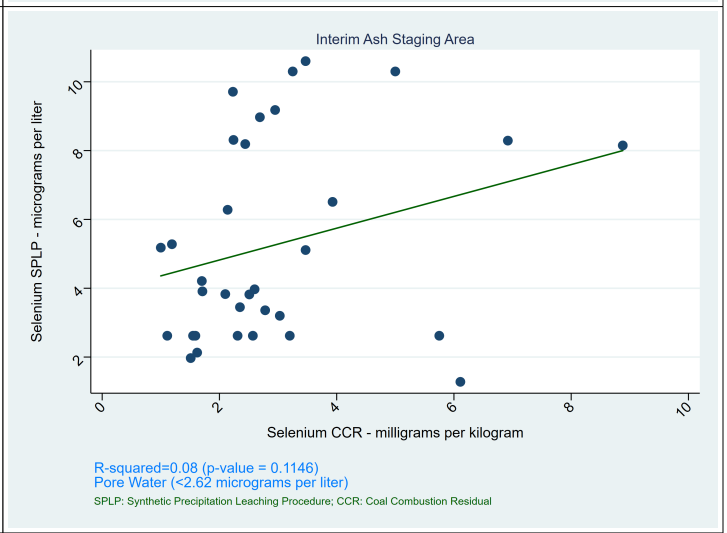
Beryllium/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

Cadmium/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Cadmium/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
Chromium/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Chromium/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
Cobalt/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	
Lead/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Lead/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
	
Mercury/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Mercury/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets



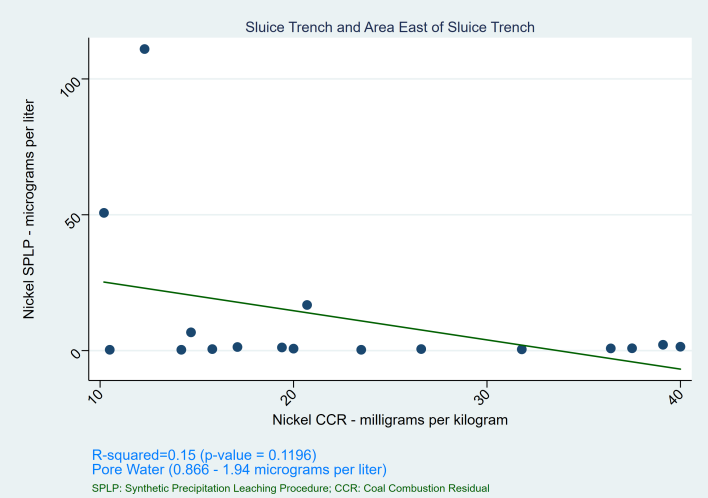
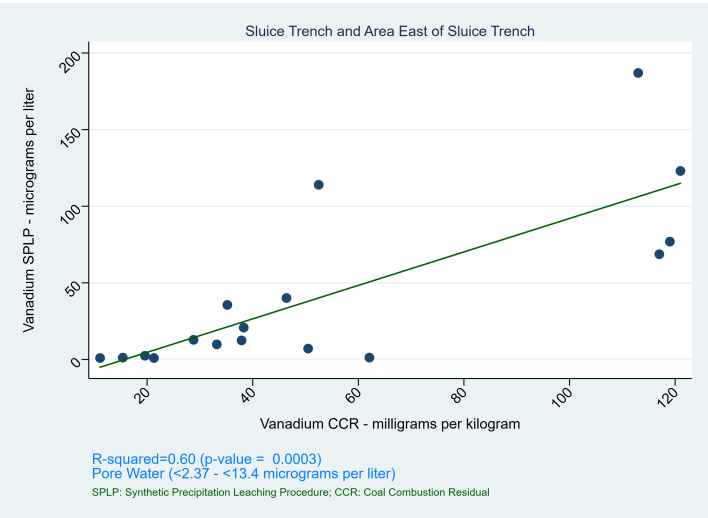
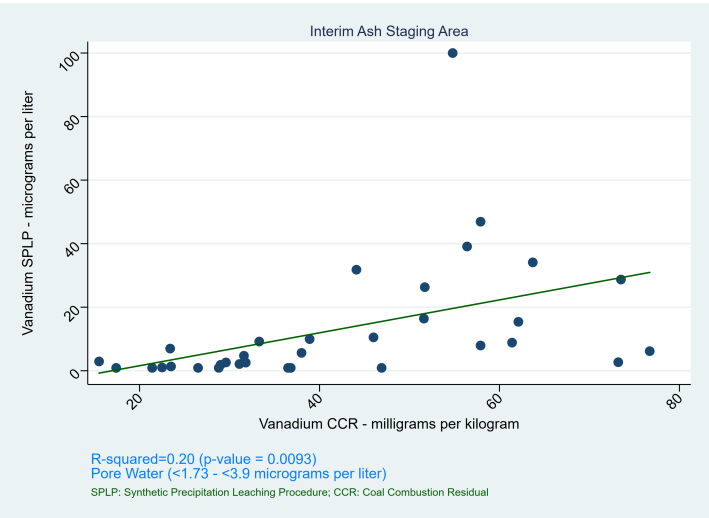






Thallium/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Thallium/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

Scatter Plots (SPLP and CCR Material)
TDEC Appendix I Parameters
CCR Material Characteristics Investigation
Kingston Fossil Plant - Harriman, Tennessee

Copper/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Copper/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
	Nickel/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
Silver/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Silver/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets
	
Zinc/Sluice Trench and Area East of Sluice Trench, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets	Zinc/Interim Ash Staging Area, Insufficient Data, > 50% non-Detects in SPLP or CCR Material Data Sets

APPENDIX E.3

STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

Appendix E.3 - Statistical Analysis of Groundwater Analytical Results

TDEC Commissioner's Order:
Environmental Assessment Report
Kingston Fossil Plant
Harriman, Tennessee

March 12, 2024

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

REVISION LOG

Revision	Description	Date
0	EAR Submittal to TDEC	May 30, 2023
1	Addresses August 16, 2023 TDEC Review Comments and Issued for TDEC	November 14, 2023
2	Addresses January 12, 2024 TDEC Review Comments and Issued for TDEC	March 12, 2024

Sign-off Sheet

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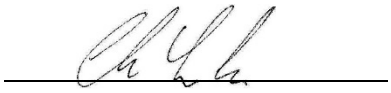
Reviewed by 

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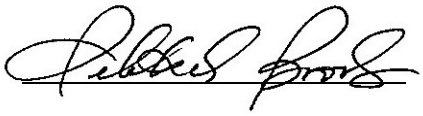
Approved by 

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Abbreviations

CASRN	Chemical Abstracts Service Registry Number
CCR	Coal Combustion Residuals
CCR Parameters	Constituents listed in Appendices III and IV of Title 40, Code of Federal Regulations, Part 257 and five inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04
CCR Rule	Title 40, Code of Federal Regulations, Part 257
CFR	Code of Federal Regulations
EAR	Environmental Assessment Report
EI	Environmental Investigation
GSLs	Groundwater Screening Levels
KIF Plant	Kingston Fossil Plant
µg/L	Micrograms Per Liter
NA	Not Available
%	Percent
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TVA	Tennessee Valley Authority
Unified Guidance	Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance
USEPA	United States Environmental Protection Agency

APPENDIX E.3 - STATISTICAL ANALYSIS OF GROUNDWATER ANALYTICAL RESULTS

March 12, 2024

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) prepared this appendix on behalf of the Tennessee Valley Authority (TVA) to summarize the statistical analyses performed on groundwater quality data to support evaluations conducted for the Environmental Assessment Report (EAR) at the Kingston Fossil Plant (KIF Plant) located in Harriman, Tennessee. These statistical analyses include an evaluation of groundwater quality data collected at the KIF Plant for the Tennessee Department of Environment and Conservation (TDEC) Order Environmental Investigation (EI), in compliance with the Title 40, Code of Federal Regulations (CFR) Part 257 (Coal Combustion Residuals [CCR Rule]) monitoring program, and the TDEC permitted landfill groundwater monitoring program. The statistical analysis in this appendix focused on the parameters listed in Appendices III and IV of Title 40 CFR 257 and five additional inorganic constituents included in Appendix I of Tennessee Rule 0400-11-01-.04 (CCR Parameters) (see Table E.3-1). The wells included in this statistical analysis are listed in Table E.3-2.

The dataset compiled for statistical analysis includes available analytical data for groundwater samples collected between June 2009 and December 2022, although the specific start date and frequency of sampling may vary between wells based on date of well installation and the applicable monitoring program. This time period was selected because it includes the data that met the data quality objectives of the EI. The complete groundwater quality results for the dataset compiled for statistical analysis are reported in Appendix H.1.

Table E.3-1 – CCR Parameters Evaluated in Statistical Analysis

Parameter	CASRN
CCR Rule Appendix III Parameters	
Boron	7440-42-8
Calcium	7440-70-2
Chloride	16887-00-6
Fluoride[1] (also Appendix IV)	16984-48-8
pH	NA
Sulfate	14808-79-8
TDS	NA
CCR Rule Appendix IV Parameters	
Antimony	7440-36-0
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Lead	7439-92-1
Lithium	7439-93-2
Mercury	7439-97-6
Molybdenum	7439-98-7
Radium-226+228	13982-63-3/ 15262-20-1
Selenium	7782-49-2
Thallium	7440-28-0
Additional TDEC Appendix I Parameters	
Copper	7440-50-8
Nickel	7440-02-0
Silver	7440-22-4
Vanadium	7440-62-2
Zinc	7440-66-6

Notes: CASRN - Chemical Abstracts Service Registry Number; CCR – Coal Combustion Residuals; NA - Not available; TDS - Total dissolved solids

[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table and in the results figures and tables for this report, fluoride has been grouped with the Appendix III constituents only to avoid duplication.

Table E.3-2 - Groundwater Monitoring Wells and Parameters Included in Statistical Analysis

Well Location	Well	Program			Parameters Included in Statistical Analysis		
		EI Wells	TDEC Permitted Landfill Wells	CCR Rule Wells	CCR Rule Appendix III	CCR Rule Appendix IV	TDEC Appendix I
Background	AD-1	-	X	X	X	X	X
	GW-2	X	-	-	X	X	X
Stilling Pond	6AR	-	X	X	X	X	X
	KIF-103	X	-	X	X	X	X
	KIF-104	X	-	X	X	X	X
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area	AD-2	-	X	X	X	X	X
	AD-3	-	X	X	X	X	X
	KIF-105	X	-	X	X	X	X
	KIF-106	X	-	X	X	X	X
	KIF-109	-	-	X	X	X	X

Notes
For each well, the program to which the well belongs as well as the parameters evaluated in this statistical analysis are identified with an 'X' and highlighted gray. Programs or parameters that are not applicable to that well are indicated with a dash (-).

2.0 METHODS

2.1 EXPLORATORY DATA ANALYSIS

The initial step of statistical analysis was the exploratory data analysis. The process of the exploratory data analysis utilizes simple summary statistics (e.g., mean, median, standard deviation and percentiles) and graphical representations to identify important characteristics of an analytical dataset, such as the center of the data (i.e., mean, median), variation, distribution, patterns, presence of outliers and randomness.

Summary statistics were calculated for each well-constituent pair. These summary statistics include information such as total number of available samples, frequency of detection, and maximum detected values and detected concentrations for each well-constituent pair. Exploratory data plots for each well-constituent pair (i.e., box plots and time series plots) were also constructed to support a visual review of the data and identify potential outliers.

Outliers are data points that are abnormally high or low as compared to other measurements and may represent anomalous data or data errors. Outliers may also represent natural variation of concentrations in environmental systems. Therefore, where potential outliers were visually identified in box plots or time-series plots, secondary statistical screening was completed using Tukey's procedure to identify extreme outliers (Tukey 1977) followed by statistical testing for outliers (Dixon or Rosner's test, α=0.05). Following confirmation of the outliers as statistically significant, a desktop evaluation was conducted to verify that the data points were not errors (e.g., laboratory or transcriptional error). Field forms, data validation reports, and other variables in the dataset that could influence analytical results were also evaluated. If a verifiable error was discovered, the outlier was removed and, if possible, replaced with a corrected value.

In the absence of a verifiable error, additional lines of evidence were reviewed to determine final outlier disposition (e.g., frequency of detection, spatial and temporal variability). If an outlier was identified as suitable for removal from further statistical analysis, a clear and defensible rationale based on multiple lines of evidence was provided. In addition, values that were identified as outliers and removed from further evaluation in the present statistical analysis were retained in the historical database and will be reevaluated for inclusion or exclusion in future statistical analyses of this dataset.

2.2 COMPARISON OF GROUNDWATER QUALITY DATA TO GROUNDWATER SCREENING LEVELS

The United States Environmental Protection Agency (USEPA) document "*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance*" (USEPA 2009; hereafter referred to as the Unified Guidance) describes statistical methods for comparing groundwater concentrations to fixed standards such as the TDEC-approved groundwater screening levels (GSLs) identified in Appendix A.2. In the Unified Guidance, a confidence interval approach is recommended for comparing groundwater monitoring data to a fixed numerical limit. If the underlying population is stable (i.e., no trend is present), then the Unified Guidance indicates that comparison to a fixed standard can be made based on a

confidence interval around the mean. However, the Unified Guidance indicates that "*where the data exhibit a trend over time the interval will incorporate not only the natural variability in the underlying population, but also additional variation induced by the trend itself. The net result is a confidence interval that can be much wider than expected for a given confidence level and sample size (n).*" Therefore, in the presence of a statistically significant trend, the Unified Guidance recommends constructing a confidence band around a trend line, where the comparison is made to the fixed standard based on the confidence band as of the most recent evaluated sampling event, rather than a static confidence interval around the mean.

For the groundwater data reviewed herein, these approaches were applied to identify well-constituent pairs where the available data indicate a statistically significant concentration above or equal to the GSL for constituents other than pH, or statistically significant values outside the GSL range for pH. For this dataset, the null hypothesis was that the groundwater concentrations were less than the GSL for constituents other than pH and that levels were within the GSL range for pH. In accordance with the methods described in the Unified Guidance, constituent concentrations were determined to represent a statistically significant concentration above or equal to a GSL for constituents other than pH, only when there were sufficient data to support statistical confidence band or interval evaluation and the applicable lower confidence band or interval was greater than or equal to the GSL as of the most recent sampling event included in the statistical analysis. For pH, which has both an upper and lower GSL, a statistical difference was identified if there were sufficient data to support statistical analysis, and either the applicable lower confidence band or interval was greater than or equal to the upper GSL or the applicable upper confidence band or interval was less than or equal to the lower GSL as of the most recent sampling event included in the statistical analysis. Whether comparison should be made using a confidence band or confidence interval was determined for each well-constituent pair based on the results of a linear regression trend analysis for each well-constituent pair. If no significant linear trend was detected ($p \geq 0.05$ for the regression slope), comparison to the GSLs was completed based on a static confidence interval around the mean. If a statistically significant linear trend was present ($p < 0.05$ for the regression slope), comparison to the GSLs was completed based on a confidence band around the linear regression trend line at the most recent evaluated sampling event. In both cases, the confidence band or intervals were constructed with 98 percent (%) confidence, which correspond to a lower confidence limit with 99% confidence.

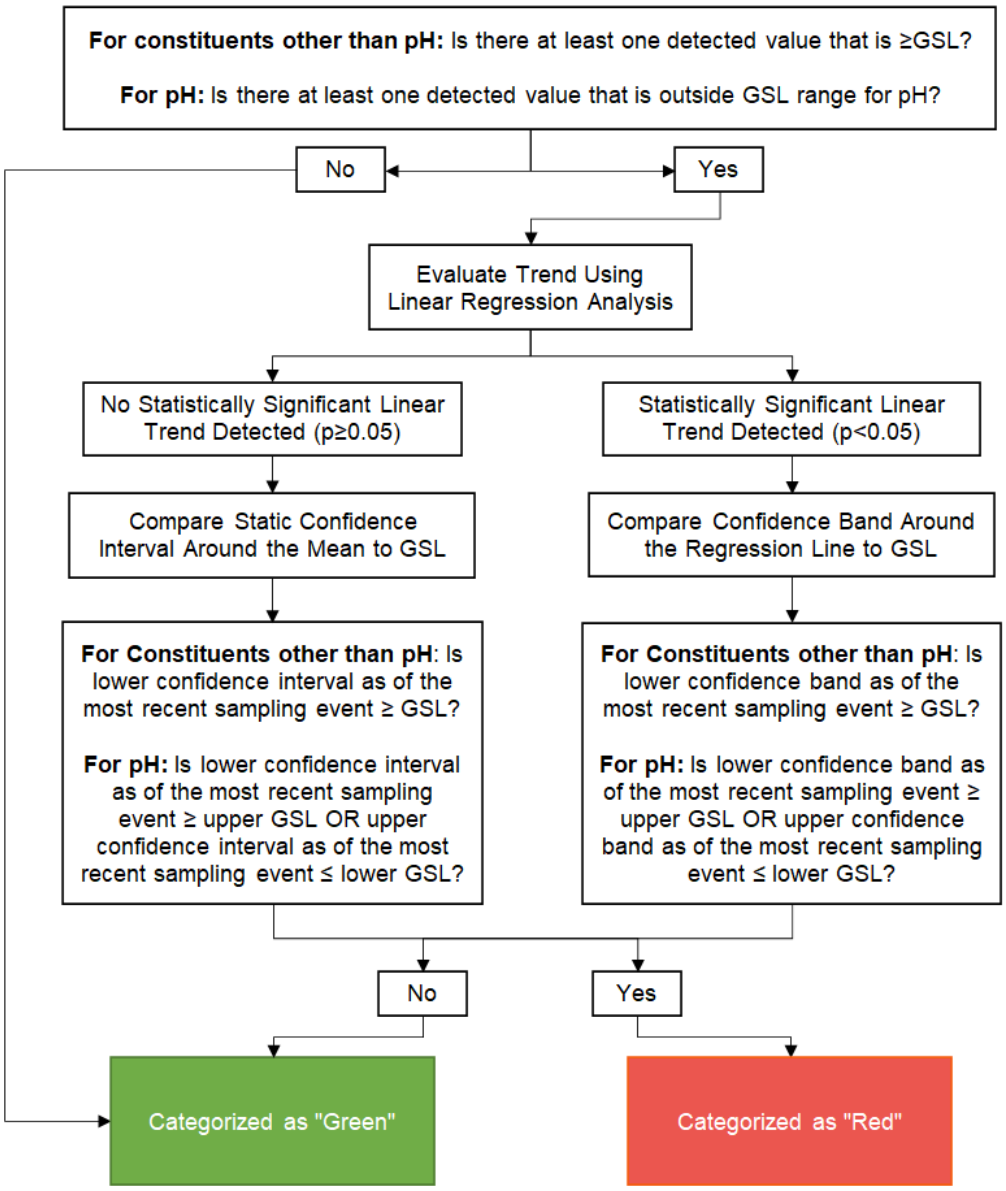
Additional details regarding the methods used to compare groundwater quality data to groundwater screening levels are provided below. As described below, the approach adopted for this comparison was dependent on the number of samples available and the proportion of detected concentrations for each well-constituent pair.

2.2.1 Linear Regression Trend Analysis and Confidence Interval/ Confidence Band Evaluation

For well-constituent pairs with five or more samples and at least four detected values, groundwater quality data were compared to GSLs using a linear regression trend analysis and confidence interval/ confidence band evaluation summarized in **Figure E.3-1** (below) and described in more detail in this section.

First, data were screened to identify if there were reported individual values greater than or equal to the GSL for constituents other than pH or outside the GSL range for pH. In the absence of such a value, well-constituent pairs were classified as 'Green'. If such a value was observed, then linear regression analysis was completed to identify well-constituent pairs with a statistically significant linear trend ($p<0.05$) over the analyzed time period. As noted above, if no statistically significant linear trend was detected ($p\geq0.05$), a static confidence interval around the mean was used for comparison to the GSLs. If a statistically significant linear trend was present ($p<0.05$), a confidence band around the linear regression trend line at the most recent evaluated sampling event was used for comparison to the GSLs. In both cases, 98% confidence intervals were constructed, which correspond to a lower confidence limit with 99% confidence. Non-detect values were conservatively represented at the reported detection limit.

The resulting confidence intervals and confidence bands were then compared to the GSL for the analyzed well-constituent pairs as of the most recent sampling event included in the statistical analysis. For constituents other than pH, well-constituent pairs were classified as 'Red', indicating a statistically significant concentration above or equal to the GSL at a 99% confidence level only if the applicable lower confidence band or interval was greater than or equal to the GSL as of the most recent sampling event included in the statistical analysis (see examples in **Figure E.3-2** below). For pH, well-constituent pairs were classified as 'Red', indicating a statistically significant difference from the GSL range at a 99% confidence level, if the applicable lower confidence band or interval was greater than or equal to the upper GSL or if the applicable upper confidence interval was less than or equal to the lower GSL as of the most recent sampling event included in the statistical analysis (see examples in **Figure E.3-3** below). The remaining well-constituent pairs with five or more samples and at least four detected values that were not classified as 'Red' using the linear regression trend analysis and confidence interval/ confidence band evaluation described above were classified as 'Green'. The 'Green' category indicates that as of the most recent sampling event included in the analysis, constituent levels were not statistically significantly greater than or equal to the GSL (for constituents other than pH) and not statistically greater than or equal to the upper GSL or less than or equal to the lower GSL for pH at a 99% confidence level.



Note: GSL = TDEC-approved Groundwater Screening Level (see Appendix A.2)

Figure E.3-1 – Flow chart summarizing linear regression trend analysis and confidence interval/ confidence band evaluation

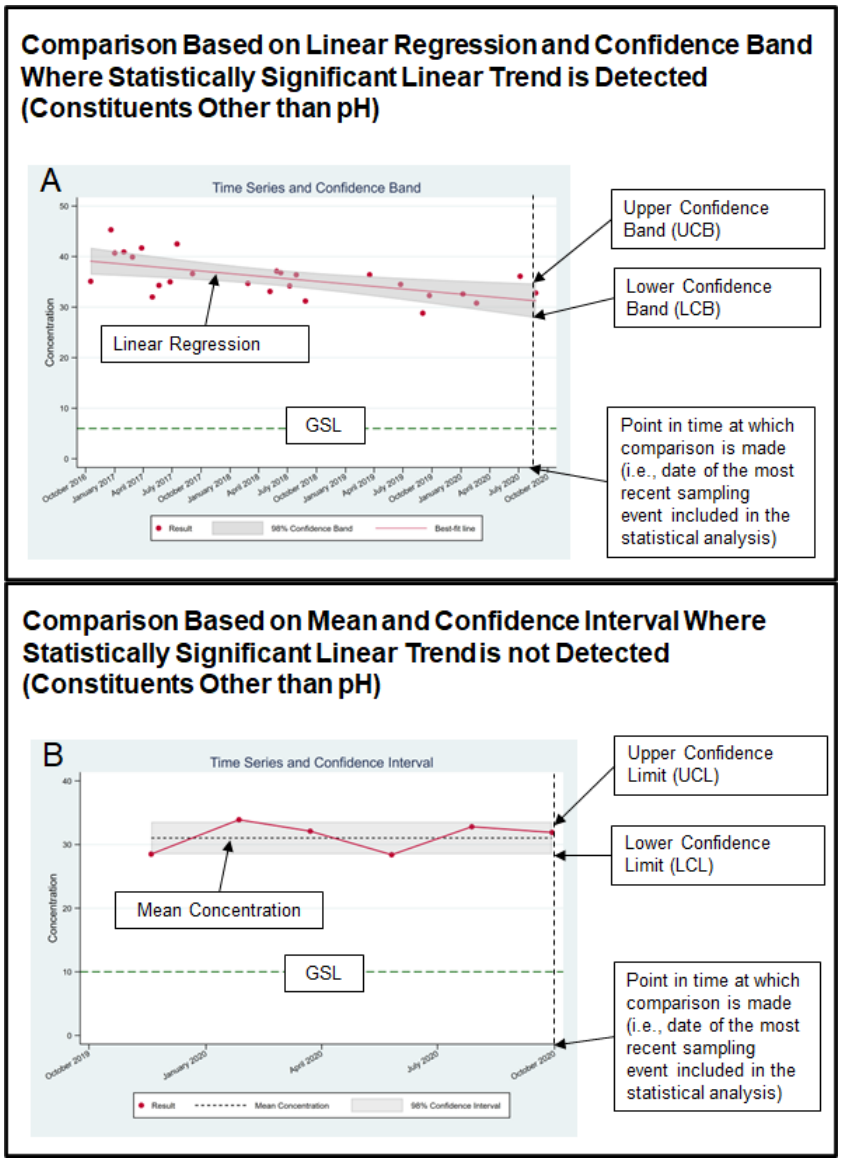


Figure E.3-2 – Examples of well-constituent pairs classified as 'Red' for constituents other than pH (A) in the presence of a statistically significant linear trend ($p<0.05$) and (B) in the absence of a statistically significant linear trend ($p\geq0.05$)

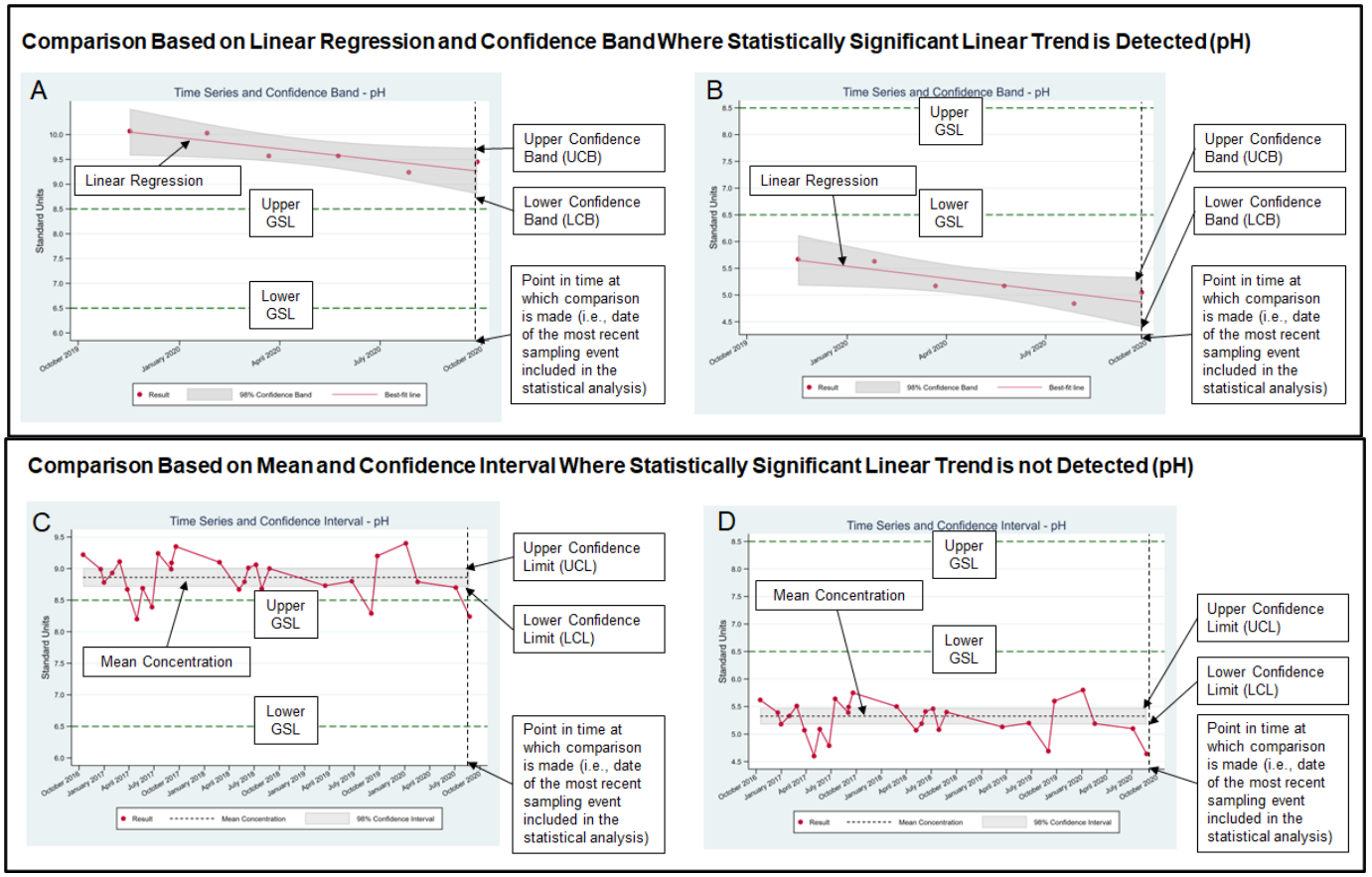


Figure E.3-3 - Examples of well-constituent pairs classified as 'Red' for pH (A, B) in the presence of a statistically significant linear trend ($p<0.05$) and (C, D) in the absence of a statistically significant linear trend ($p\geq0.05$)

2.2.2 Evaluation for Well-Constituent Pairs Using Point-by-Point Method

Well-constituent pairs with less than five samples in the dataset or less than four detected results were not well suited to a linear regression trend analysis and confidence band or interval evaluation. Therefore, an alternate evaluation was completed for these well-constituent pairs based on a point-by-point comparison of the reported concentration for each sample to the applicable GSL. In this approach, well-constituent pairs were classified as 'Green*,' if there were no detected values that were greater than or equal to the GSL for constituents other than pH, or there were no detected values outside the GSL range for pH. However, if there was a limited dataset (i.e., less than five samples in the dataset or less than four detected results), and at least one value was greater than or equal to the GSL for constituents other than pH or there were detected values outside the GSL range for pH, this triggered further data review and an alternate evaluation of that well-constituent pair. For these well-constituent pairs, the available data were reviewed and alternate statistical approaches were considered (e.g., completing a statistical evaluation resulting in a 'Red' or 'Green' classification as described in Section 2.2.1 using the limited dataset). If such an alternate evaluation was required, then this was clearly identified and additional rationale provided in the applicable sub-sections of Section 3.0.

3.0 RESULTS AND DISCUSSION

3.1 EXPLORATORY DATA ANALYSIS

Summary statistics for each evaluated well-constituent pair are provided in Attachment E.3-A**,** with results grouped by well and sorted by constituent type. Exploratory data analysis plots for each well-constituent pair (i.e., box plots and time-series plots) are provided in Attachments E.3-B and E.3-C. These plots were reviewed to identify potential outliers and provide a qualitative evaluation of data distribution. The plots also provide a preliminary comparison of the results from individual sampling events to the applicable GSLs. Based on this evaluation, five outliers that were sufficiently abnormal to justify their removal from further statistical analysis were identified. These outliers and their rationale for removal are summarized below:

- For total dissolved solids at well AD-1, a value of 1,500,000 micrograms per Liter (µg/L) was reported for a sample collected in June 2016. In comparison, the values of the 66 additional samples for AD-1 collected before or after that event between June 2009 and December 2022 ranged from 196,000 to 376,000 µg/L (i.e., approximately 4 to 8 times lower than the identified outlier). Furthermore, the increased total dissolved solids result from the June 2016 sampling event was not supported by a concurrent increase in specific conductance (417 µS/cm in June 2016, where subsequent events ranged from 361 to 590 µS/cm, with the exception of one sampling event in February 2019, which had a specific conductance value of 7 µS/cm). Given that no similarly high TDS concentrations have been observed in 13 years of sampling at this well, the TDS concentration of 1,500,000 µg/L observed for a sample collected at well AD-1 in June 2016 was excluded from additional statistical analysis.

- For total dissolved solids at well GW-2, a value of 4,950,000 µg/L was reported for a sample collected in December 2019. In comparison, the values of the remaining five samples for GW-2 collected both before and after that event between June 2019 and April 2020 ranged from 10,000 to 70,000 µg/L (i.e., approximately 70 to 500 times lower than the identified outlier). Furthermore, the increased total dissolved solids result from the December 2019 sampling event was not supported by a concurrent increase in specific conductance (95.4 µS/cm in December 2019, where previous and subsequent events ranged from 58-141 µS/cm).

- For zinc at AD-2 and AD-3, concentrations of 12,500 µg/L and 6,570 µg/L, respectively, were observed for samples collected in September 2018. In comparison, the values of the 136 additional samples for AD-2 and AD-3 collected before or after that event between June 2009 and November 2022 ranged from 1.83 µg/L to <50 µg/L, with the next highest detected concentration equal to 35.3 µg/L (i.e., at least 190 times lower than the identified outliers). Furthermore, the increased zinc results from the September 2018 sampling events at AD-2 and AD-3 were not correlated with an increase in sample turbidity (turbidity at AD-2 was 5.11 NTU in September 2018 and ranged from 0.78 – 60.8 NTU for other sampling events and turbidity at AD-3 was 3.15 NTU in September 2018 and ranged from 0.21 – 4.21 NTU for other sampling events). Given that no similarly high zinc concentrations have been observed in 13 years of sampling at these wells, the zinc concentrations of 12,500 µg/L and 6,570 µg/L from AD-2 and AD-3 from September 2018 were excluded from additional statistical analysis.

- For sulfate at 6AR, a concentration of 18,900 µg/L was reported for a sample collected in September 2009. In comparison, sulfate concentrations for the additional 55 samples collected since that sampling event between 2010 and 2022 were more than ten times higher than the identified outlier, with the next highest reported sulfate concentration having a value of 212,000 µg/L in December 2011. Because no similarly low sulfate concentrations have been observed at 6AR in 13 subsequent years of sampling, the sulfate concentration of 18,900 µg/L for 6AR from September 2009 was excluded from additional statistical analysis.

As such, statistical analysis for total dissolved solids at AD-1 and GW-2, for zinc at AD-2 and AD-3, and for sulfate at 6AR was carried out with the identified outliers removed. There were no other potential outliers removed from further statistical analysis.

3.2 COMPARISON OF GROUNDWATER QUALITY DATA TO APPROVED GROUNDWATER SCREENING LEVELS

A summary of the results comparing groundwater quality data to GSLs is provided in Table E.3-3. The confidence bands or confidence intervals generated to support this comparison are provided in Attachment E.3-D, and the statistical results of these regression analyses are reported in Attachment E.3-E. Further discussion is provided below.

For most well-constituent pairs that were evaluated by linear regression, no statistically significant trend over time was observed based on the linear regression analyses. Comparison to the GSLs for these well-constituent pairs was completed based on a static confidence interval around the mean as shown in

Attachment E.3-D. However, there were three well-constituent pairs where a statistically significant decreasing trend was detected and fifteen well-constituent pairs where a statistically significant increasing trend was detected, as indicated in Attachment E.3-E. Comparison to the GSLs for these well-constituent pairs was completed based on a confidence band around the trend line as shown in Attachment E.3-D.

Table E.3-3 – Summary of Statistically Significant Concentrations/Values

Parameter	Background		Stilling Pond			Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area				
	AD-1	GW-2	6AR	KIF-103	KIF-104	AD-2	AD-3	KIF-105	KIF-106	KIF-109
CCR Rule Appendix III Parameters										
Boron	Green	Green*	Green	Green	Green	Green	Green	Green	Green	Green
Chloride	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Fluoride[1] (also Appendix IV)	Green	Green*	Green	Green	Green	Green	Green	Green	Green	Green
pH (field)	Green	Red	Red	Red	Red	Red	Green	Red	Green	Red
Sulfate	Green	Green	Red	Green	Red	Red	Red	Red	Red	Green
Total Dissolved Solids	Green	Green	Green	Green	Red	Red	Red	Red	Red	Green
CCR Rule Appendix IV Parameters										
Antimony	Green*	Green*	Green	Green*	Green	Green*	Green*	Green*	Green*	Green*
Arsenic	Green	Green*	Green	Green	Green	Green	Green	Green	Green	Green
Barium	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Beryllium	Green*	Green*	Green	Green*	Green*	Green	Green*	Green	Green*	Green*
Cadmium	Green*	Green*	Green	Green*	Green*	Green*	Green*	Green	Green*	Green*
Chromium	Green	Green*	Green	Green*	Green*	Green	Green	Green*	Green*	Green*
Cobalt	Green	Green*	Red	Red	Red	Red	Green	Red	Green	Green
Lead	Green*	Green*	Green	Green*	Green*	Green	Green*	Green	Green*	Green*
Lithium	Green	Green*	Green*	Green*	Green	Green	Green	Green	Green	Green
Mercury	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Molybdenum	Green	Green*	Green*	Green*	Green	Green	Green	Green*	Green	Green*
Radium-226+228	Green	Green*	Green	Green	Green	Green	Green	Green	Green*	Green
Selenium	Green*	Green*	Green*	Green*	Green*	Green	Green*	Green*	Green*	Green*
Thallium	Green	Green*	Green	Green*	Green*	Green	Green	Green	Green*	Green*
Additional TDEC Appendix I Parameters										
Copper	Green	Green*	Green*	Green*	Green	Green*	Green	Green*	Green*	Green*
Nickel	Green*	Green*	Green	Green	Green	Green	Green	Green	Green	Green
Silver	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*	Green*
Vanadium	Green*	Green*	Green*	Green*	Green	Green*	Green*	Green*	Green*	Green*
Zinc	Green*	Green*	Green	Green	Green	Green	Green	Green	Green	Green

Notes:
Green - No statistically significant concentration greater than or equal to the GSL for constituents other than pH and no statistically significant difference outside the GSL range for pH.
Green* - Limited dataset (sample size <5 or <4 detected values), but none of the available results are greater than or equal to the GSL or outside the GSL range for pH.
Red - Statistically significant concentration greater than or equal to the GSL for constituents other than pH or a statistically significant difference outside the GSL range for pH.
Bold colors are used to represent CCR Rule Appendix IV Parameter and TDEC Appendix I Parameter results; subdued colors represent CCR Rule Appendix III Parameter results.
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped only with the Appendix III constituents to avoid duplication of results.

In total, 16 well-constituent pairs were identified with CCR Parameters at statistically significant concentrations greater than or equal to the GSL for constituents other than pH. There were also seven wells where statistically significant difference from the GSL range for pH were observed. The well-constituent pairs with statistically significant concentrations greater than or equal to the GSL or outside the GSL range for pH (i.e., categorized as 'Red' in Table E.3-3) are summarized in Table E.3-4.

Table E.3-4 – Summary of Statistically Significant Concentrations Greater than the GSL

Well	Appendix III			Appendix IV
	pH (field)	Sulfate	Total Dissolved Solids	Cobalt
GW-2	X	-	-	-
6AR	X	X	-	X
KIF-103	X	-	-	X
KIF-104	X	X	X	X
AD-2	X	X	X	X
AD-3	-	X	X	-
KIF-105	X	X	X	X
KIF-106	-	X	X	-
KIF-109	X	-	-	-

Notes
Well-constituent pairs with CCR Parameters at statistically significant concentrations greater than or equal to the GSL for constituents other than pH or outside the GSL range for pH are identified with an 'X' and highlighted gray.
Dash (-) indicates the absence of a statistically significant concentration greater than or equal to the GSL or outside the GSL range for pH for that well-constituent pair.

4.0 REFERENCES

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesley. 1977.

United States Environmental Protection Agency (USEPA). (2009). *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance*. EPA 530/R-09-007, 884 pp.

ATTACHMENT E.3-A
SUMMARY STATISTICS

Summary Statistics - Groundwater Investigation Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: AD-1									
CCR Rule Appendix III Parameters									
Boron	50/70	(0.7 - 1,000)	28.6%	106	227	129.2	37.11	136.5	1,000
Calcium	70/70	--	0.0%	2,790	18,100	7,084	3,583	5,960	13,855
Chloride	59/69	(1,550 - 5,100)	14.5%	1,190	6,730	1,660	664.8	1,590	2,654
Fluoride[1] (also Appendix IV)	66/71	(100 - 257)	7.0%	28.4	707	244.5	84.56	244	325.5
pH	43/43	--	0.0%	6.81	9.15	8.494	0.406	8.6	8.869
Sulfate	68/69	(1,000 - 1,000)	1.4%	19,000	83,400	25,896	8,618	24,400	30,840
TDS	68/68	--	0.0%	196,000	376,000	255,544	21,868	253,000	289,200
CCR Rule Appendix IV Parameters									
Antimony	3/72	(0.303 - 2)	95.8%	0.361	0.695	0.317	0.0639	0.378	2
Arsenic	50/72	(0.0743 - 2)	30.6%	0.36	2.46	0.573	0.284	0.586	2
Barium	71/72	(200 - 200)	1.4%	43.9	115	70.59	18.93	66.9	109.7
Beryllium	0/72	(0.057 - 2)	100.0%	--	--	--	--	0.33	2
Cadmium	0/72	(0.125 - 1)	100.0%	--	--	--	--	0.33	1
Chromium	15/72	(0.09 - 3.31)	79.2%	0.331	2.9	0.341	0.419	1.53	2.078
Cobalt	4/72	(0.0246 - 2)	94.4%	0.093	0.707	0.0525	0.0966	0.33	2
Lead	3/72	(0.0603 - 2)	95.8%	0.303	1.74	0.104	0.225	0.33	2
Lithium	31/44	(0.794 - 50)	29.5%	15.2	25.5	18.18	5.555	20.65	50
Mercury	0/72	(0.0392 - 1.5)	100.0%	--	--	--	--	0.15	0.2
Molybdenum	26/70	(0.474 - 5)	62.9%	0.34	2.72	0.518	0.3	0.61	2
Radium-226+228	10/48	(0 - 2)	79.2%	0.182	1.56	0.172	0.345	0.326	1.2
Selenium	0/72	(0.316 - 5)	100.0%	--	--	--	--	1.162	2.62
Thallium	4/72	(0.0239 - 2)	94.4%	0.322	0.5	0.0622	0.115	0.472	2
TDEC Appendix I Parameters									
Copper	22/72	(0.33 - 5)	69.4%	0.36	9.54	0.746	1.177	0.649	2.339
Nickel	10/72	(0.243 - 5)	86.1%	0.33	1.49	0.305	0.184	0.336	2
Silver	0/72	(0.0878 - 2)	100.0%	--	--	--	--	0.33	2
Vanadium	4/72	(0.1 - 5.22)	94.4%	0.59	0.919	0.375	0.298	1	4
Zinc	4/72	(1.83 - 50)	94.4%	3.58	9.18	2.23	1.282	8.3	25
Well: GW-2									
CCR Rule Appendix III Parameters									
Boron	3/6	(70.6 - 273)	50.0%	77.3	367	142.2	107.1	157	343.5
Calcium	6/6	--	0.0%	5,160	15,900	10,222	4,432	10,300	15,500
Chloride	5/6	(1,840 - 1,840)	16.7%	1,240	1,610	1,454	130.9	1,505	1,783
Fluoride[1] (also Appendix IV)	3/6	(41.6 - 71.5)	50.0%	36.4	68	46.67	12.36	52.55	70.63
pH	6/6	--	0.0%	5.28	6.11	5.84	0.308	5.93	6.1
Sulfate	6/6	--	0.0%	12,300	35,200	22,050	9,000	20,350	33,900
Total Dissolved Solids[2]	4/5	(10,000 - 10,000)	20.0%	38,000	70,000	48,400	22,033	60,000	68,800
CCR Rule Appendix IV Parameters									
Antimony	0/6	(0.378 - 1.07)	100.0%	--	--	--	--	0.378	0.897
Arsenic	2/6	(0.313 - 0.574)	66.7%	0.338	0.377	0.331	0.025	0.331	0.525
Barium	6/6	--	0.0%	19.9	49.3	33.45	12.19	32.8	48.3
Beryllium	1/6	(0.182 - 0.182)	83.3%	0.267	0.267	0.196	0.0317	0.182	0.246
Cadmium	0/6	(0.125 - 0.217)	100.0%	--	--	--	--	0.125	0.217
Chromium	0/6	(1.53 - 4.19)	100.0%	--	--	--	--	2.04	4.165
Cobalt	2/6	(0.075 - 0.134)	66.7%	0.076	0.082	0.077	0.00292	0.079	0.134
Lead	0/6	(0.128 - 0.128)	100.0%	--	--	--	--	0.128	0.128
Lithium	1/6	(3.39 - 3.39)	83.3%	3.65	3.65	3.433	0.0969	3.39	3.585
Mercury	0/6	(0.101 - 0.13)	100.0%	--	--	--	--	0.101	0.123
Molybdenum	0/6	(0.61 - 0.61)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	0/6	(0.00721 - 0.736)	100.0%	--	--	--	--	0.449	0.702
Selenium	0/6	(1.51 - 2.62)	100.0%	--	--	--	--	1.51	2.343
Thallium	0/6	(0.128 - 0.41)	100.0%	--	--	--	--	0.148	0.345
TDEC Appendix I Parameters									
Copper	0/6	(0.627 - 0.775)	100.0%	--	--	--	--	0.627	0.738
Nickel	2/6	(0.312 - 0.336)	66.7%	0.377	0.885	0.418	0.21	0.336	0.758
Silver	0/6	(0.121 - 0.177)	100.0%	--	--	--	--	0.177	0.177
Vanadium	1/6	(0.991 - 2.34)	83.3%	1.66	1.66	1.125	0.268	1.201	2.17
Zinc	2/6	(3.22 - 3.22)	66.7%	3.24	56.7	12.14	19.93	3.22	43.34

Summary Statistics - Groundwater Investigation Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: 6AR									
CCR Rule Appendix III Parameters									
Boron	45/56	(2.49 - 1,000)	19.6%	465	723	585	104	618	1,000
Calcium	56/56	--	0.0%	41,000	66,600	54,368	6,363	54,700	65,100
Chloride	56/56	--	0.0%	4,020	10,100	6,918	1,347	7,275	8,610
Fluoride[1] (also Appendix IV)	26/57	(26 - 500)	54.4%	26.8	243	50.37	41.24	66	199.8
pH	41/41	--	0.0%	4.52	5.84	5.028	0.306	5.02	5.54
Sulfate	55/55	--	0.0%	212,000	327,000	263,345	28,054	267,000	306,800
TDS	56/56	--	0.0%	328,000	550,000	434,161	48,261	445,500	502,750
CCR Rule Appendix IV Parameters									
Antimony	8/57	(0.303 - 2)	86.0%	0.432	2.93	0.477	0.552	0.378	2.04
Arsenic	30/57	(0.0743 - 2)	47.4%	0.338	3.24	0.499	0.491	0.549	2
Barium	55/57	(50 - 200)	3.5%	20.2	43.2	24.8	4.51	22.9	36.4
Beryllium	49/62	(0.064 - 2)	21.0%	0.195	0.977	0.619	0.177	0.695	2
Cadmium	62/62	--	0.0%	0.147	35.7	2.99	4.55	2.25	5.9
Chromium	5/57	(0.09 - 2.86)	91.2%	0.34	2.12	0.249	0.378	1.53	2
Cobalt	62/62	--	0.0%	84.1	165	117.9	17.23	118	140
Lead	14/57	(0.0603 - 2)	75.4%	0.131	0.427	0.127	0.0863	0.226	2
Lithium	2/43	(0.794 - 50)	95.3%	0.855	0.867	0.813	0.0304	3.39	50
Mercury	0/57	(0.0392 - 0.2)	100.0%	--	--	--	--	0.13	0.2
Molybdenum	0/56	(0.33 - 5)	100.0%	--	--	--	--	0.61	2
Radium-226+228	10/46	(0 - 2)	78.3%	0.174	2.304	0.206	0.437	0.321	1.212
Selenium	2/57	(0.316 - 5)	96.5%	0.401	1.32	0.368	0.209	1.51	2.62
Thallium	6/57	(0.0239 - 2)	89.5%	0.073	0.724	0.101	0.148	0.472	2
TDEC Appendix I Parameters									
Copper	7/57	(0.33 - 4.12)	87.7%	0.34	2.75	0.421	0.333	0.627	2
Nickel	62/62	--	0.0%	30.4	65.8	45.52	6.678	44.1	54.9
Silver	1/57	(0.0878 - 2)	98.2%	0.315	0.315	0.0949	0.0395	0.223	2
Vanadium	4/57	(0.1 - 4)	93.0%	0.973	2.55	0.252	0.447	0.991	4
Zinc	57/57	--	0.0%	25.5	73.9	41.28	9.192	39.6	55.82
Well: KIF-103									
CCR Rule Appendix III Parameters									
Boron	27/27	--	0.0%	742	1,140	941.6	91.47	933	1,071
Calcium	27/27	--	0.0%	25,000	56,900	36,007	7,884	34,700	50,930
Chloride	27/27	--	0.0%	4,930	9,350	6,349	946.3	6,400	7,395
Fluoride[1] (also Appendix IV)	16/27	(26.3 - 154)	40.7%	27.7	71.6	39.62	12.23	43.4	92.88
pH	26/26	--	0.0%	5.55	6.31	5.962	0.16	5.965	6.165
Sulfate	27/27	--	0.0%	56,600	102,000	82,615	10,823	82,600	98,450
TDS	27/27	--	0.0%	190,000	340,000	259,704	38,013	254,000	323,000
CCR Rule Appendix IV Parameters									
Antimony	1/27	(0.378 - 1.12)	96.3%	0.524	0.524	0.384	0.0281	0.378	0.519
Arsenic	25/27	(1.16 - 3.12)	7.4%	0.441	8.33	2.756	1.646	2.93	4.653
Barium	27/27	--	0.0%	32.9	62.3	43.83	6.356	43.9	54.19
Beryllium	0/27	(0.057 - 0.274)	100.0%	--	--	--	--	0.182	0.274
Cadmium	0/27	(0.125 - 0.217)	100.0%	--	--	--	--	0.125	0.217
Chromium	0/27	(1.32 - 3.16)	100.0%	--	--	--	--	1.53	1.991
Cobalt	27/27	--	0.0%	29.9	71.4	60.05	8.974	62.5	70.17
Lead	2/27	(0.094 - 0.167)	92.6%	0.617	1.12	0.151	0.214	0.128	0.482
Lithium	1/27	(0.831 - 3.39)	96.3%	0.864	0.864	0.839	0.0143	3.14	3.39
Mercury	0/27	(0.101 - 0.13)	100.0%	--	--	--	--	0.101	0.13
Molybdenum	0/27	(0.474 - 2.7)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	6/27	(0 - 1.082)	77.8%	0.241	1.291	0.164	0.283	0.347	1.038
Selenium	0/27	(0.739 - 2.62)	100.0%	--	--	--	--	1.51	2.62
Thallium	3/27	(0.063 - 0.472)	88.9%	0.16	0.227	0.0816	0.0488	0.148	0.472
TDEC Appendix I Parameters									
Copper	0/27	(0.627 - 11.1)	100.0%	--	--	--	--	0.627	1.252
Nickel	24/27	(2.06 - 4.1)	11.1%	0.86	3.29	2.524	0.557	2.66	3.275
Silver	3/27	(0.121 - 0.223)	88.9%	0.128	0.284	0.132	0.0361	0.177	0.223
Vanadium	0/27	(0.776 - 1.3)	100.0%	--	--	--	--	0.899	1.074
Zinc	18/27	(2.88 - 9.29)	33.3%	3.28	9.13	4.16	1.495	3.85	8.653

Summary Statistics - Groundwater Investigation									
Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: KIF-104									
CCR Rule Appendix III Parameters									
Boron	27/27	--	0.0%	780	1,990	1,536	313	1,590	1,881
Calcium	27/27	--	0.0%	133,000	197,000	166,185	16,692	167,000	193,400
Chloride	27/27	--	0.0%	6,420	20,100	10,938	3,248	10,600	18,720
Fluoride[1] (also Appendix IV)	19/27	(64.5 - 134)	29.6%	30.5	218	89.84	46.13	92.8	168.5
pH	25/25	--	0.0%	5.88	6.9	6.186	0.189	6.19	6.4
Sulfate	27/27	--	0.0%	397,000	812,000	552,815	92,690	552,000	705,200
TDS	27/27	--	0.0%	870,000	1,280,000	1,043,185	96,736	1,030,000	1,218,000
CCR Rule Appendix IV Parameters									
Antimony	5/27	(0.378 - 1.13)	81.5%	0.481	1.36	0.456	0.214	0.378	1.127
Arsenic	27/27	--	0.0%	3.59	13.8	8.191	2.676	8.57	11.58
Barium	27/27	--	0.0%	60.2	192	123.5	34.92	119	183.2
Beryllium	2/27	(0.057 - 0.274)	92.6%	0.267	0.427	0.0799	0.0805	0.182	0.274
Cadmium	0/27	(0.125 - 0.217)	100.0%	--	--	--	--	0.125	0.217
Chromium	2/27	(0.754 - 3.25)	92.6%	1.74	2.01	0.858	0.328	1.53	3.219
Cobalt	27/27	--	0.0%	1.08	26.3	12.5	5.197	10.8	23.18
Lead	3/27	(0.094 - 0.167)	88.9%	0.128	0.27	0.107	0.0403	0.128	0.204
Lithium	14/27	(0.831 - 9.35)	48.1%	1.07	23.9	4.08	4.623	3.39	9.035
Mercury	0/27	(0.101 - 0.13)	100.0%	--	--	--	--	0.101	0.13
Molybdenum	21/27	(0.61 - 3.94)	22.2%	0.679	3.83	1.578	1.074	1.04	3.824
Radium-226+228	17/27	(0.124 - 1.931)	37.0%	0.337	1.616	0.716	0.426	0.758	1.603
Selenium	1/27	(0.739 - 2.62)	96.3%	2.13	2.13	0.816	0.319	1.51	2.62
Thallium	0/27	(0.063 - 0.754)	100.0%	--	--	--	--	0.148	0.472
TDEC Appendix I Parameters									
Copper	4/27	(0.627 - 1.3)	85.2%	0.76	1.14	0.68	0.13	0.627	1.14
Nickel	21/27	(0.517 - 4.16)	22.2%	0.446	2.77	1.424	0.7	1.54	2.755
Silver	1/27	(0.121 - 0.49)	96.3%	0.441	0.441	0.133	0.0615	0.177	0.376
Vanadium	5/27	(0.776 - 1.47)	81.5%	0.909	1.19	0.843	0.118	0.991	1.33
Zinc	19/27	(3.22 - 10.1)	29.6%	3.27	10.5	4.586	1.711	4.34	9.899
Well: AD-2									
CCR Rule Appendix III Parameters									
Boron	58/67	(1,000 - 1,000)	13.4%	358	1,360	847	252.1	908	1,291
Calcium	67/67	--	0.0%	25,700	182,000	102,809	47,498	97,300	173,000
Chloride	66/66	--	0.0%	4,910	21,200	10,535	4,076	9,250	18,950
Fluoride[1] (also Appendix IV)	38/68	(64.7 - 130)	44.1%	39.6	162	79.34	29.21	100	137.2
pH	40/40	--	0.0%	5.42	6.27	5.839	0.14	5.84	6.04
Sulfate	66/66	--	0.0%	69,600	534,000	314,456	141,045	351,000	509,000
TDS	67/67	--	0.0%	28,000	878,000	507,582	219,191	567,000	844,300
CCR Rule Appendix IV Parameters									
Antimony	3/69	(0.303 - 2)	95.7%	0.38	0.774	0.316	0.0659	0.378	2
Arsenic	58/69	(0.0743 - 2)	15.9%	0.512	29.7	2.825	3.863	2	9.304
Barium	66/69	(31.8 - 200)	4.3%	22.4	48.6	34.58	6.612	33.5	46.9
Beryllium	23/69	(0.064 - 2)	66.7%	0.124	0.436	0.219	0.0937	0.33	2
Cadmium	0/69	(0.125 - 1)	100.0%	--	--	--	--	0.33	1
Chromium	9/69	(0.09 - 2.3)	87.0%	0.33	4.63	0.385	0.776	1.53	2.26
Cobalt	69/69	--	0.0%	3.72	18.7	10.38	4.12	10.6	17.02
Lead	30/69	(0.0603 - 2)	56.5%	0.208	1.32	0.32	0.225	0.33	2
Lithium	29/43	(0.794 - 50)	32.6%	9.71	15.4	12.02	2.647	13.4	50
Mercury	0/69	(0.0392 - 1.5)	100.0%	--	--	--	--	0.15	0.2
Molybdenum	54/67	(0.33 - 5)	19.4%	0.42	9.76	1.96	1.818	1.57	5.59
Radium-226+228	12/44	(0 - 1.273)	72.7%	0.0839	1.132	0.207	0.331	0.45	1.081
Selenium	5/69	(0.316 - 5)	92.8%	0.401	1.66	0.394	0.24	1.51	2.62
Thallium	11/69	(0.0239 - 2)	84.1%	0.068	0.752	0.132	0.164	0.472	2
TDEC Appendix I Parameters									
Copper	6/69	(0.33 - 5)	91.3%	0.703	5.91	0.514	0.752	0.627	2
Nickel	64/69	(2 - 5.86)	7.2%	1.96	7.84	4.262	1.501	4.45	6.608
Silver	0/69	(0.0878 - 2)	100.0%	--	--	--	--	0.33	2
Vanadium	3/69	(0.1 - 4.96)	95.7%	0.97	3.64	0.229	0.514	1	4
Zinc[2]	29/68	(1.83 - 50)	57.4%	6.17	35.3	7.897	4.342	8.3	25

Summary Statistics - Groundwater Investigation Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: AD-3									
CCR Rule Appendix III Parameters									
Boron	63/67	(379 - 1,000)	6.0%	361	1,870	1,036	444.6	1,000	1,768
Calcium	67/67	--	0.0%	120,000	432,000	281,075	102,086	315,000	395,800
Chloride	61/67	(1,000 - 20,000)	9.0%	1,710	8,660	5,167	2,392	5,960	8,444
Fluoride[1] (also Appendix IV)	56/69	(72.3 - 2,000)	18.8%	51.5	426	163.4	76.72	146	308.6
pH	42/42	--	0.0%	6.27	7.3	6.657	0.218	6.675	7.071
Sulfate	66/67	(1,000 - 1,000)	1.5%	186,000	1,130,000	601,687	294,215	696,000	961,700
TDS	67/67	--	0.0%	247,000	1,870,000	1,161,970	462,685	1,310,000	1,757,000
CCR Rule Appendix IV Parameters									
Antimony	1/69	(0.303 - 2)	98.6%	0.345	0.345	0.305	0.00839	0.378	2
Arsenic	12/69	(0.0743 - 2)	82.6%	0.34	2.57	0.211	0.397	0.33	2
Barium	67/69	(19.5 - 200)	2.9%	12.5	57.9	26.88	9.835	24.7	47.94
Beryllium	1/69	(0.064 - 2)	98.6%	0.205	0.205	0.0696	0.0276	0.33	2
Cadmium	0/69	(0.125 - 1)	100.0%	--	--	--	--	0.33	1
Chromium	5/69	(0.09 - 4.1)	92.8%	0.333	5.64	0.261	0.765	1.53	2.18
Cobalt	73/73	--	0.0%	2.35	8.57	5.268	1.852	5.32	8.136
Lead	1/69	(0.0603 - 2)	98.6%	0.183	0.183	0.0641	0.0213	0.33	2
Lithium	28/43	(0.794 - 50)	34.9%	4.92	22.1	9.691	3.829	11.4	50
Mercury	0/69	(0.0392 - 1.5)	100.0%	--	--	--	--	0.15	0.2
Molybdenum	6/67	(0.33 - 5)	91.0%	0.36	0.769	0.356	0.0732	0.61	2
Radium-226+228	10/48	(0 - 2)	79.2%	0.096	1.691	0.168	0.33	0.42	1.061
Selenium	0/69	(0.316 - 5)	100.0%	--	--	--	--	1.51	2.62
Thallium	6/69	(0.0239 - 2)	91.3%	0.179	0.941	0.0891	0.199	0.472	2
TDEC Appendix I Parameters									
Copper	6/69	(0.33 - 5)	91.3%	0.53	14.4	0.575	1.681	0.627	2
Nickel	59/69	(1.33 - 5)	14.5%	0.97	7.78	2.424	1.114	2.59	4.366
Silver	0/69	(0.0878 - 2)	100.0%	--	--	--	--	0.33	2
Vanadium	3/69	(0.1 - 4)	95.7%	1.21	2.56	0.185	0.385	1	4
Zinc[2]	9/68	(1.83 - 50)	86.8%	3.29	15.4	2.733	2.352	8.3	25
Well: KIF-105									
CCR Rule Appendix III Parameters									
Boron	27/27	--	0.0%	1,650	2,250	1,848	145.9	1,820	2,105
Calcium	27/27	--	0.0%	155,000	203,000	176,481	9,776	176,000	187,700
Chloride	27/27	--	0.0%	6,760	25,500	11,190	5,442	8,720	23,410
Fluoride[1] (also Appendix IV)	18/27	(26.3 - 132)	33.3%	38.8	123	54.52	18.84	58.3	118.8
pH	26/26	--	0.0%	5.16	5.78	5.563	0.174	5.615	5.77
Sulfate	27/27	--	0.0%	503,000	601,000	545,481	26,471	546,000	591,000
TDS	27/27	--	0.0%	781,000	919,000	847,185	33,185	840,000	902,600
CCR Rule Appendix IV Parameters									
Antimony	1/27	(0.378 - 1.12)	96.3%	0.83	0.83	0.396	0.0886	0.378	1.033
Arsenic	22/27	(0.466 - 1.17)	18.5%	0.35	1.21	0.596	0.212	0.623	1.134
Barium	25/27	(18.1 - 18.6)	7.4%	17.5	23	19.33	1.412	19.1	22.32
Beryllium	8/27	(0.155 - 1.15)	70.4%	0.057	0.473	0.123	0.0992	0.182	0.414
Cadmium	27/27	--	0.0%	0.387	2.38	1.026	0.546	0.751	1.936
Chromium	0/27	(1.17 - 3.77)	100.0%	--	--	--	--	1.53	2.64
Cobalt	27/27	--	0.0%	16.5	33.9	21.17	5.57	18.5	31.35
Lead	19/27	(0.128 - 0.225)	29.6%	0.132	0.325	0.19	0.0671	0.17	0.314
Lithium	8/27	(2.56 - 3.39)	70.4%	2.6	7.44	3.034	0.922	3.39	3.638
Mercury	0/27	(0.101 - 0.13)	100.0%	--	--	--	--	0.101	0.13
Molybdenum	0/27	(0.474 - 1.05)	100.0%	--	--	--	--	0.61	0.61
Radium-226+228	8/27	(0.215 - 1.398)	70.4%	0.429	1.748	0.449	0.373	0.56	1.37
Selenium	1/27	(0.739 - 2.62)	96.3%	0.883	0.883	0.763	0.0537	1.51	2.62
Thallium	19/27	(0.128 - 0.472)	29.6%	0.159	0.975	0.26	0.168	0.232	0.493
TDEC Appendix I Parameters									
Copper	0/27	(0.627 - 4.33)	100.0%	--	--	--	--	0.627	1.3
Nickel	27/27	--	0.0%	16.1	33.6	20.84	5.544	18.8	32.39
Silver	0/27	(0.121 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	1/27	(0.776 - 2.43)	96.3%	1.09	1.09	0.792	0.0684	0.991	2.103
Zinc	24/27	(13.5 - 17.5)	11.1%	12.5	38	19.03	8.294	14.9	36.93

Summary Statistics - Groundwater Investigation									
Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: KIF-106									
CCR Rule Appendix III Parameters									
Boron	26/27	(345 - 345)	3.7%	248	414	324.5	42.37	315	382.2
Calcium	27/27	--	0.0%	71,200	202,000	116,281	47,052	86,800	195,800
Chloride	27/27	--	0.0%	7,160	36,000	16,348	9,858	9,200	34,260
Fluoride[1] (also Appendix IV)	23/27	(120 - 149)	14.8%	68.2	202	144.6	40.14	157	192.7
pH	28/28	--	0.0%	6.48	6.94	6.667	0.102	6.65	6.823
Sulfate	27/27	--	0.0%	85,000	446,000	204,789	135,221	106,000	418,700
TDS	27/27	--	0.0%	283,000	883,000	489,630	219,962	329,000	837,800
CCR Rule Appendix IV Parameters									
Antimony	0/27	(0.378 - 1.12)	100.0%	--	--	--	--	0.378	0.984
Arsenic	23/27	(0.904 - 2.66)	14.8%	0.668	4.28	1.694	1.249	1.05	4.154
Barium	27/27	--	0.0%	34.2	65.8	48.35	7.929	48.1	58.89
Beryllium	1/27	(0.057 - 0.274)	96.3%	0.206	0.206	0.0635	0.0304	0.182	0.274
Cadmium	1/27	(0.125 - 0.217)	96.3%	0.159	0.159	0.127	0.00848	0.125	0.217
Chromium	2/27	(1.17 - 4.48)	92.6%	1.64	1.99	1.228	0.191	1.53	2.481
Cobalt	27/27	--	0.0%	2.3	3.68	3.088	0.322	3.17	3.432
Lead	3/27	(0.094 - 0.309)	88.9%	0.132	0.187	0.103	0.0251	0.128	0.22
Lithium	24/27	(3.33 - 6.97)	11.1%	3.44	14.9	7.043	3.507	5.64	14.15
Mercury	0/27	(0.101 - 0.13)	100.0%	--	--	--	--	0.101	0.13
Molybdenum	11/27	(0.474 - 0.61)	59.3%	2.08	5.27	1.742	1.68	0.61	4.954
Radium-226+228	3/27	(0.0143 - 1.357)	88.9%	0.427	1.541	0.125	0.319	0.407	1.235
Selenium	0/27	(0.739 - 2.62)	100.0%	--	--	--	--	1.51	2.62
Thallium	2/27	(0.063 - 0.472)	92.6%	0.161	0.199	0.0747	0.0356	0.148	0.472
TDEC Appendix I Parameters									
Copper	1/27	(0.627 - 1.3)	96.3%	0.699	0.699	0.631	0.0157	0.627	1.252
Nickel	24/27	(1.36 - 1.93)	11.1%	1.01	2.11	1.566	0.249	1.57	1.979
Silver	0/27	(0.121 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	0/27	(0.776 - 4.96)	100.0%	--	--	--	--	0.991	2.33
Zinc	8/27	(2.42 - 3.53)	70.4%	2.48	48.1	5.055	8.805	3.22	12.2

Summary Statistics - Groundwater Investigation Kingston Fossil Plant - Harriman, Tennessee									
Parameter	Frequency of Detection	Range of Reporting Limits	% Non Detect	Statistics using Detected Data Only		Statistics using Detects & Non-Detects			
				Minimum Detect	Maximum Detect	Mean	Standard Deviation	50th Percentile	95th Percentile
Well: KIF-109									
CCR Rule Appendix III Parameters									
Boron	6/13	(38.6 - 116)	53.8%	45.3	939	138.1	244	60.1	579
Calcium	13/13	--	0.0%	49,100	120,000	61,985	19,743	53,500	96,780
Chloride	13/13	--	0.0%	4,570	8,810	5,896	1,127	5,990	7,664
Fluoride[1] (also Appendix IV)	9/13	(26 - 64.8)	30.8%	26.8	67.5	39.9	13.22	46.7	65.88
pH	12/12	--	0.0%	5.81	6.33	6.003	0.126	5.99	6.187
Sulfate	13/13	--	0.0%	112,000	395,000	187,000	97,444	136,000	385,400
TDS	13/13	--	0.0%	350,000	721,000	484,923	118,309	444,000	709,000
CCR Rule Appendix IV Parameters									
Antimony	0/13	(0.378 - 0.506)	100.0%	--	--	--	--	0.378	0.506
Arsenic	13/13	--	0.0%	1.47	2.82	2.388	0.349	2.43	2.766
Barium	13/13	--	0.0%	127	162	153	9.983	156	161.4
Beryllium	0/13	(0.182 - 0.274)	100.0%	--	--	--	--	0.182	0.274
Cadmium	0/13	(0.217 - 0.217)	100.0%	--	--	--	--	0.217	0.217
Chromium	0/13	(1.53 - 1.53)	100.0%	--	--	--	--	1.53	1.53
Cobalt	13/13	--	0.0%	1.8	13.9	4.122	3.239	2.92	9.22
Lead	0/13	(0.128 - 0.167)	100.0%	--	--	--	--	0.128	0.167
Lithium	5/13	(3.39 - 3.39)	61.5%	0.934	5.2	1.548	1.069	3.39	4.114
Mercury	0/13	(0.13 - 0.13)	100.0%	--	--	--	--	0.13	0.13
Molybdenum	1/13	(0.61 - 0.61)	92.3%	0.67	0.67	0.615	0.016	0.61	0.634
Radium-226+228	6/13	(0.246 - 1.687)	53.8%	0.828	1.652	0.826	0.56	1.05	1.666
Selenium	0/13	(0.739 - 1.51)	100.0%	--	--	--	--	1.51	1.51
Thallium	1/13	(0.148 - 0.472)	92.3%	0.341	0.341	0.169	0.0607	0.148	0.472
TDEC Appendix I Parameters									
Copper	1/13	(0.627 - 1.14)	92.3%	10.1	10.1	1.356	2.524	0.627	4.724
Nickel	12/13	(1.63 - 1.63)	7.7%	0.959	13.1	2.64	3.136	1.49	7.772
Silver	0/13	(0.177 - 0.223)	100.0%	--	--	--	--	0.177	0.223
Vanadium	0/13	(0.776 - 0.991)	100.0%	--	--	--	--	0.991	0.991
Zinc	7/13	(2.88 - 5.3)	46.2%	3.31	8.6	4.269	1.734	4.08	7.202

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

"-- " : Not Applicable

TDEC - Tennessee Department of Environment and Conservation

Except for Radium-226 + 228, and pH, all units micrograms per liter (µg/L).

Units for Radium 226+228 are picocuries per liter (pCi/L).

Units for pH are standard units (SU).

Mean and Standard Deviation are Kaplan Meier (KM) Mean and Standard Deviation for data with reported non-detect values.

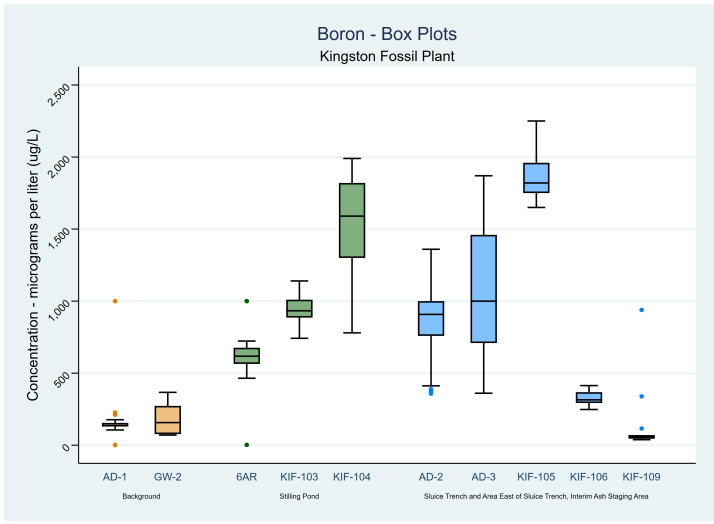
All non-detects reported at the laboratory reporting limit

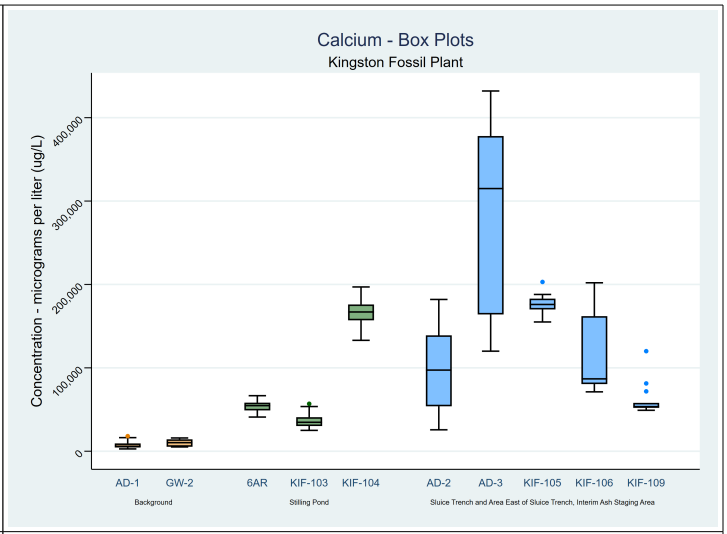
[1]Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped with the Appendix III constituents only to avoid duplication of results.

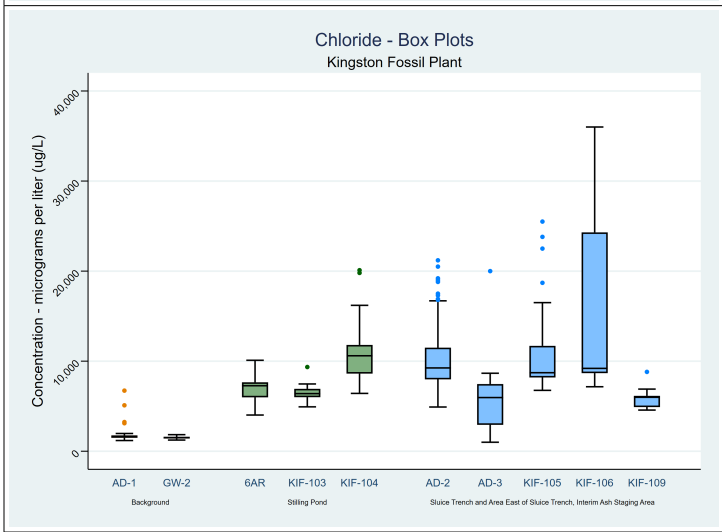
[2]Summary statistics shown here calculated with identified outlier removed (see Section 3.1 for list of identified outliers)

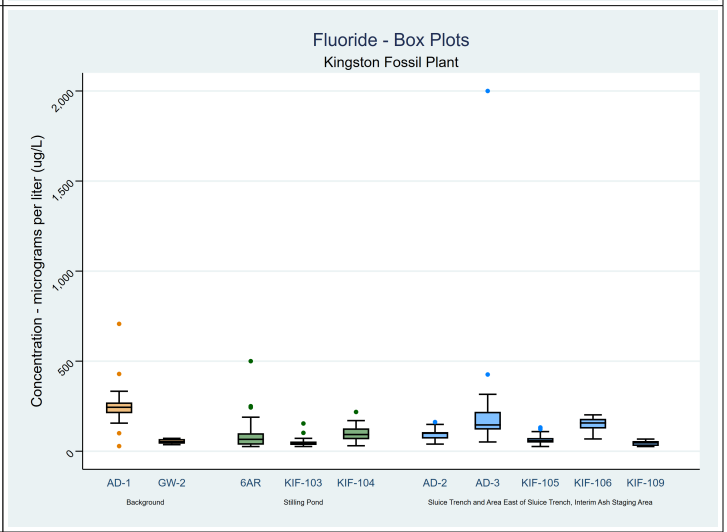
ATTACHMENT E.3-B
BOX PLOTS

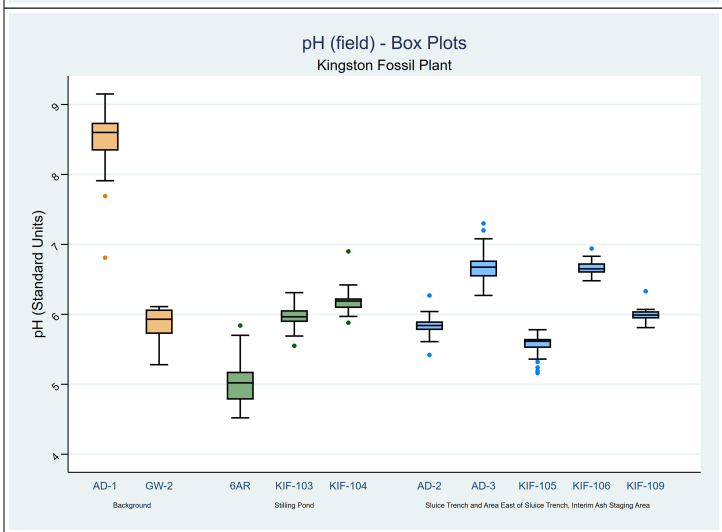
Box Plots
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

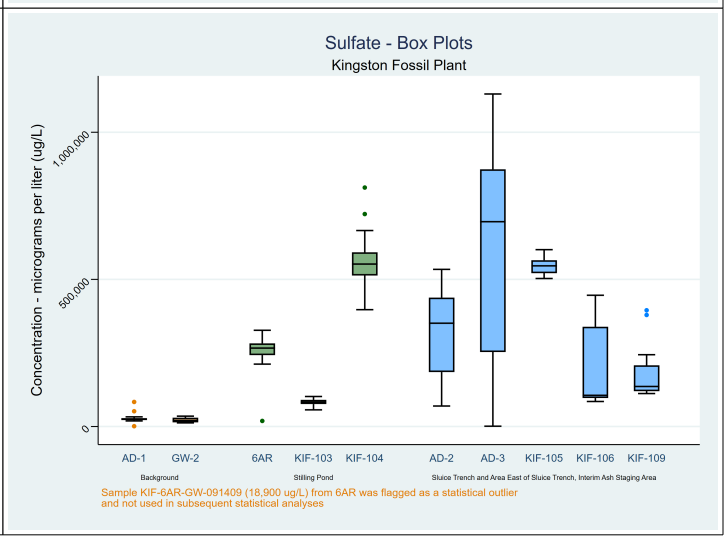


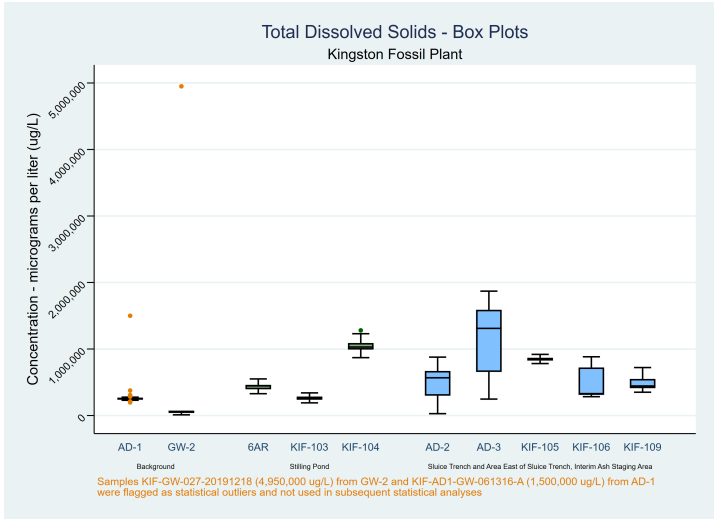












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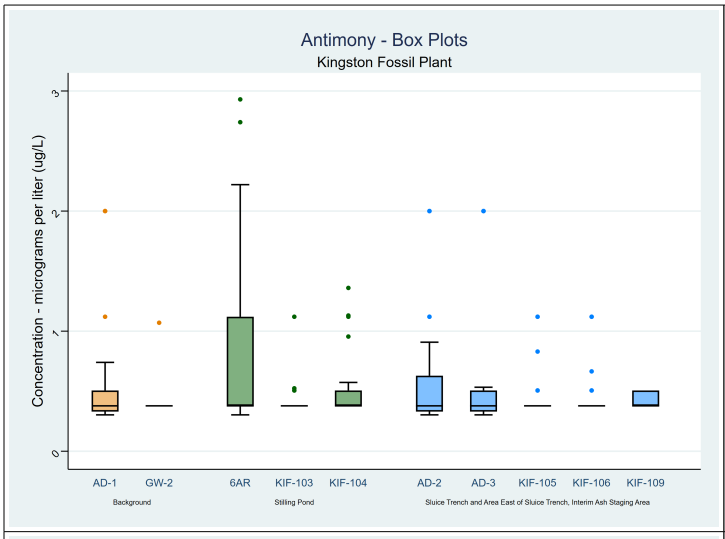
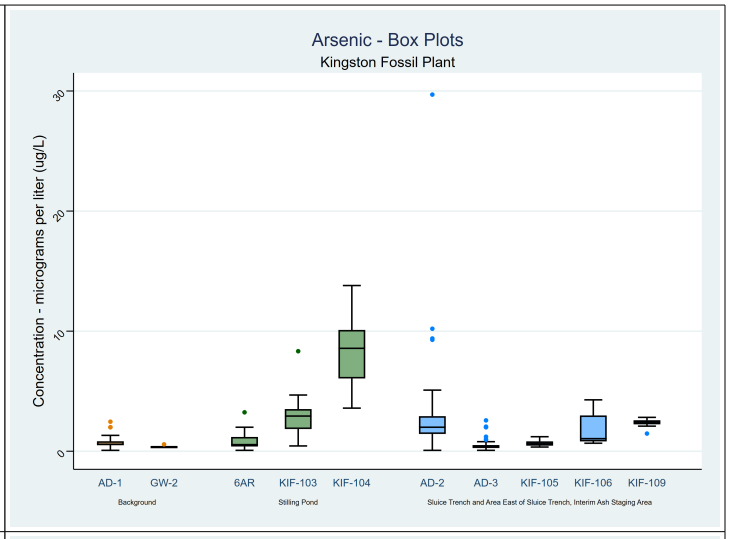
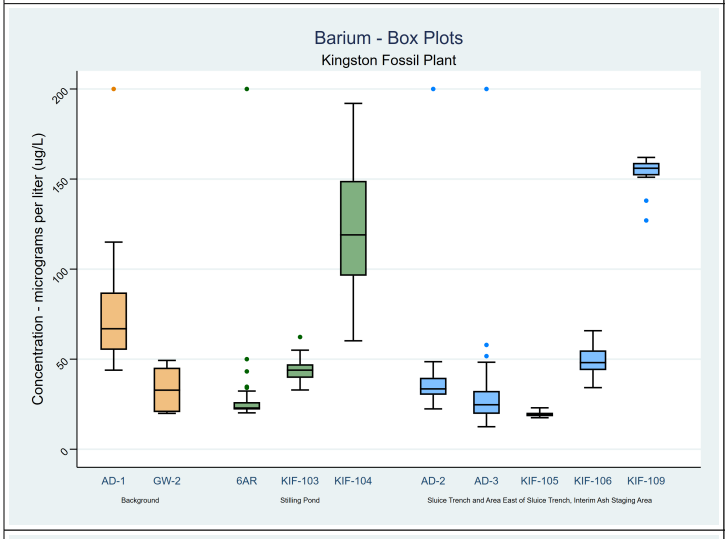
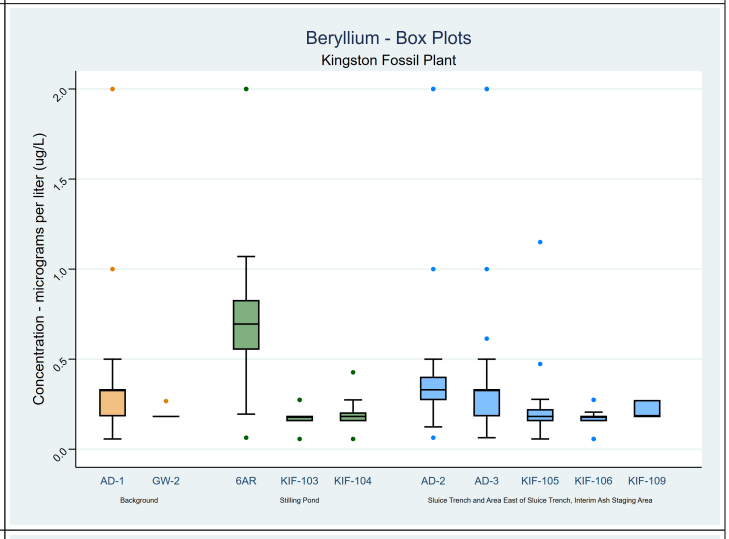
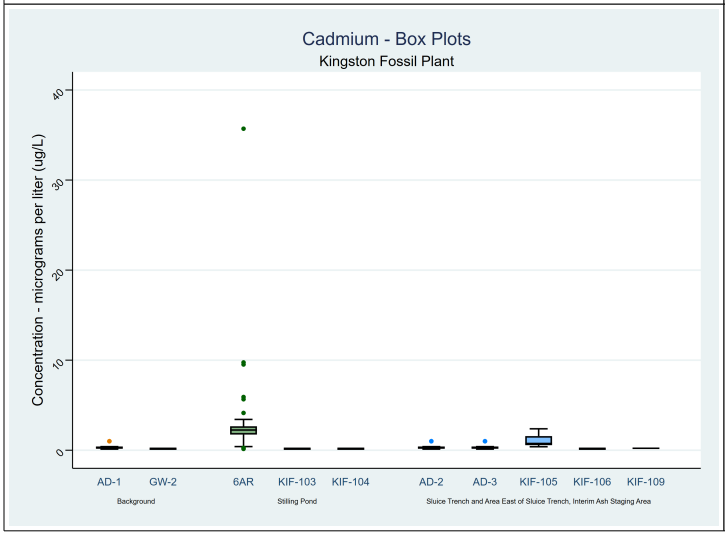
Box Plots
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee

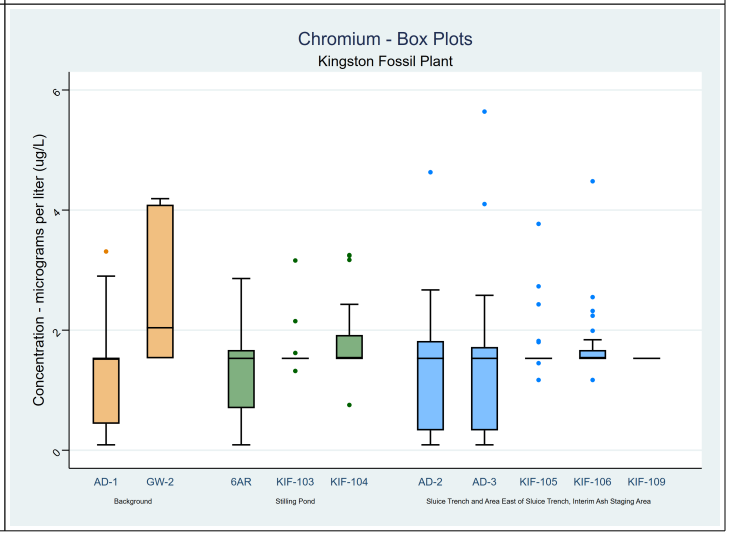


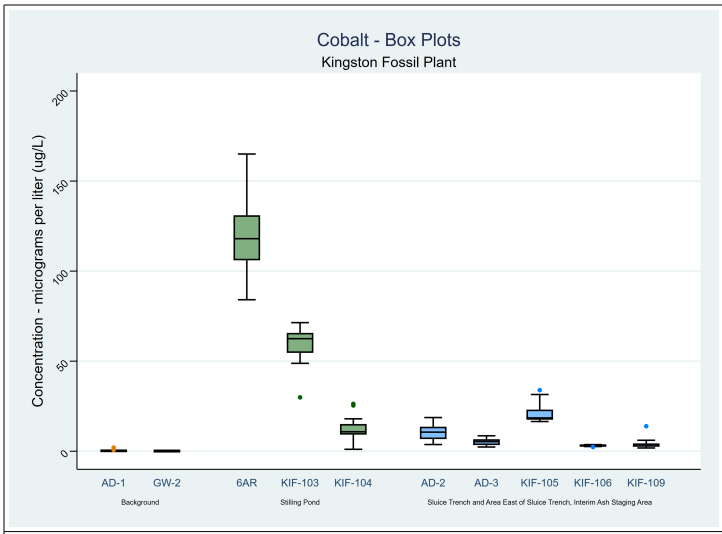


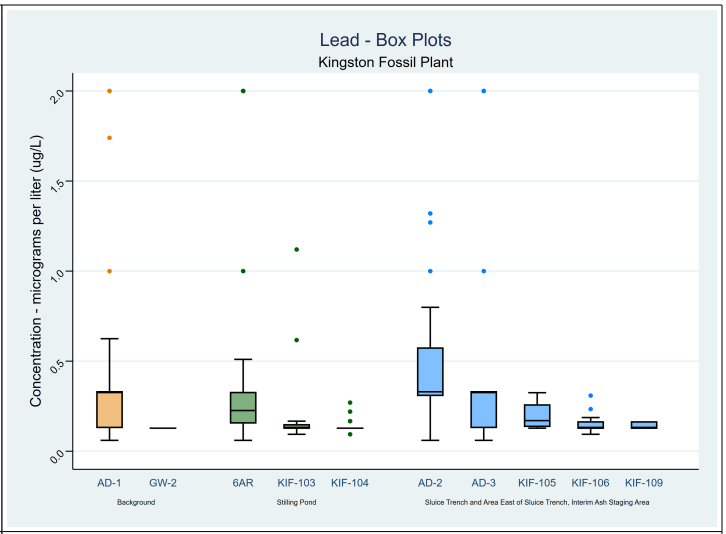


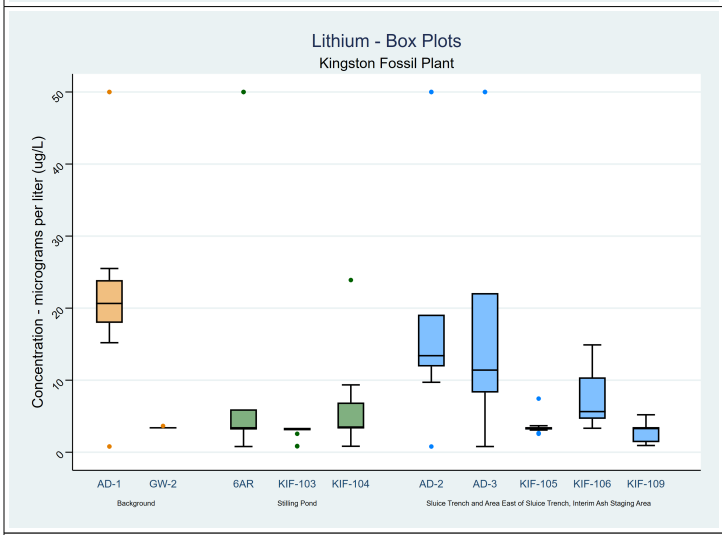


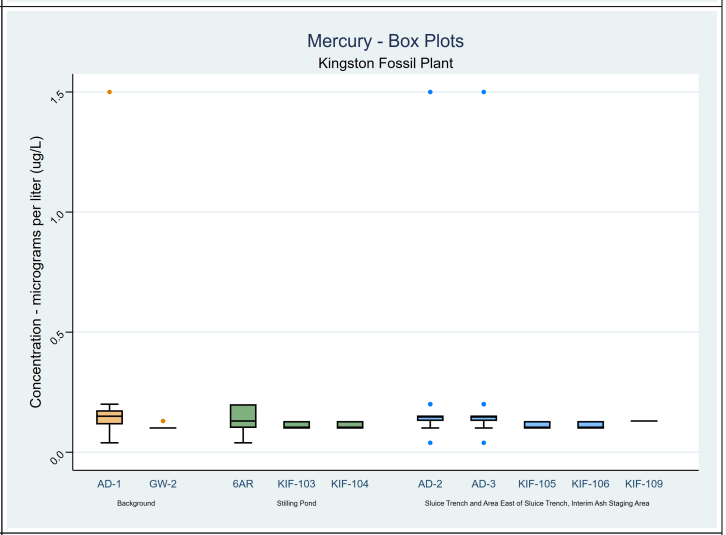


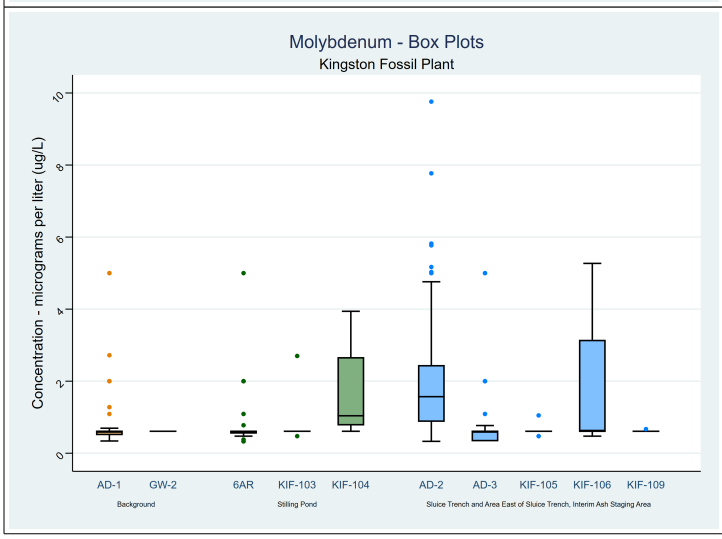


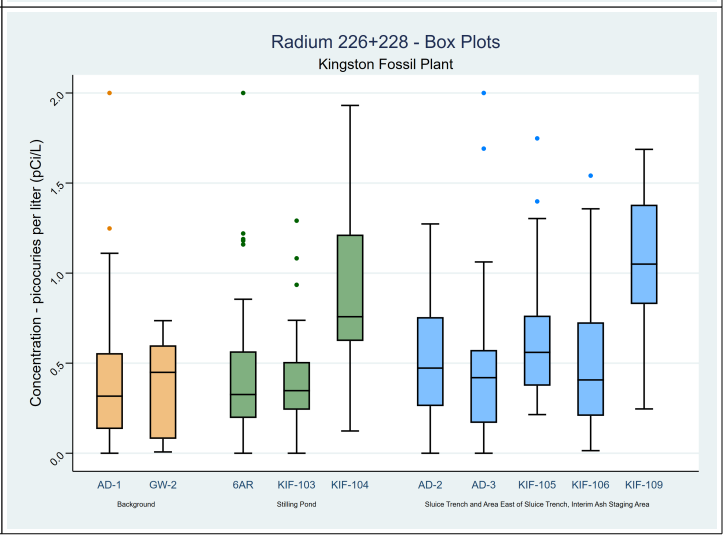

Cobalt - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0
50
100
150
200
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

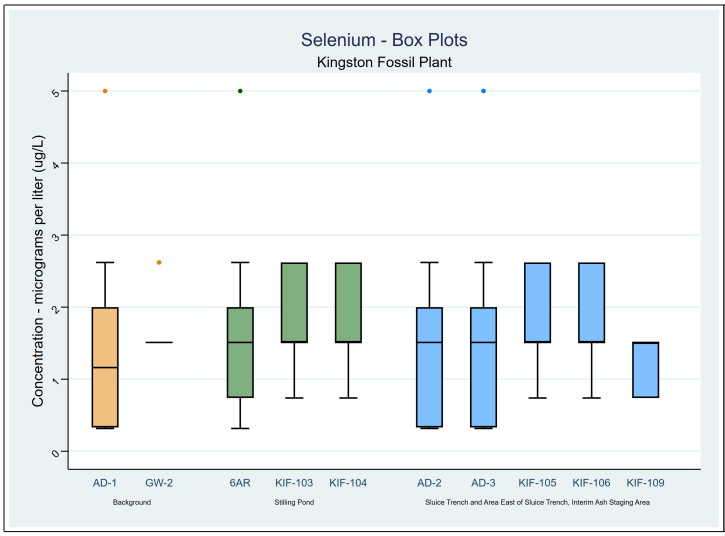

Lead - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0.0
0.5
1.0
1.5
2.0
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

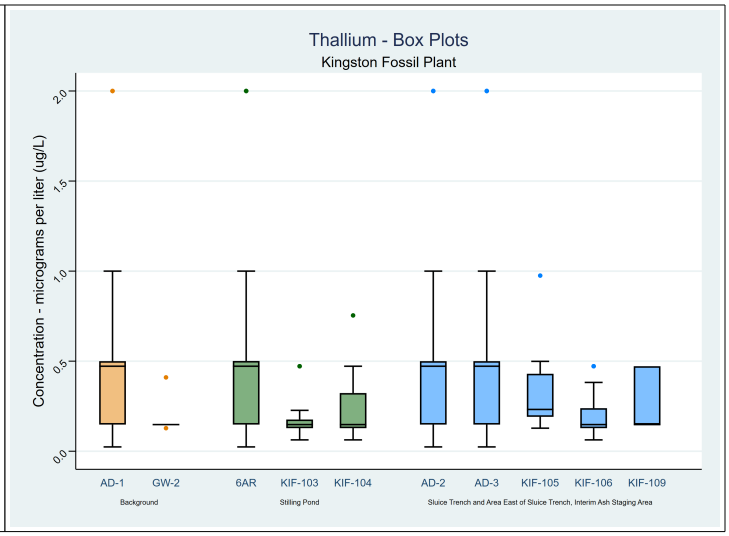

Lithium - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0
10
20
30
40
50
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area


Mercury - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0.0
0.5
1.0
1.5
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

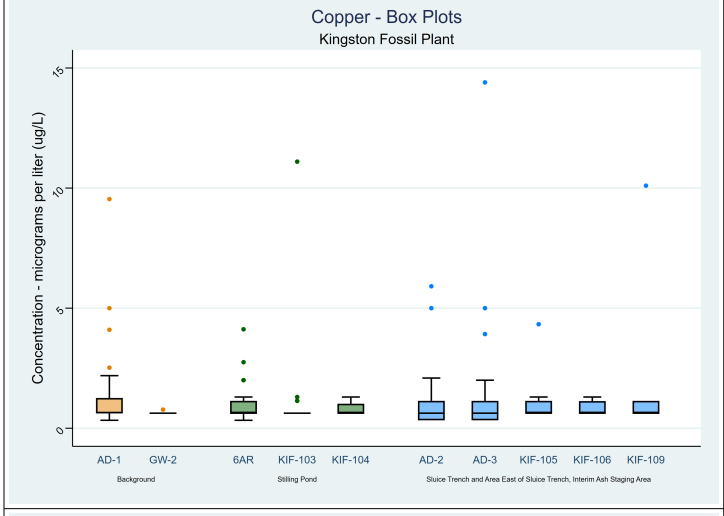

Molybdenum - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0
2
4
6
8
10
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

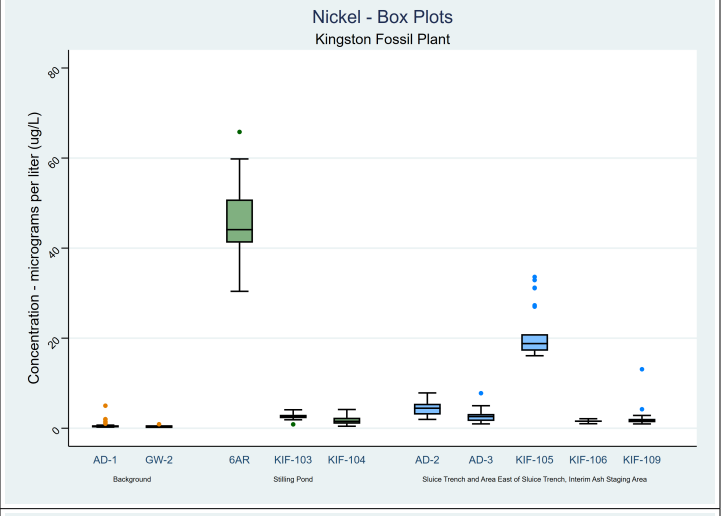

Radium 226+228 - Box Plots
Kingston Fossil Plant
Concentration - picocuries per liter (pCi/L)
0.0
0.5
1.0
1.5
2.0
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

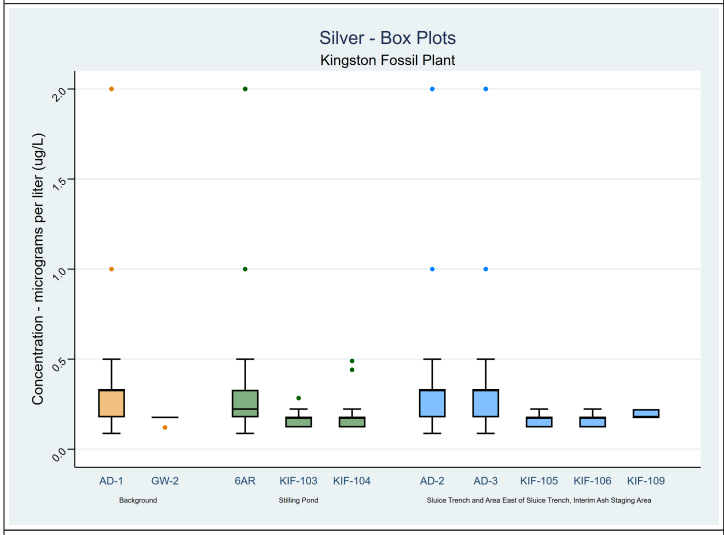

Selenium - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0
1
2
3
4
5
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

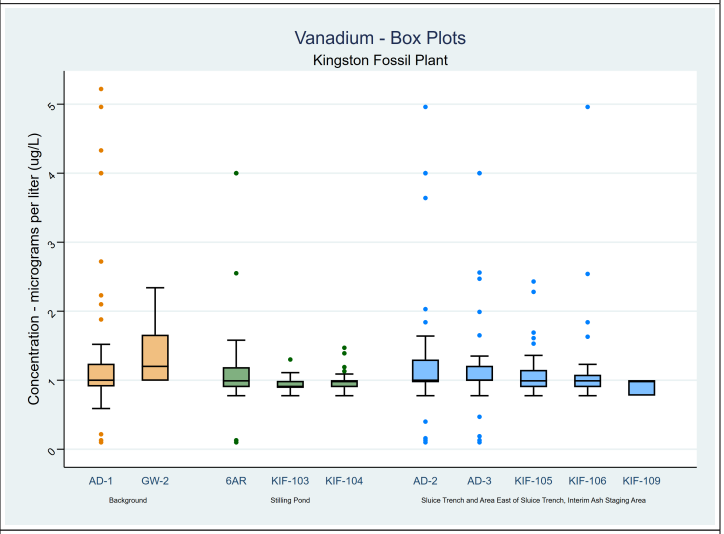

Thallium - Box Plots
Kingston Fossil Plant
Concentration - micrograms per liter (ug/L)
0.0
0.5
1.0
1.5
2.0
AD-1
GW-2
6AR
KIF-103
KIF-104
AD-2
AD-3
KIF-105
KIF-106
KIF-109
Background
Stilling Pond
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

Box Plots
TDEC Appendix I Parameters
Kingston Fossil Plant - Harriman, Tennessee









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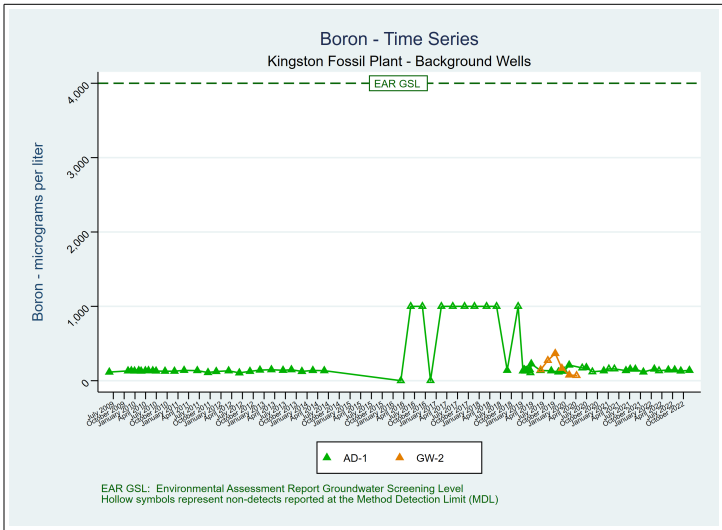
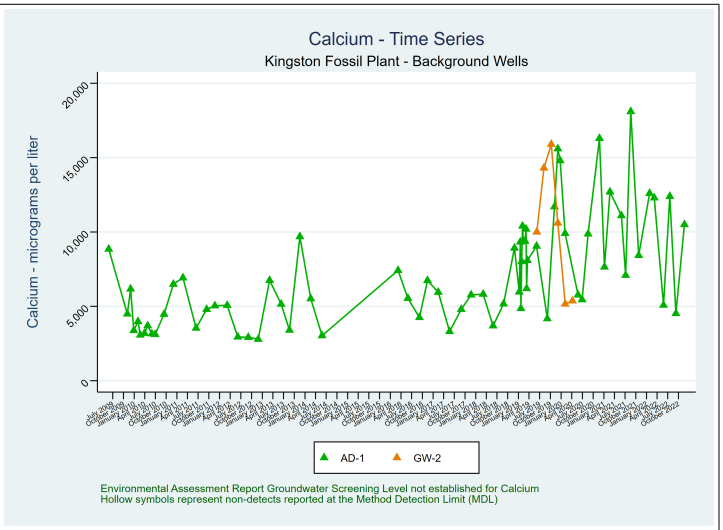
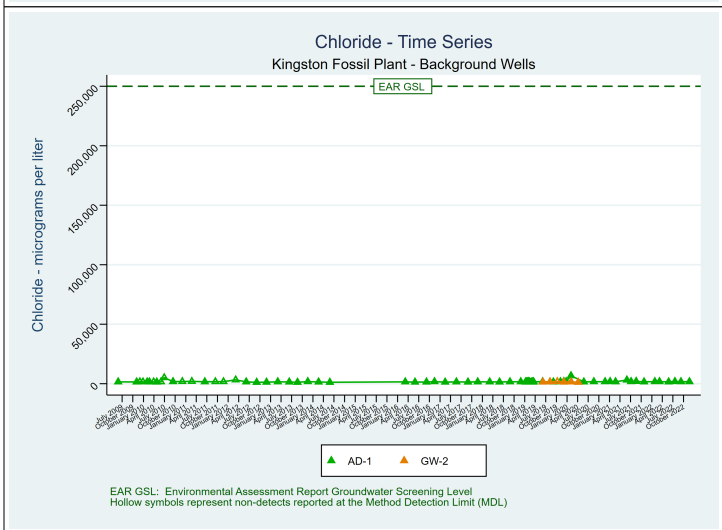
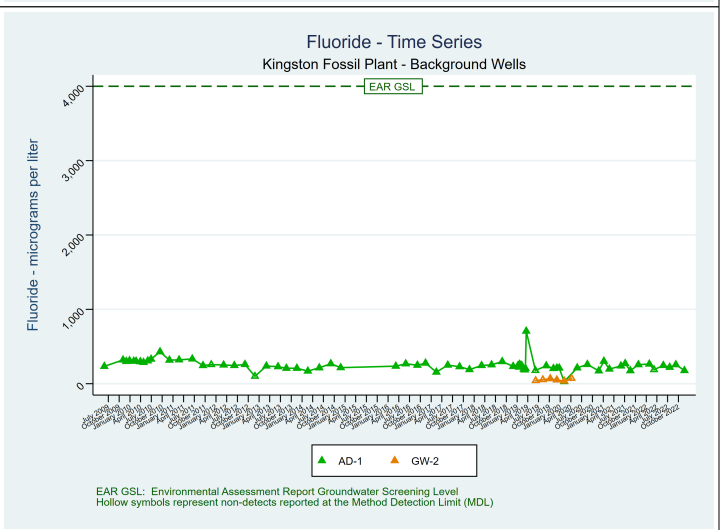
ATTACHMENT E.3-C
TIME SERIES PLOTS

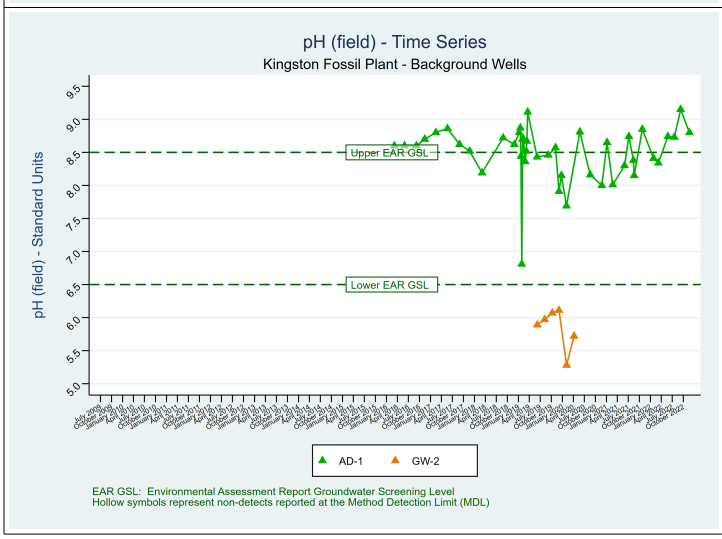
Time Series Plots
Background Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

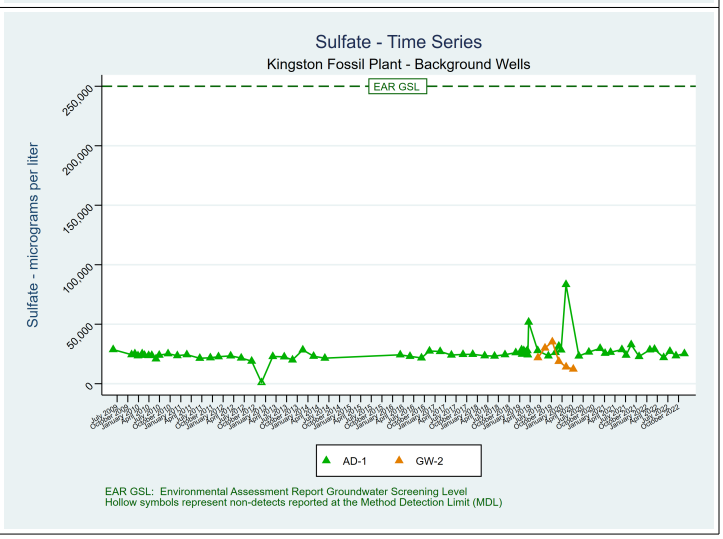


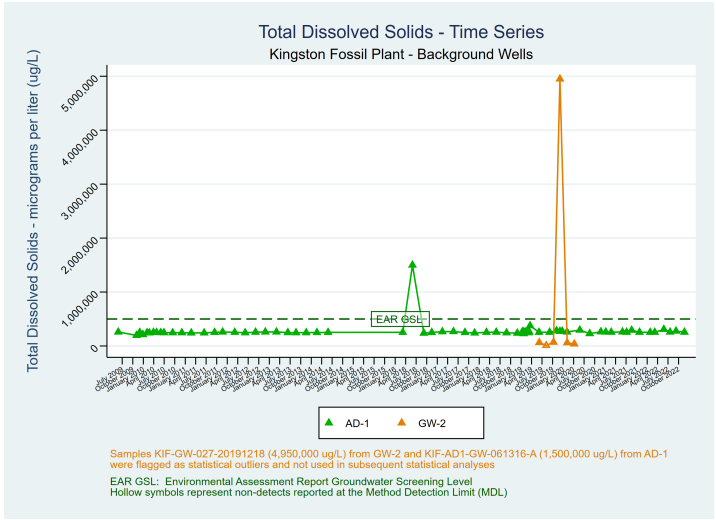












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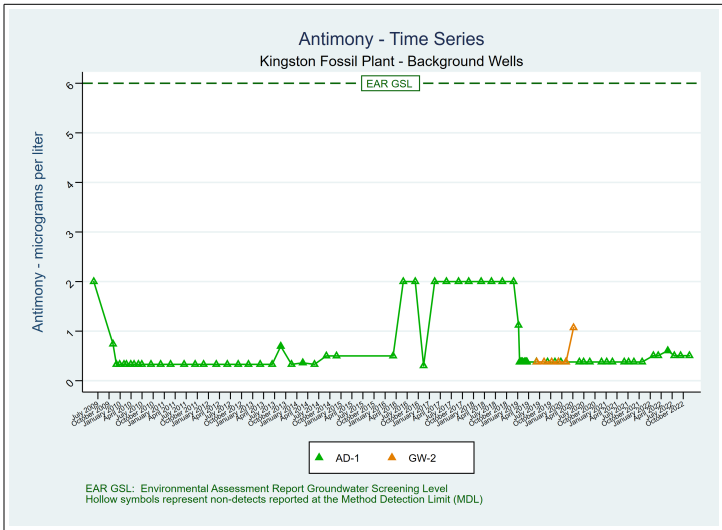
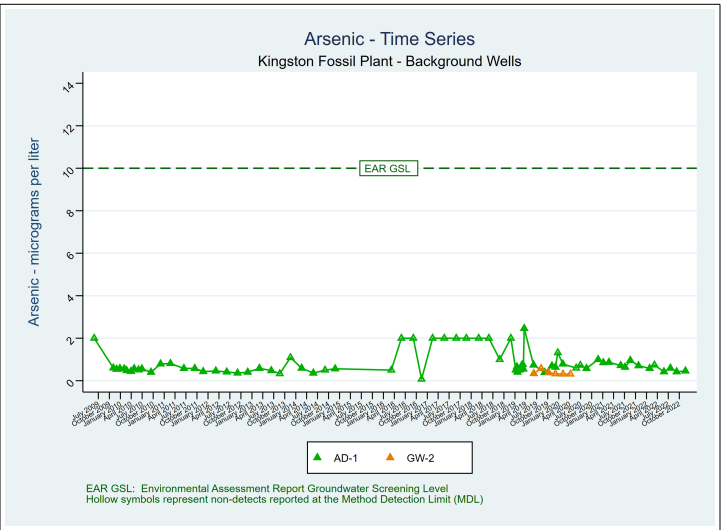
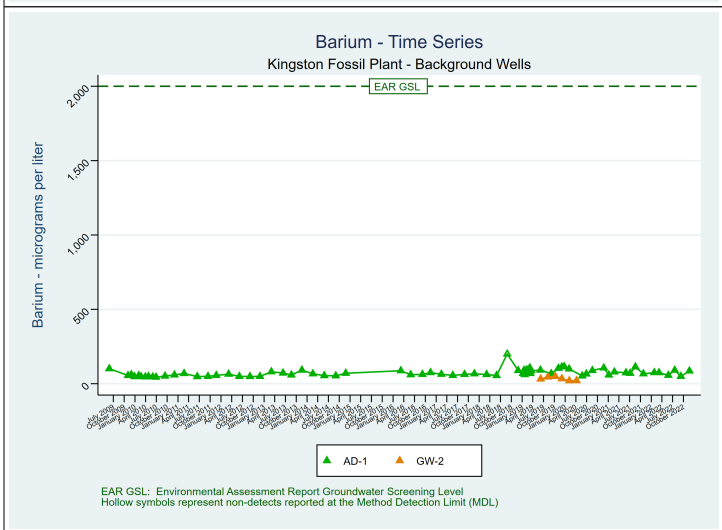
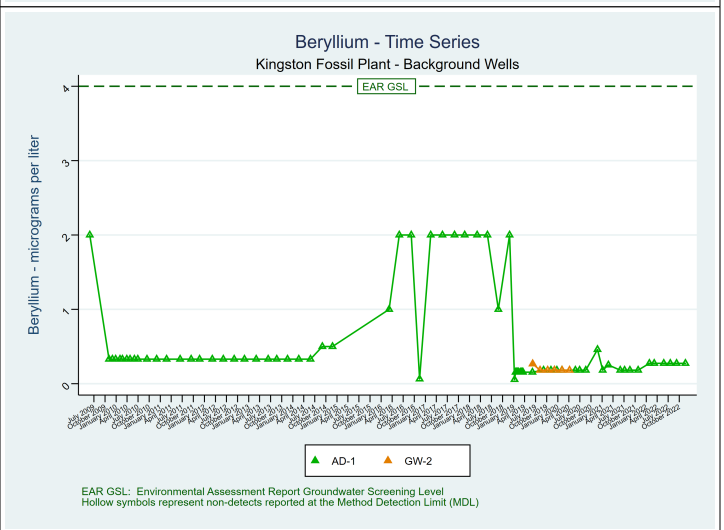
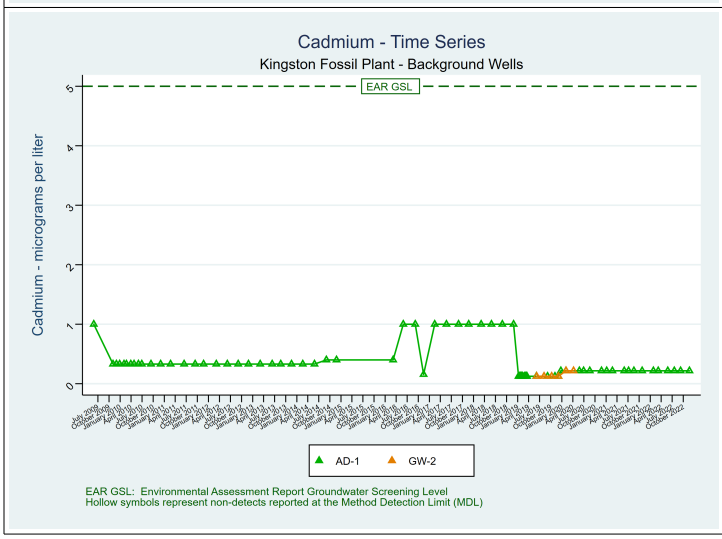
Time Series Plots
Background Wells
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee

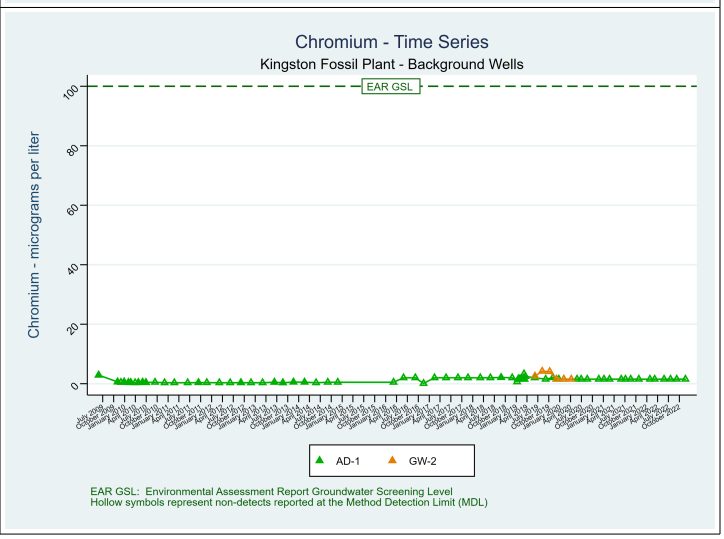


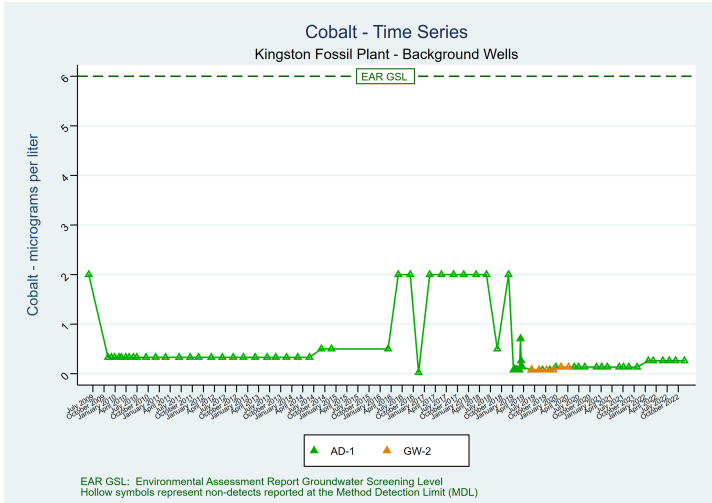


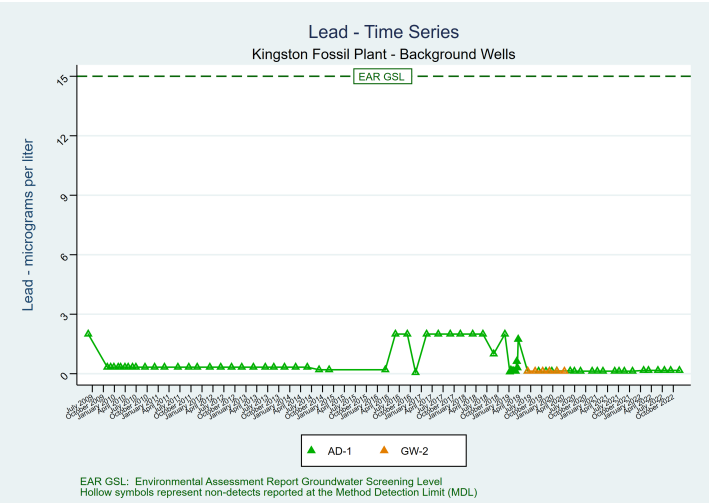


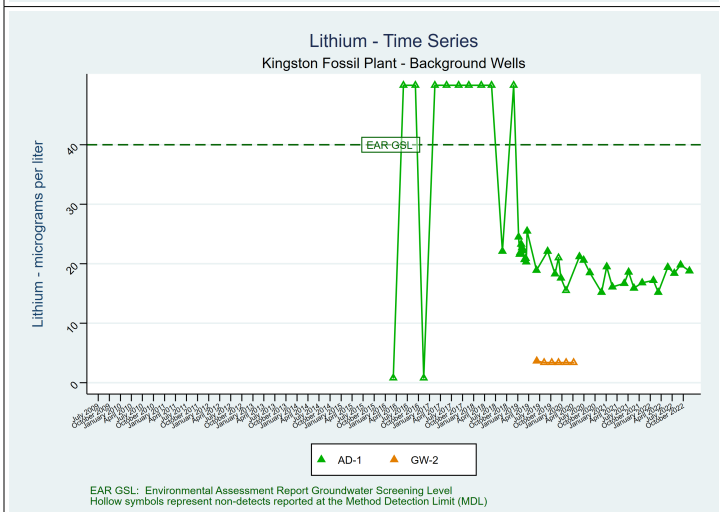


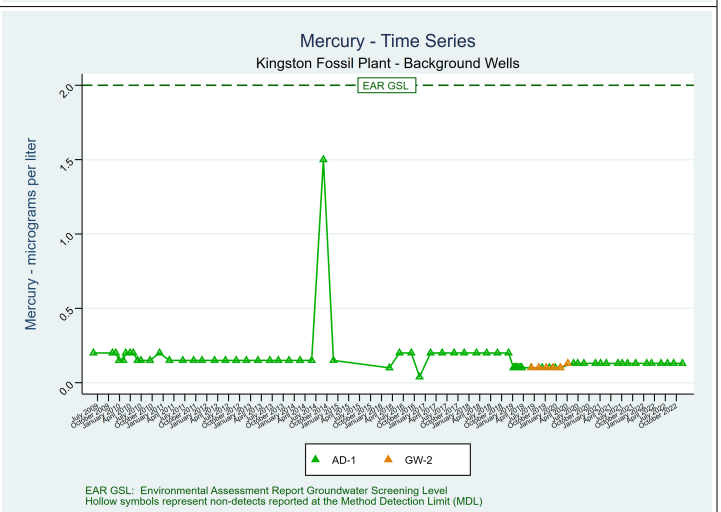


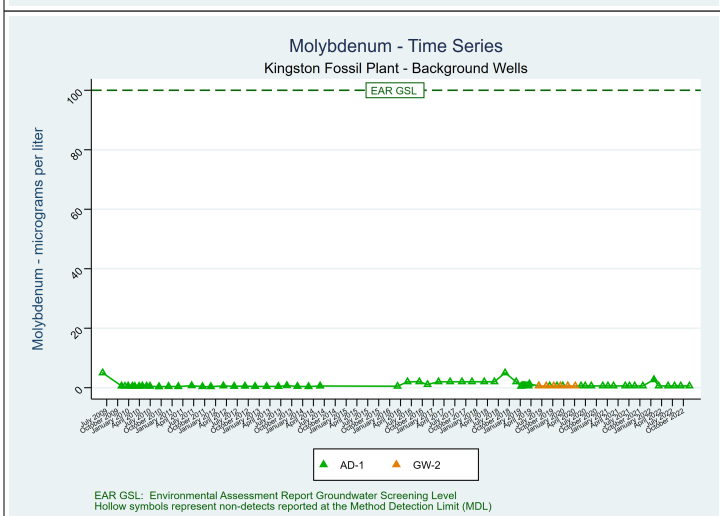


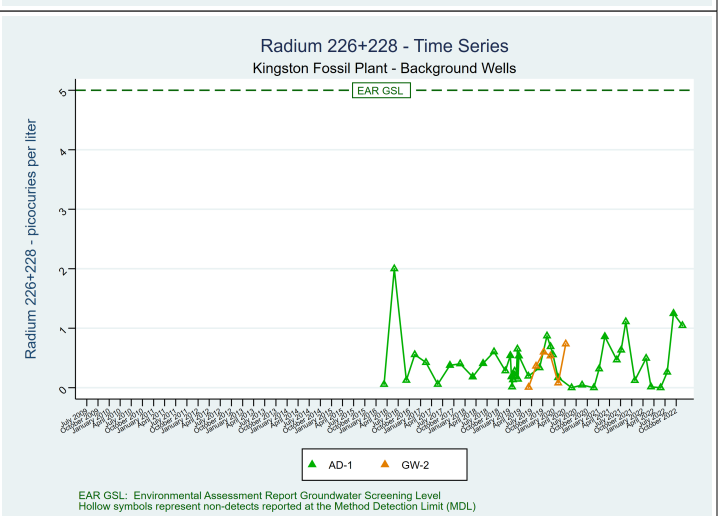

Cobalt - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Cobalt - micrograms per liter
0
1
2
3
4
5
6
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

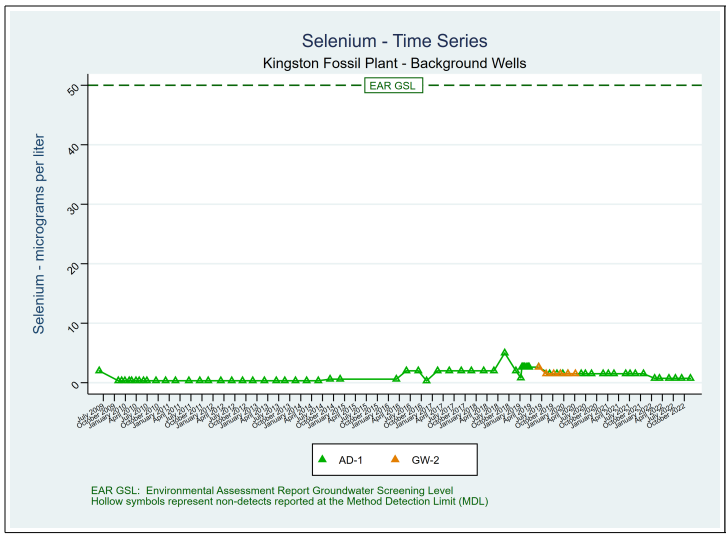

Lead - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Lead - micrograms per liter
0
3
6
9
12
15
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

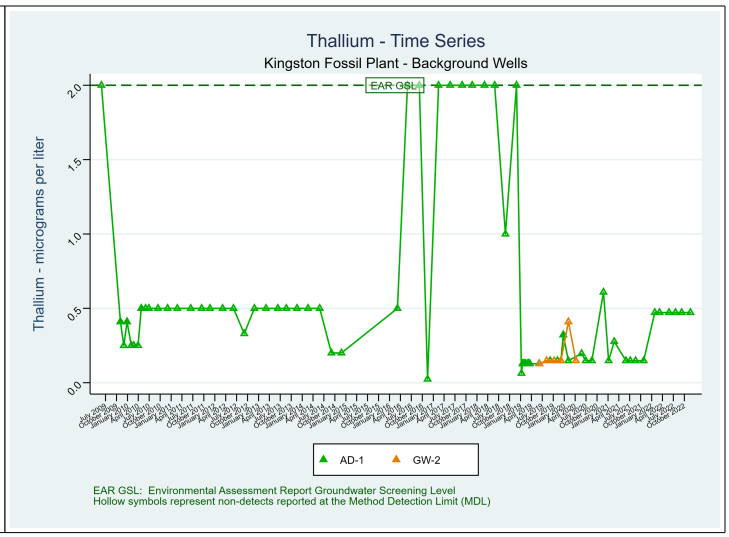

Lithium - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Lithium - micrograms per liter
0
10
20
30
40
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Mercury - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Mercury - micrograms per liter
0.0
0.5
1.0
1.5
2.0
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

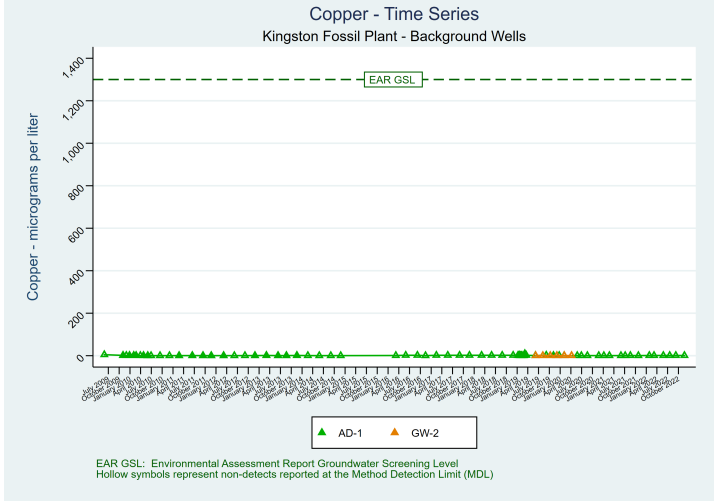

Molybdenum - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Molybdenum - micrograms per liter
0
20
40
60
80
100
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

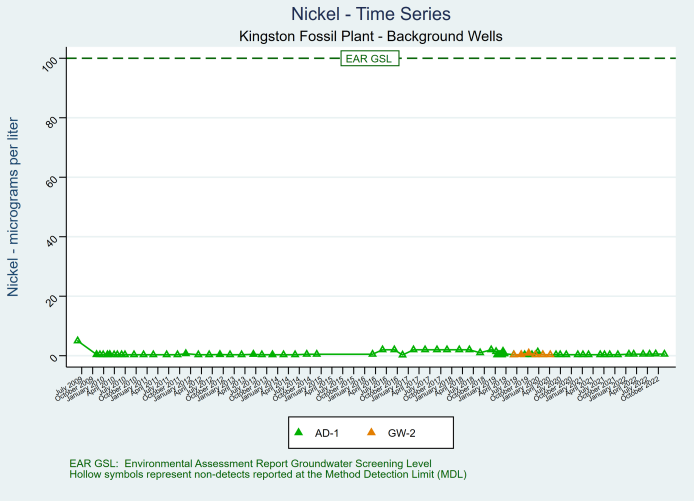

Radium 226+228 - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Radium 226+228 - picocuries per liter
0
1
2
3
4
5
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

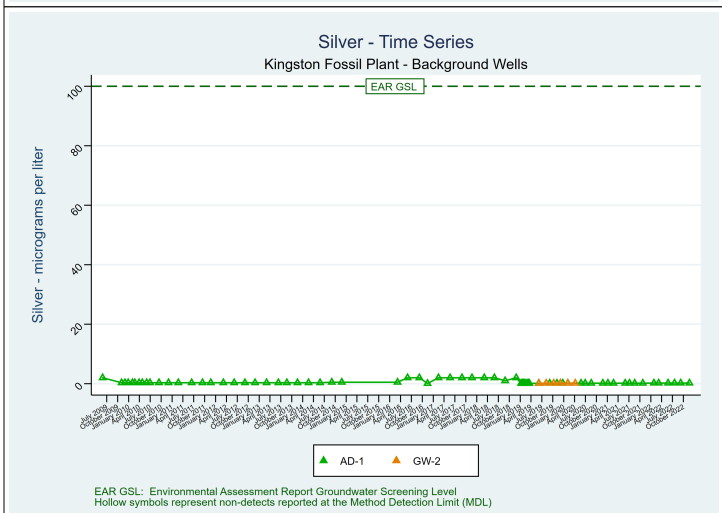

Selenium - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

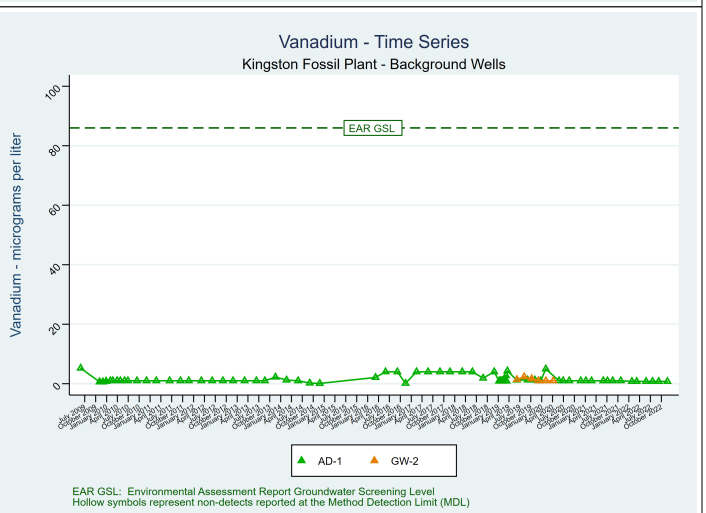

Thallium - Time Series
Kingston Fossil Plant - Background Wells
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
AD-1
GW-2
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

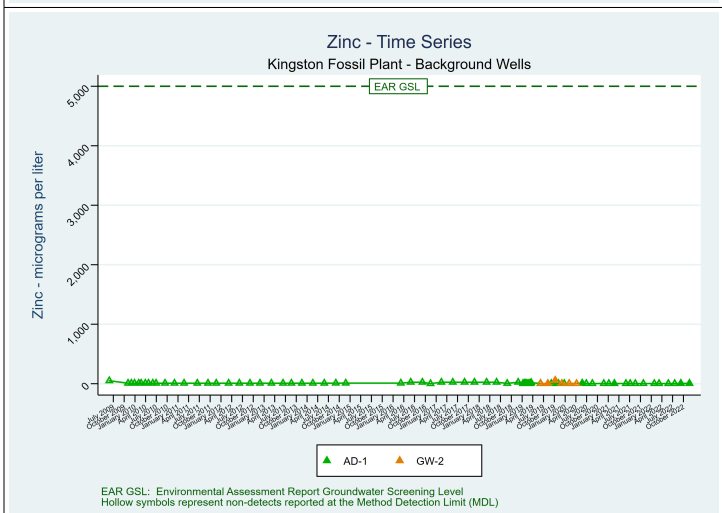
Time Series Plots
Background Wells
TDEC Appendix I Parameters
Kingston Fossil Plant - Harriman, Tennessee











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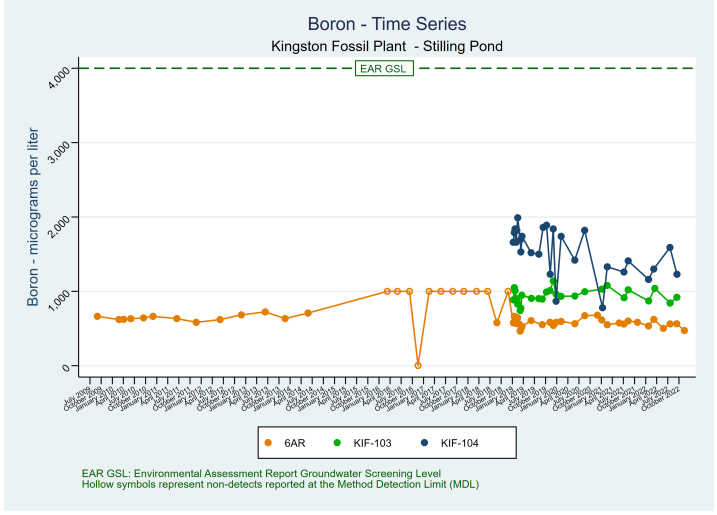
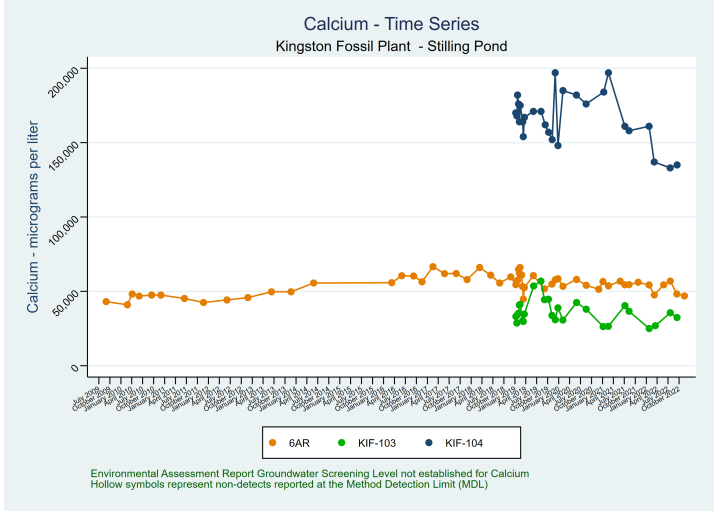
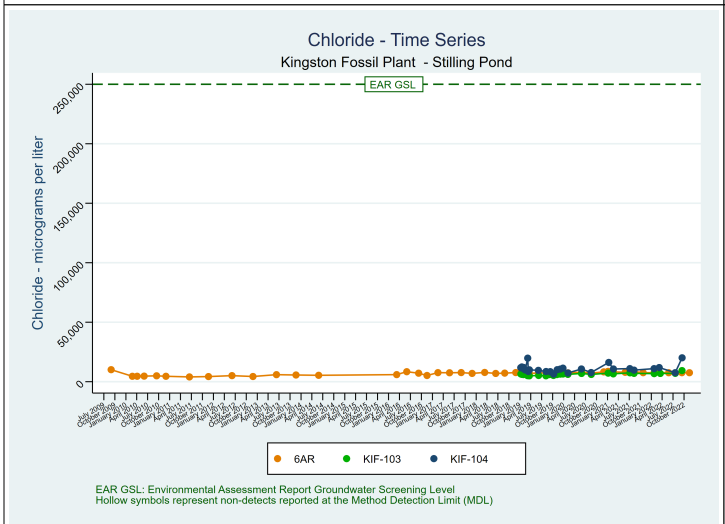
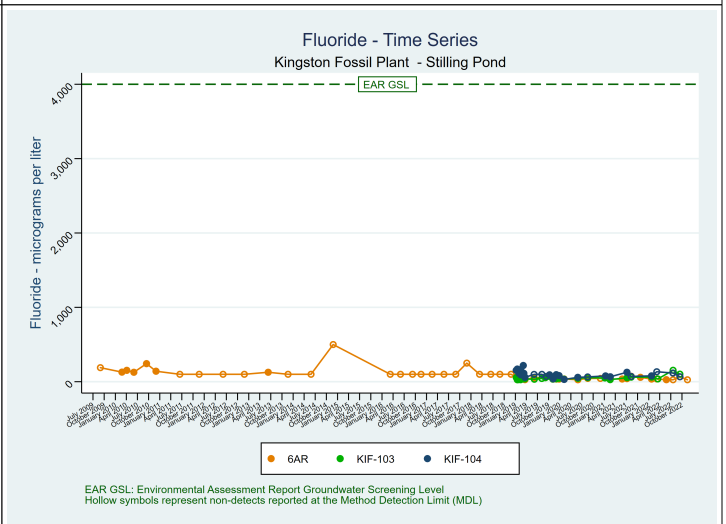
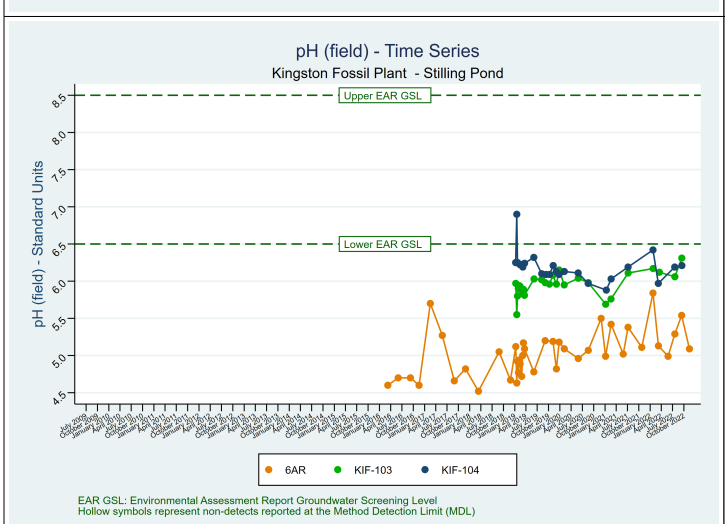
Time Series Plots
Stilling Pond Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

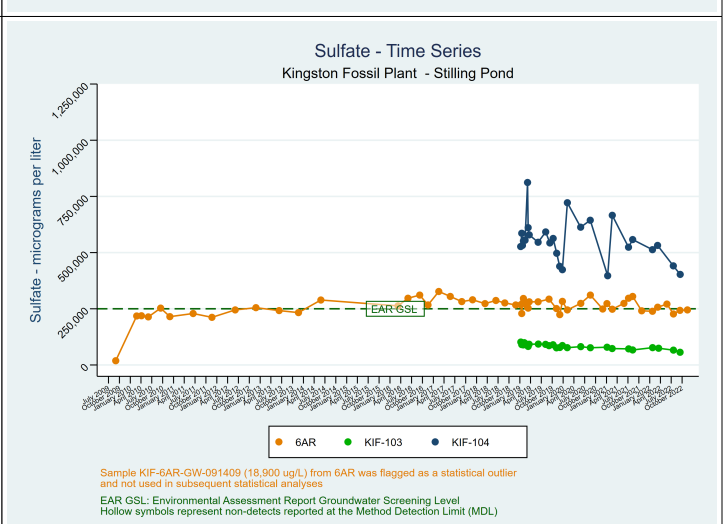


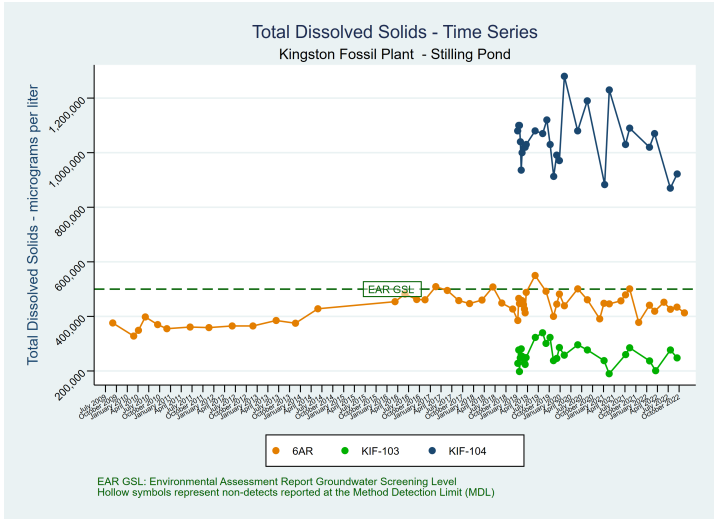












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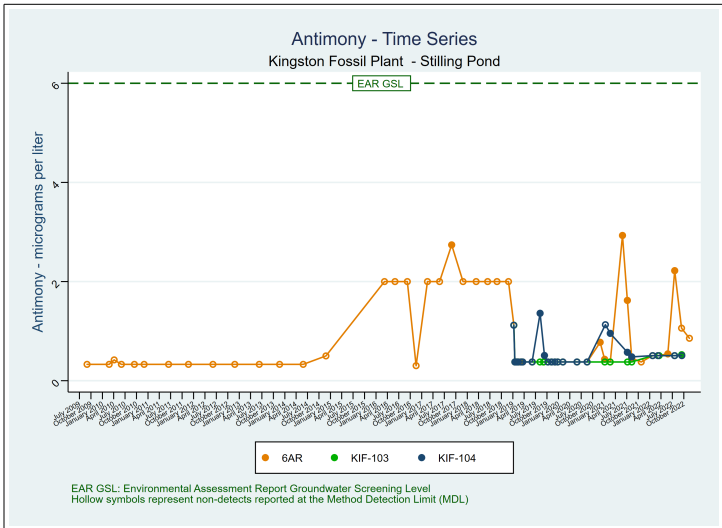
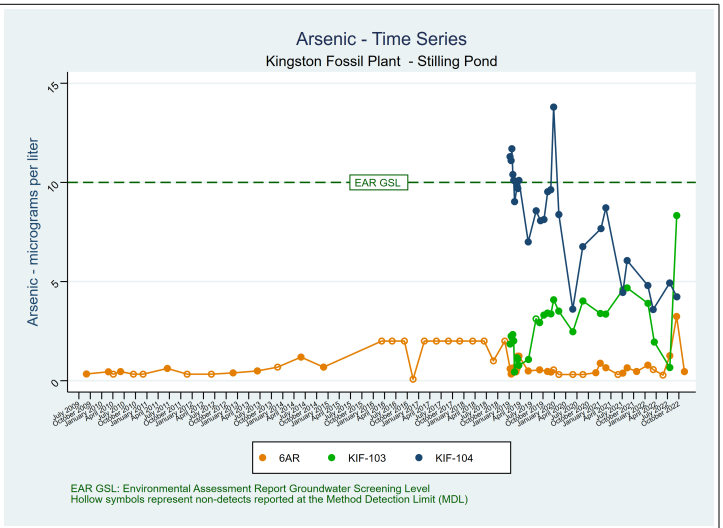
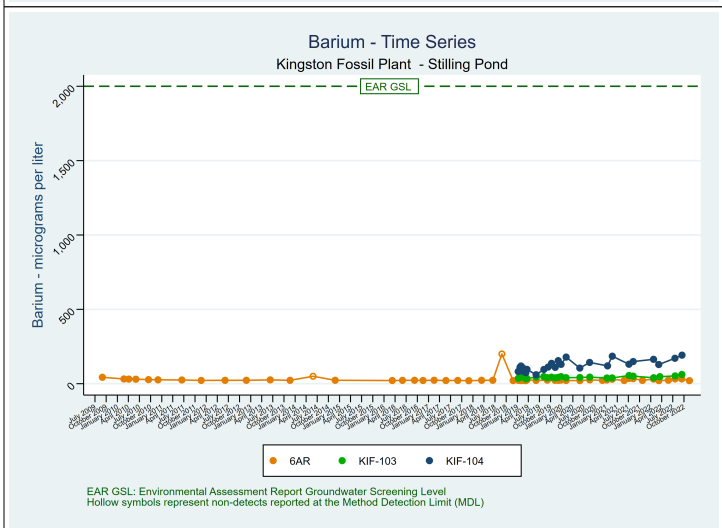
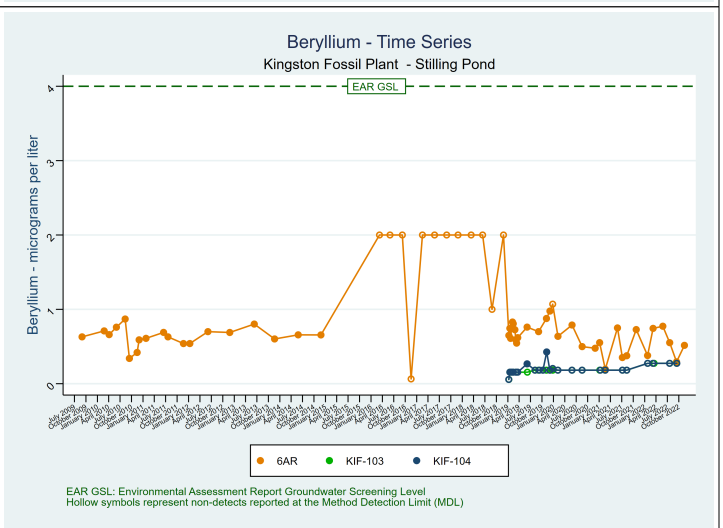
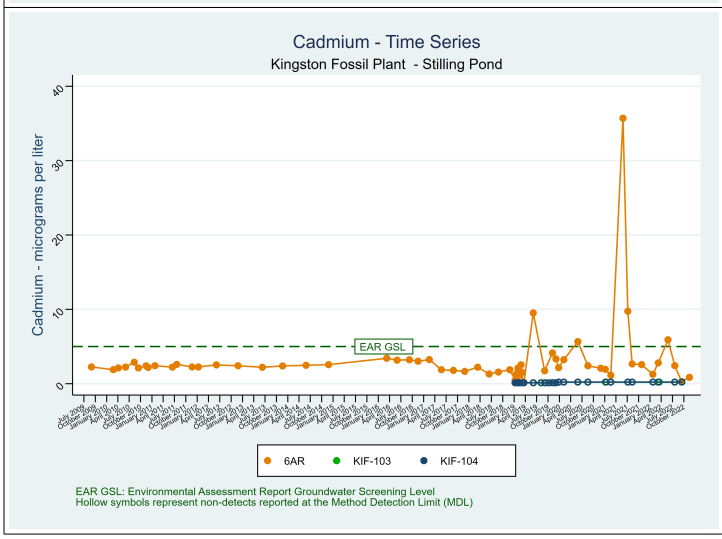
Time Series Plots
Stilling Pond Wells
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee

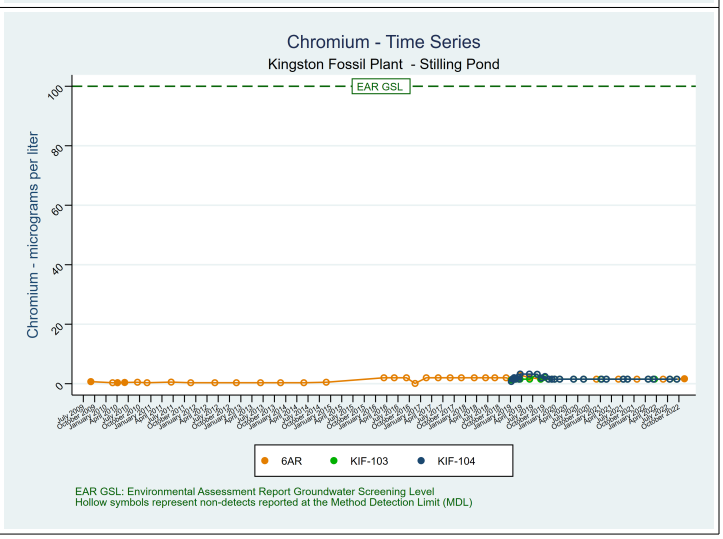


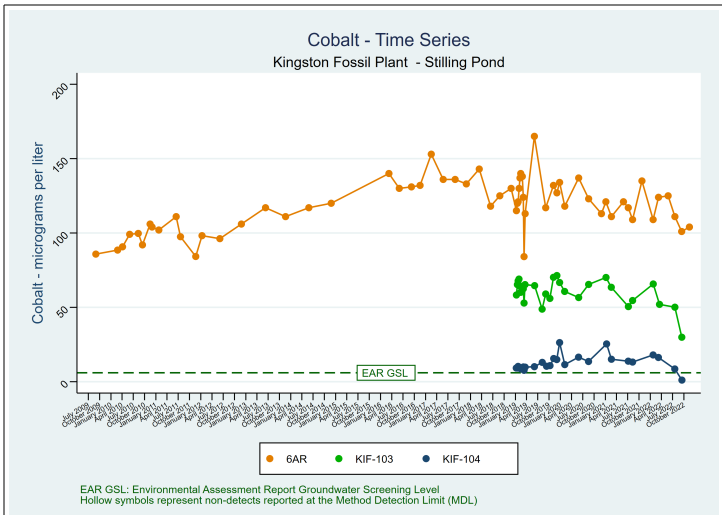


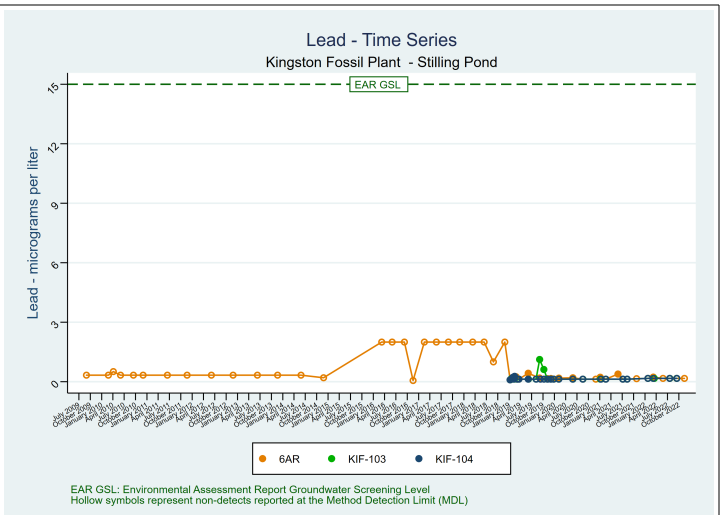


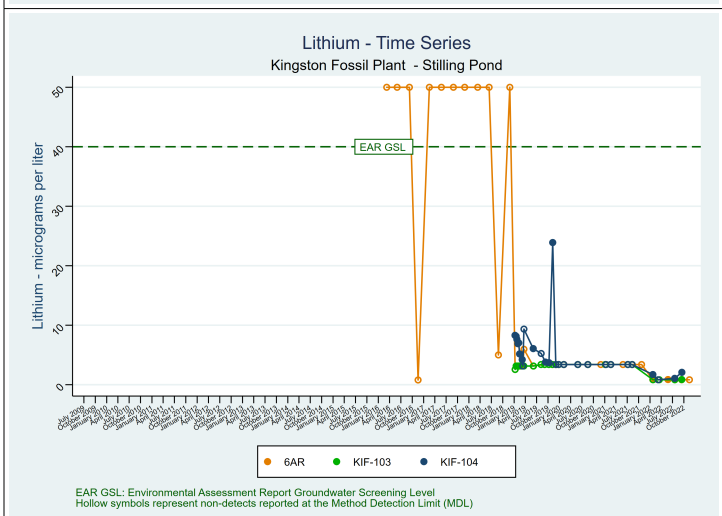


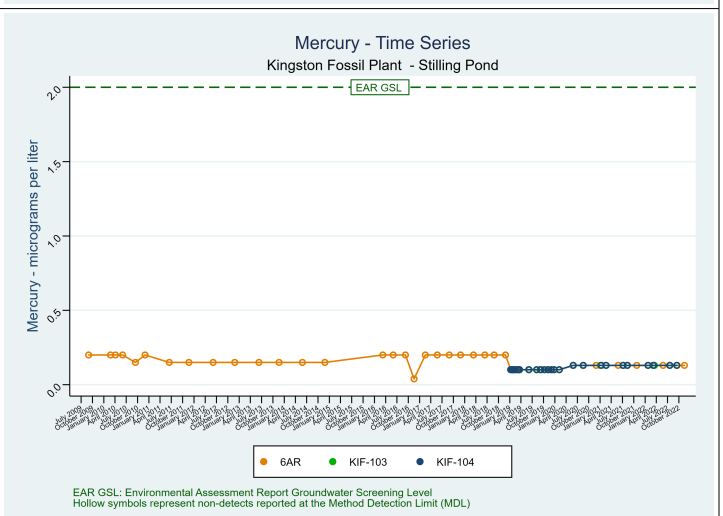


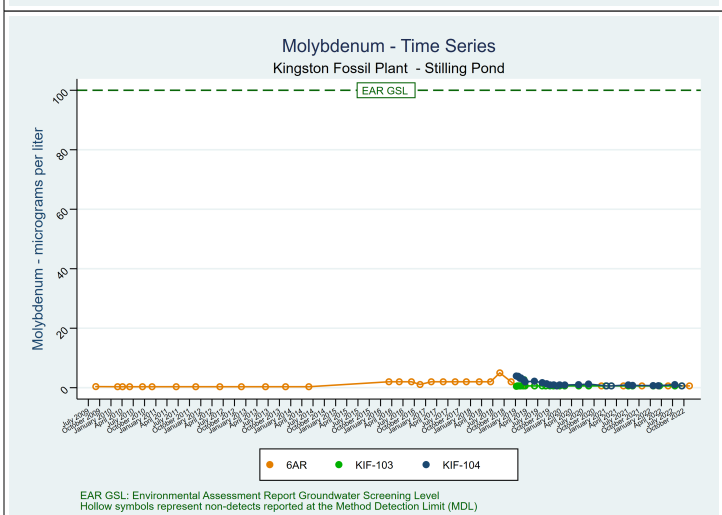


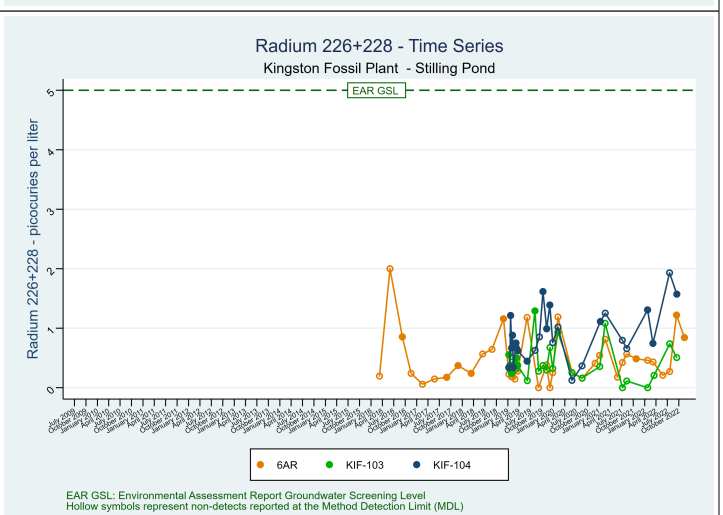

Cobalt - Time Series
Kingston Fossil Plant - Stilling Pond
Cobalt - micrograms per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

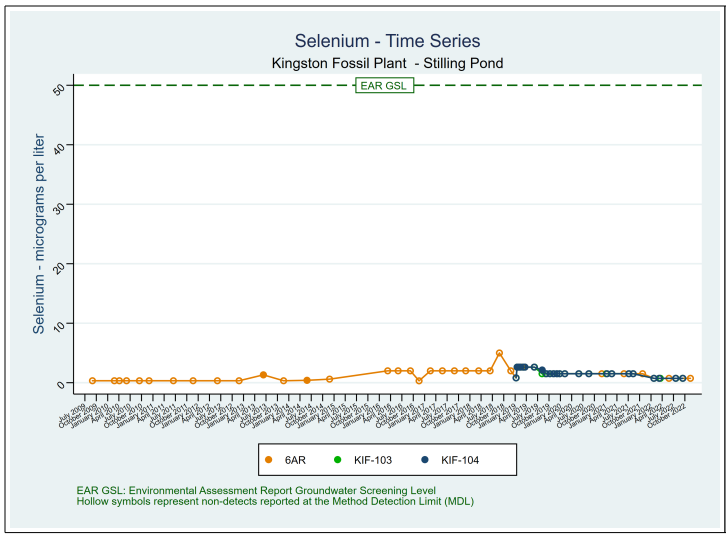

Lead - Time Series
Kingston Fossil Plant - Stilling Pond
Lead - micrograms per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

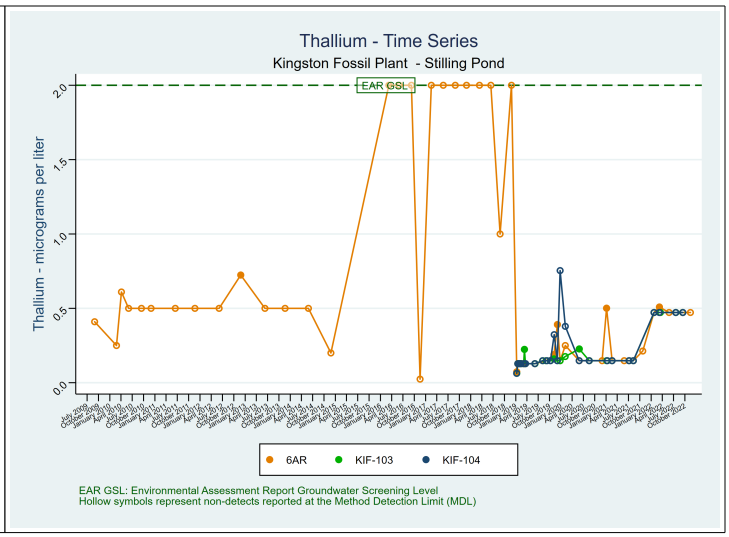

Lithium - Time Series
Kingston Fossil Plant - Stilling Pond
Lithium - micrograms per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)


Mercury - Time Series
Kingston Fossil Plant - Stilling Pond
Mercury - micrograms per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

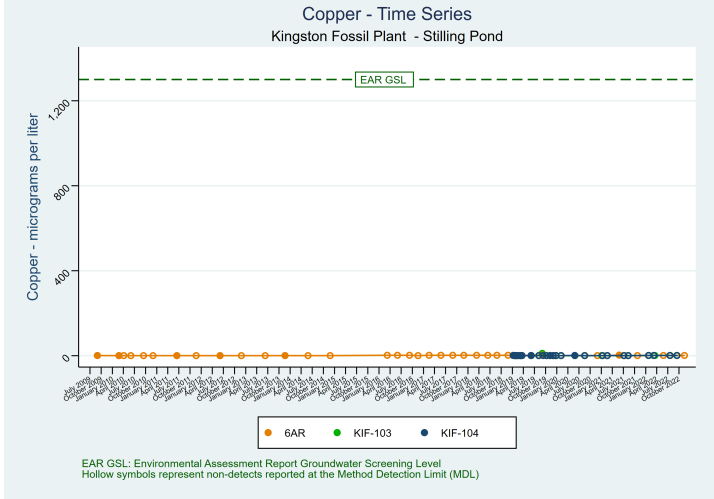

Molybdenum - Time Series
Kingston Fossil Plant - Stilling Pond
Molybdenum - micrograms per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

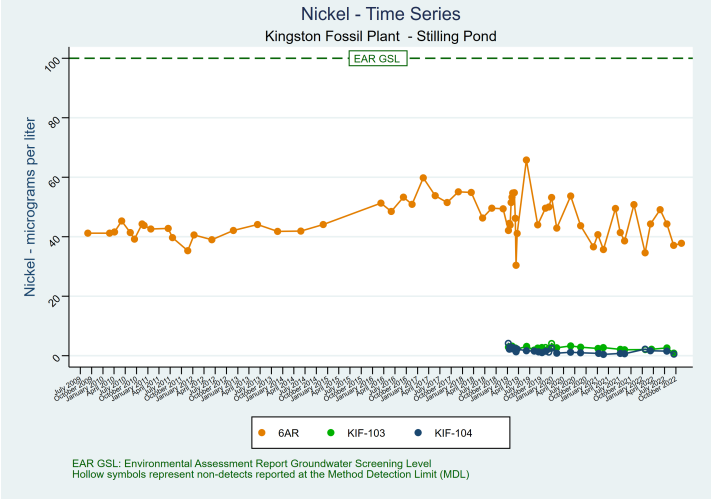

Radium 226+228 - Time Series
Kingston Fossil Plant - Stilling Pond
Radium 226+228 - picocuries per liter
EAR GSL
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

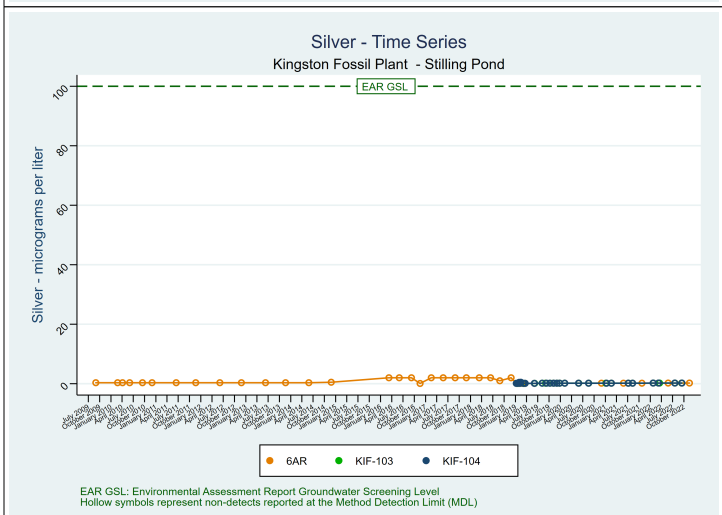

Selenium - Time Series
Kingston Fossil Plant - Stilling Pond
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

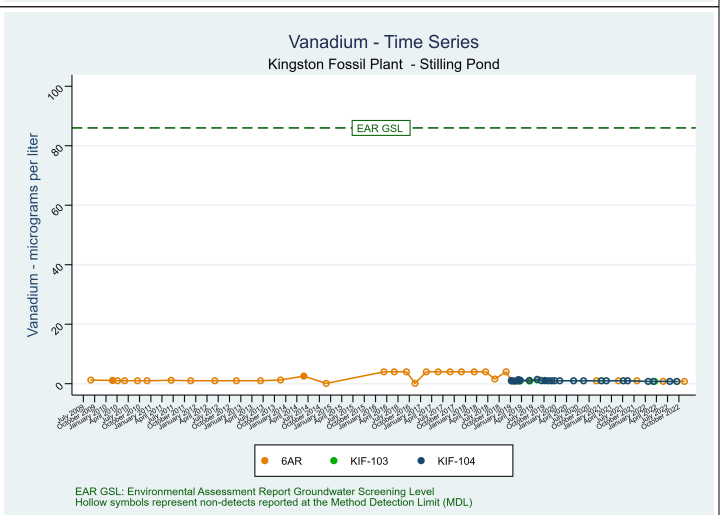

Thallium - Time Series
Kingston Fossil Plant - Stilling Pond
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
6AR
KIF-103
KIF-104
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

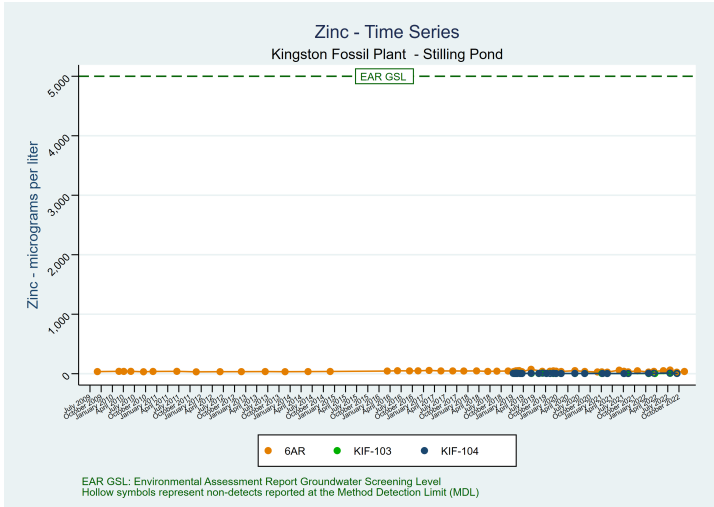
Time Series Plots
Stilling Pond Wells
TDEC Appendix I Parameters
Kingston Fossil Plant - Harriman, Tennessee











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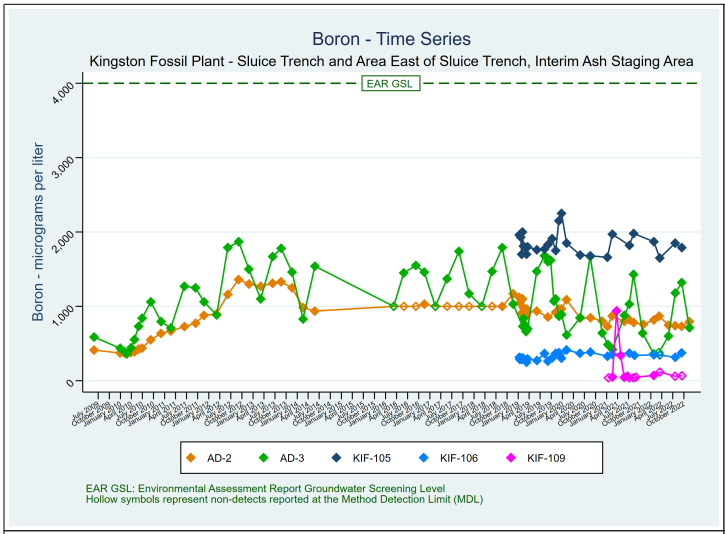
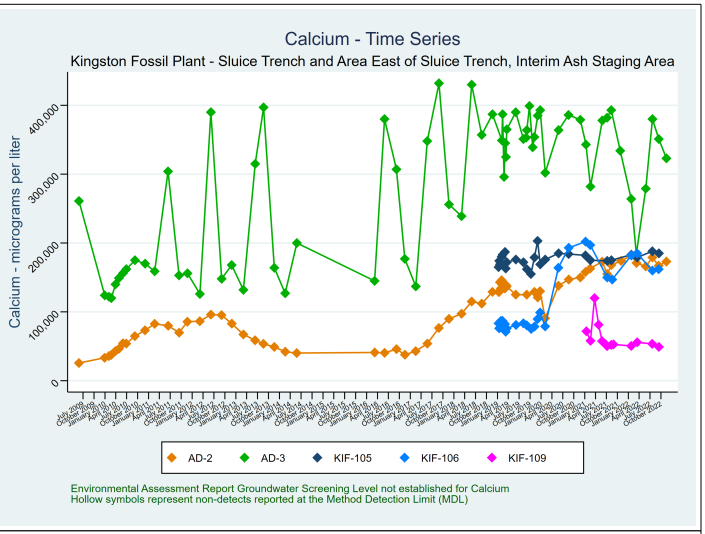
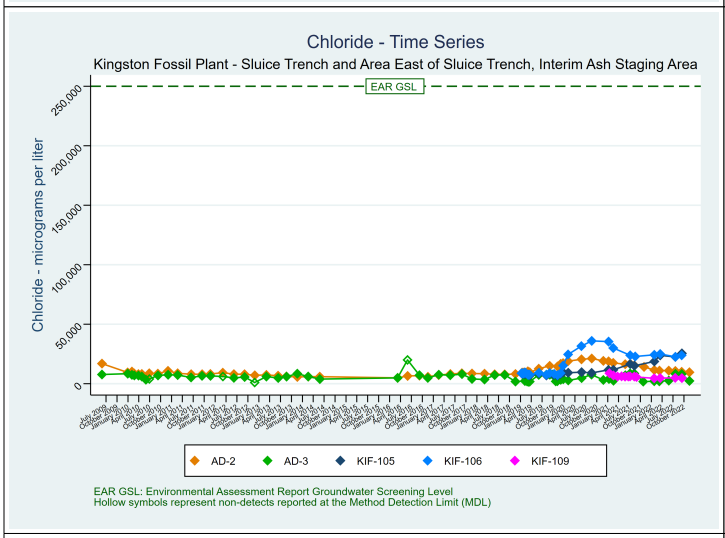
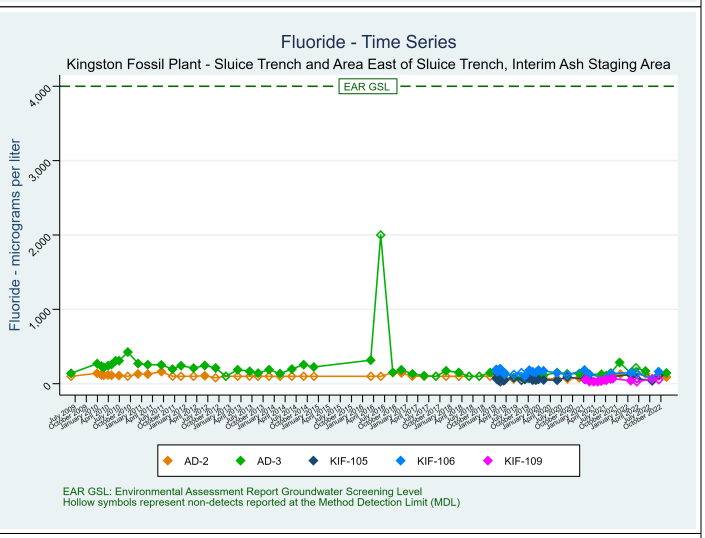
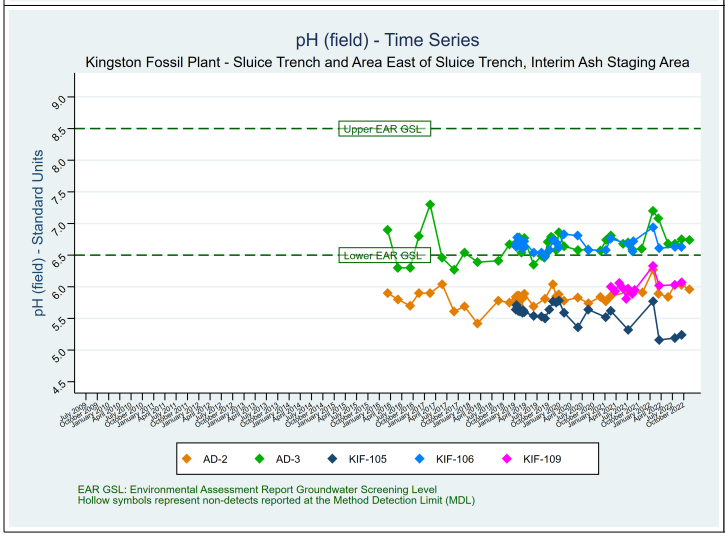
Time Series Plots
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

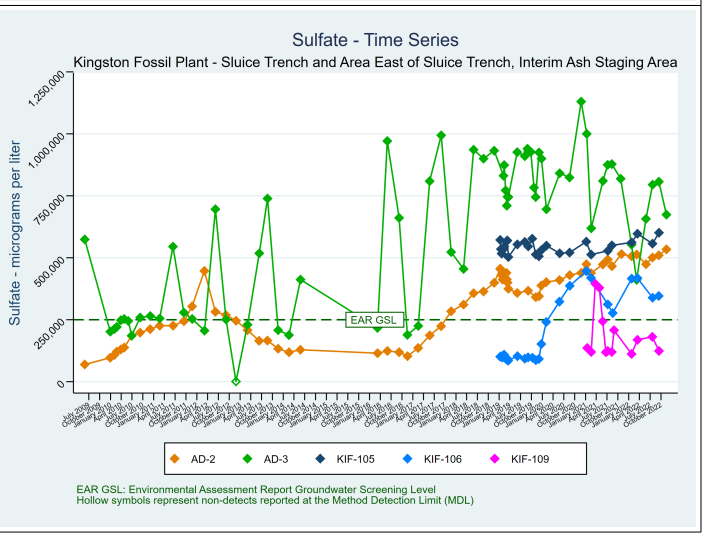


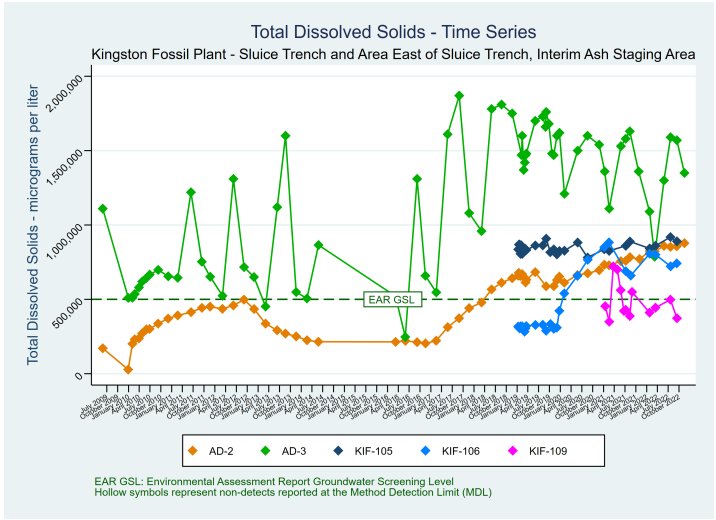












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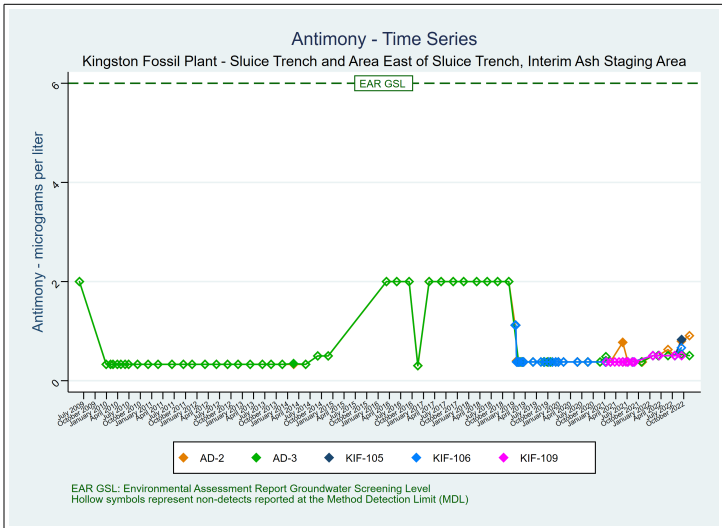
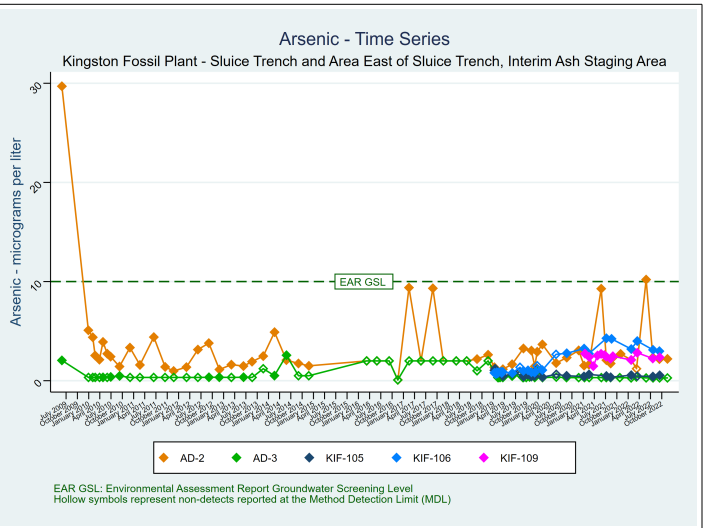
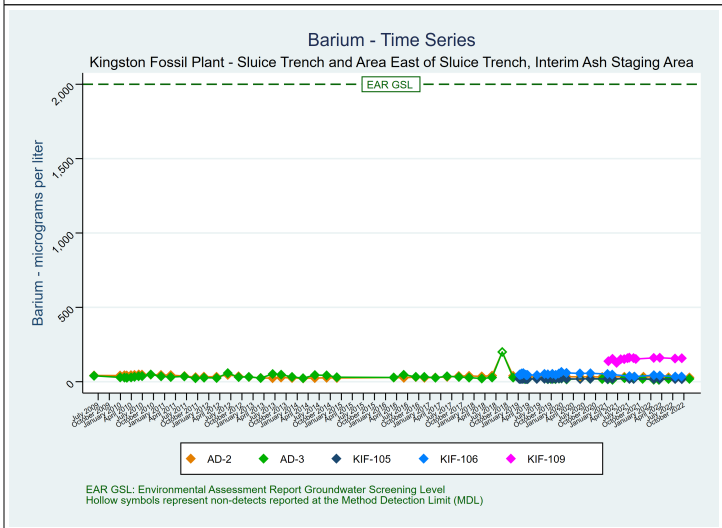
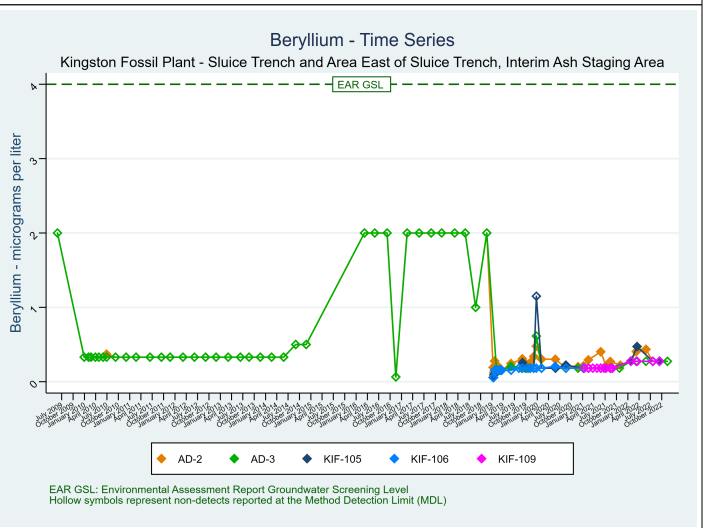
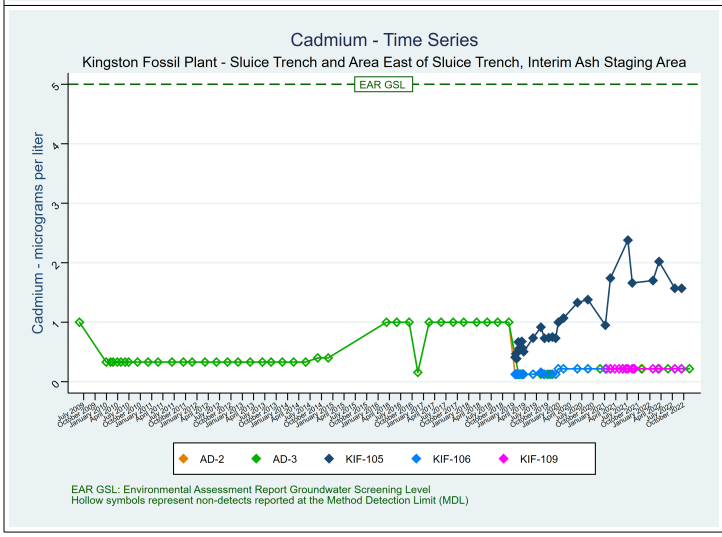
Time Series Plots
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area Wells
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee

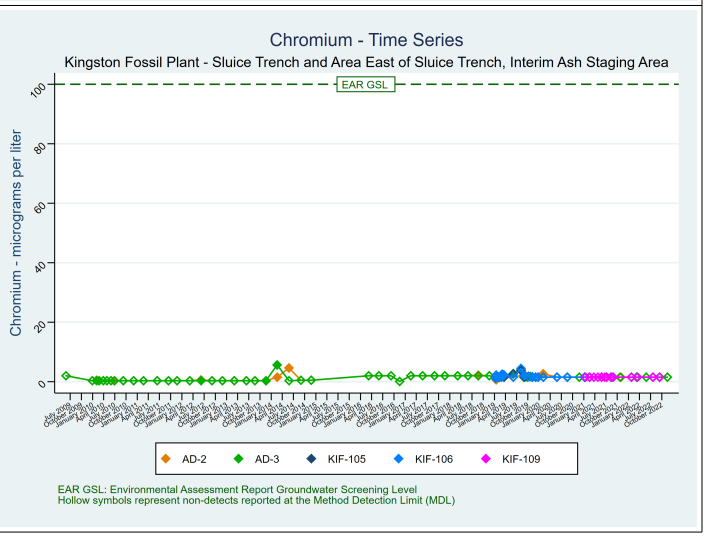






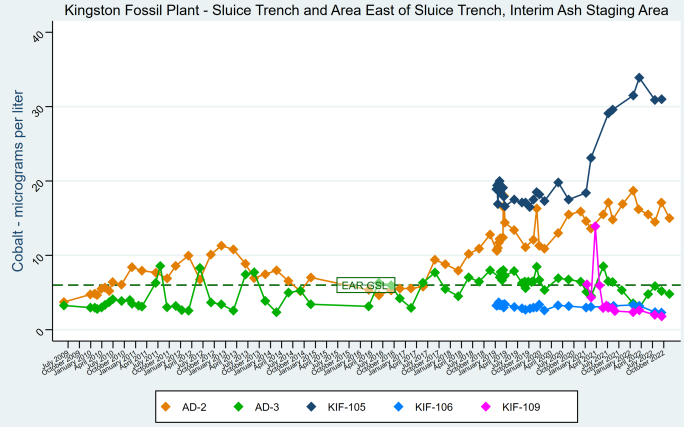






Cobalt - Time Series

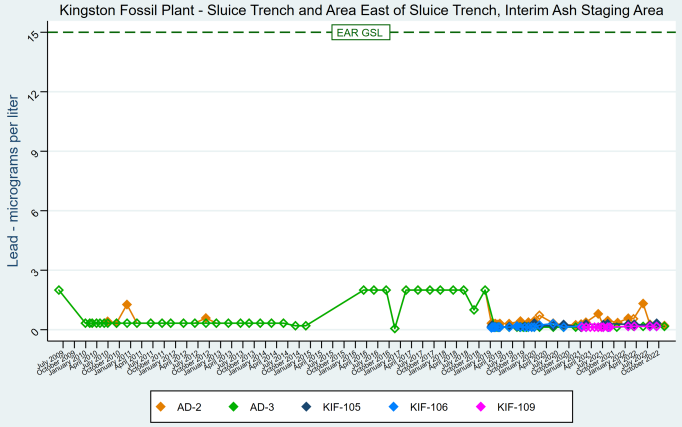
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Lead - Time Series

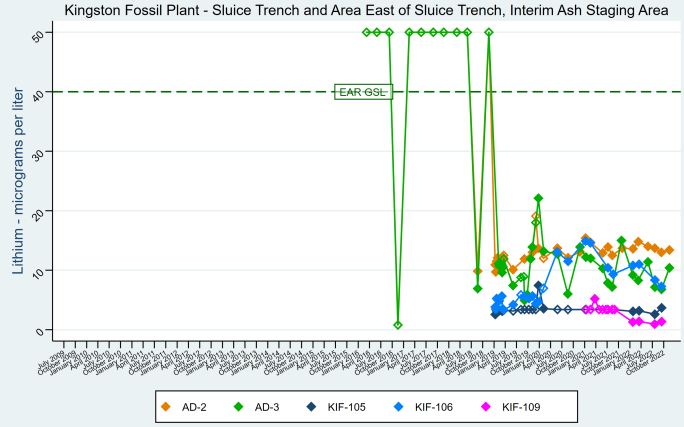
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Lithium - Time Series

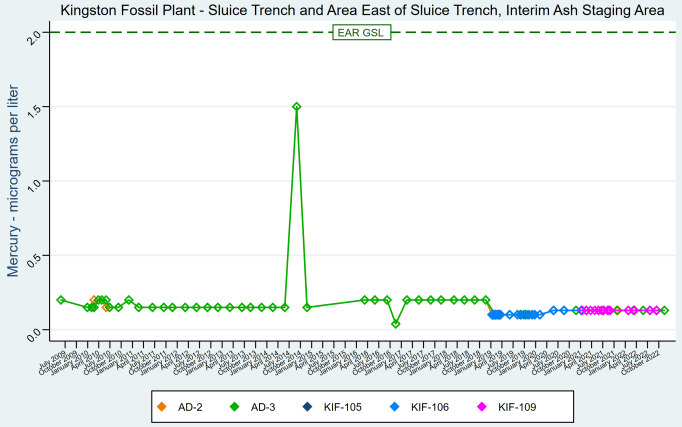
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Mercury - Time Series

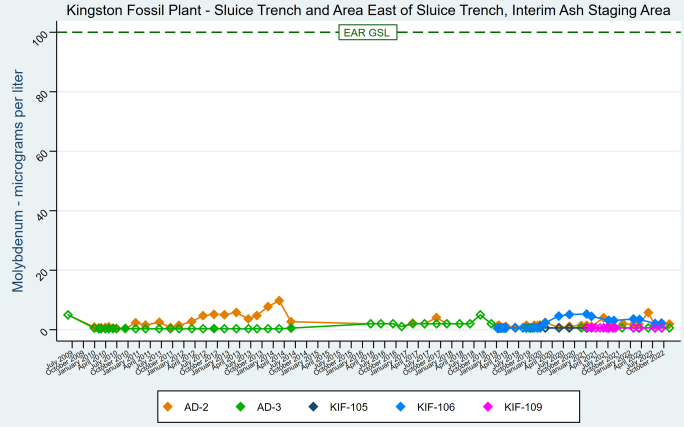
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

Molybdenum - Time Series

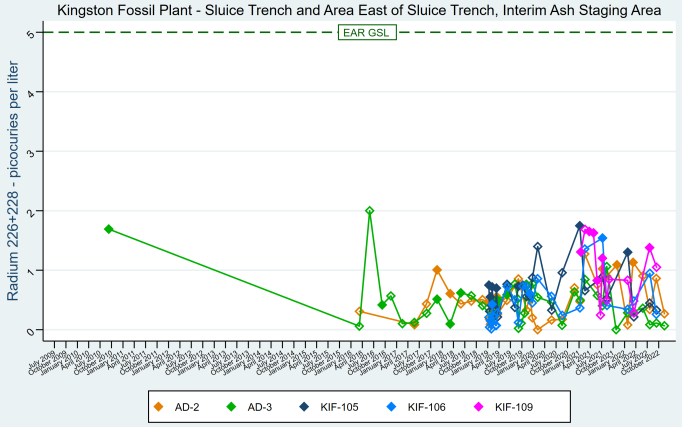
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



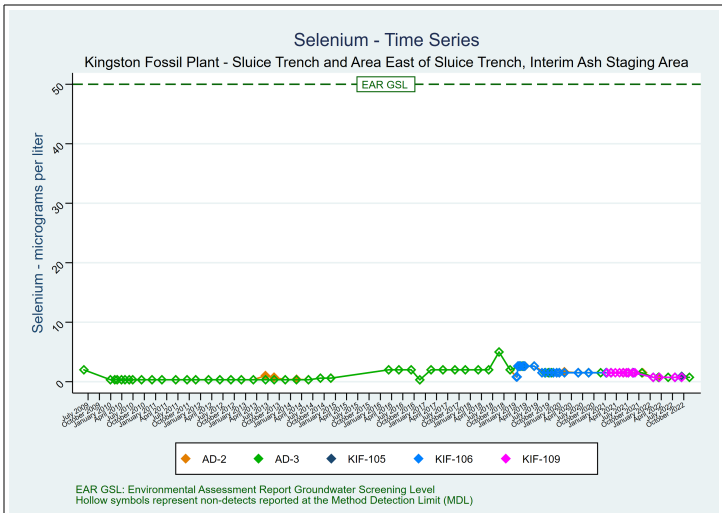
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

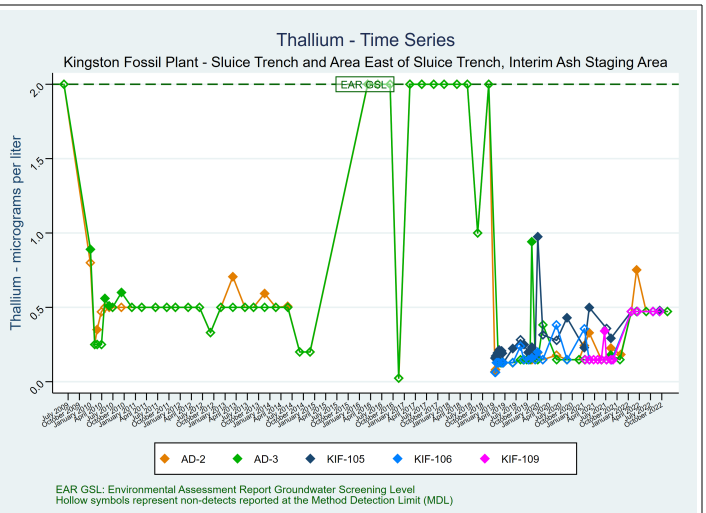
Radium 226+228 - Time Series

Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area

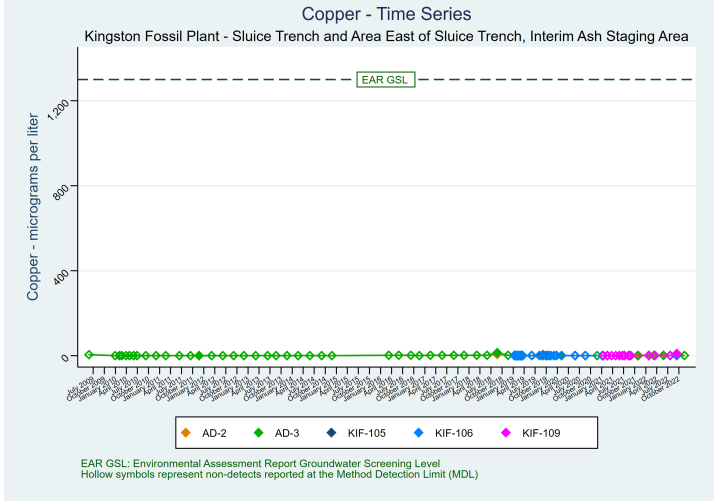


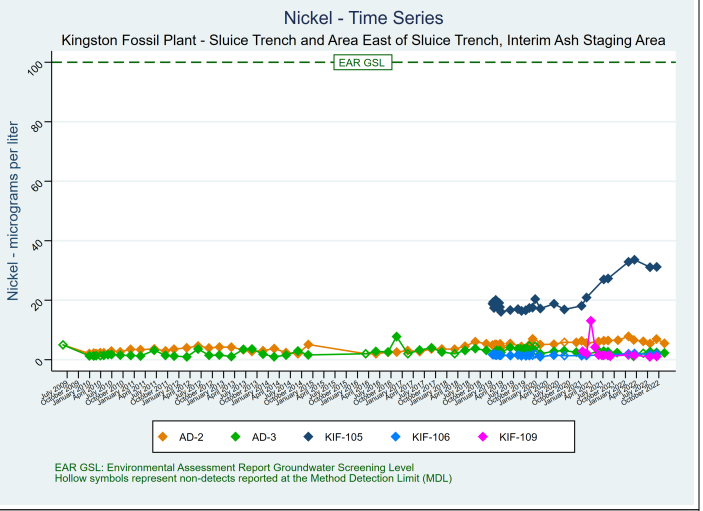
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

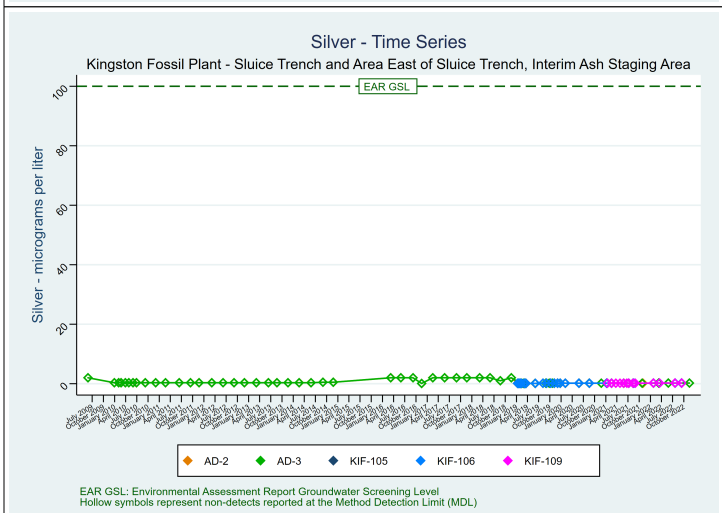

Selenium - Time Series
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area
EAR GSL
Selenium - micrograms per liter
0
10
20
30
40
50
AD-2
AD-3
KIF-105
KIF-106
KIF-109
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

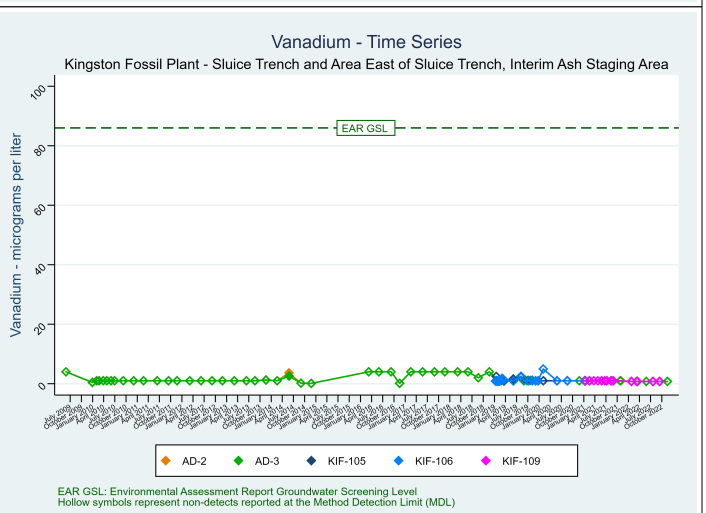

Thallium - Time Series
Kingston Fossil Plant - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area
EAR GSL
Thallium - micrograms per liter
0.0
0.5
1.0
1.5
2.0
AD-2
AD-3
KIF-105
KIF-106
KIF-109
EAR GSL: Environmental Assessment Report Groundwater Screening Level
Hollow symbols represent non-detects reported at the Method Detection Limit (MDL)

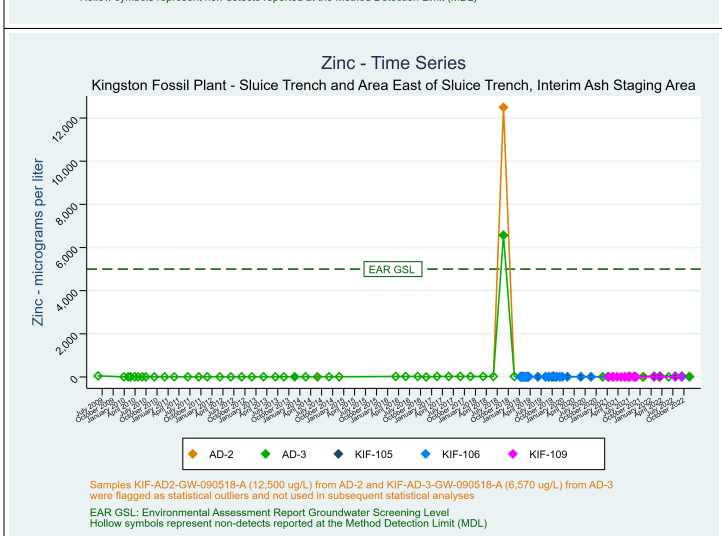
Time Series Plots
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area Wells
TDEC Appendix I Parameters
Kingston Fossil Plant - Harriman, Tennessee











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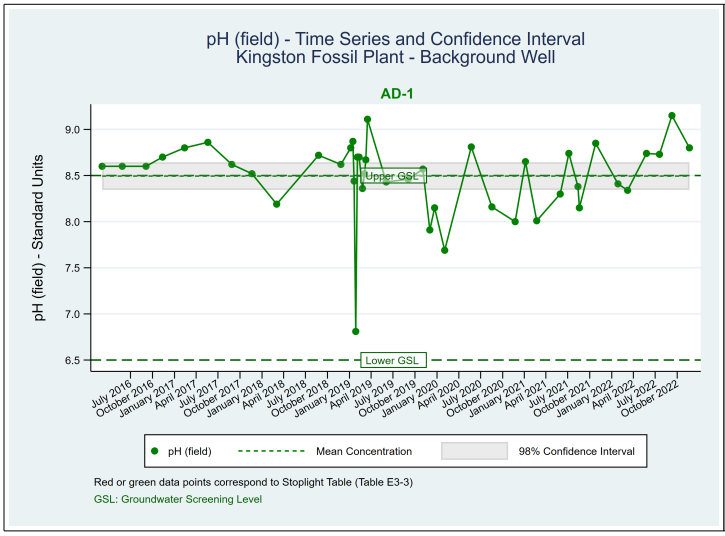
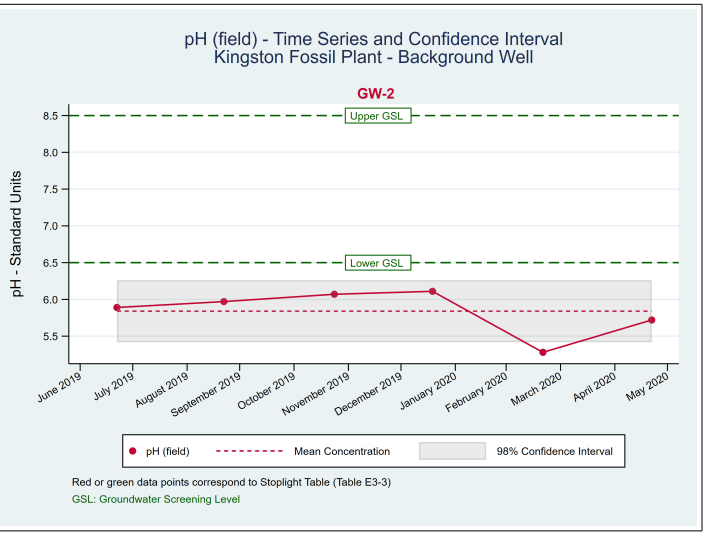
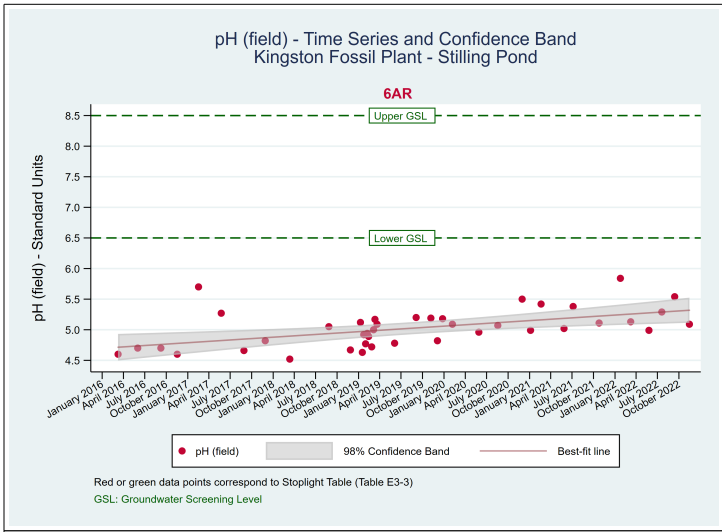
ATTACHMENT E.3-D
LINEAR REGRESSION PLOTS

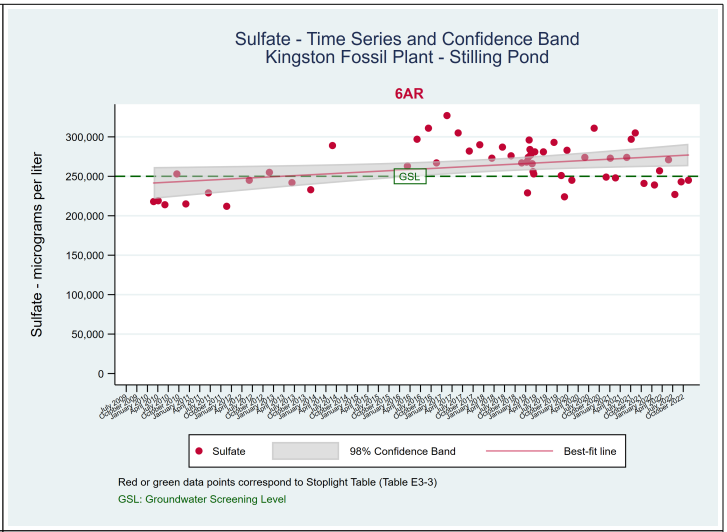
Regression Plots
Background Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

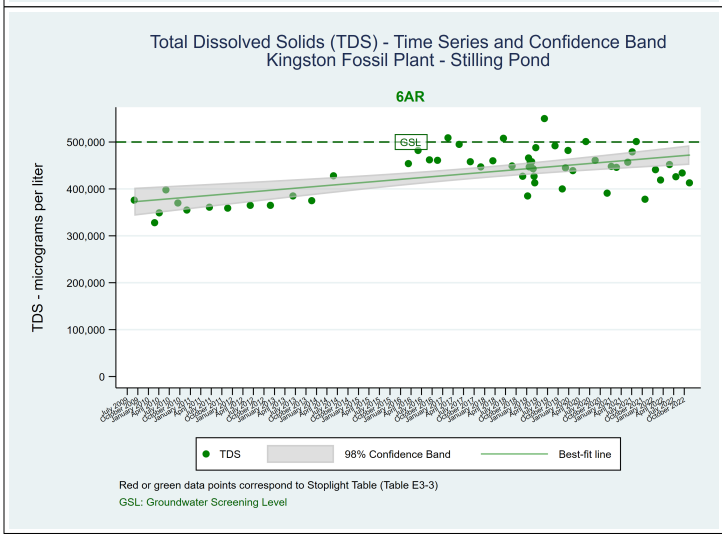


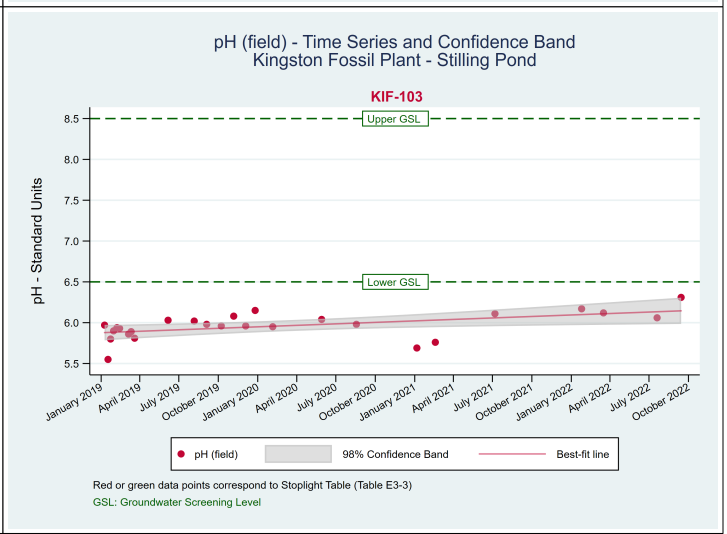


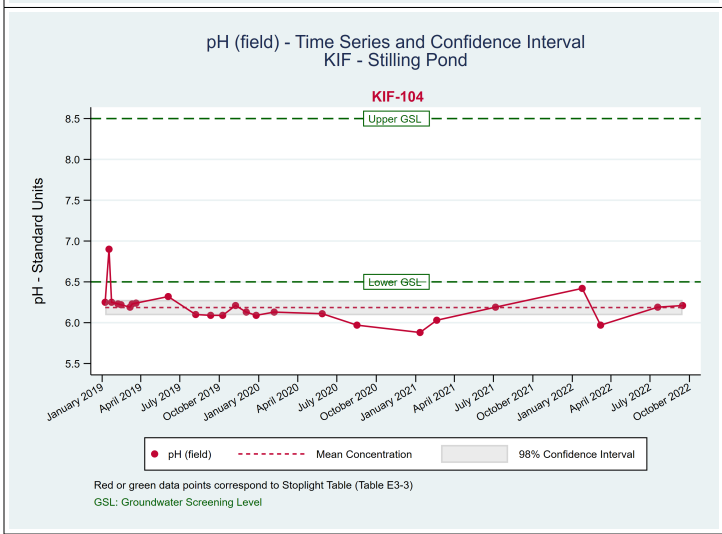
Regression Plots
Stilling Pond Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

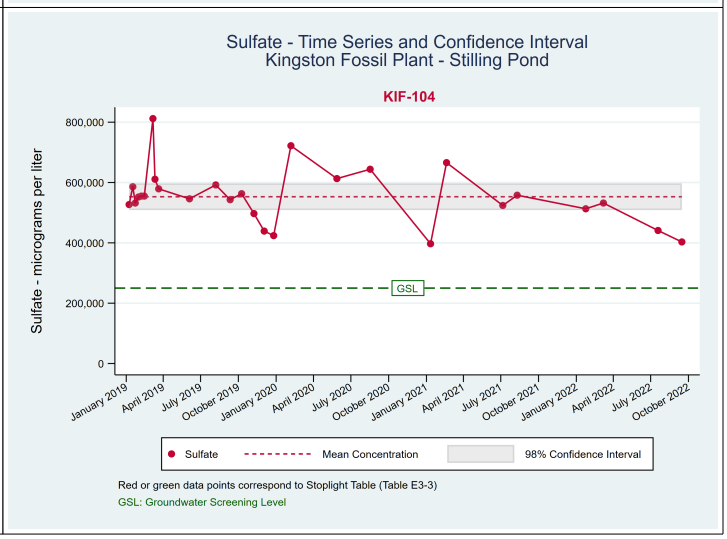


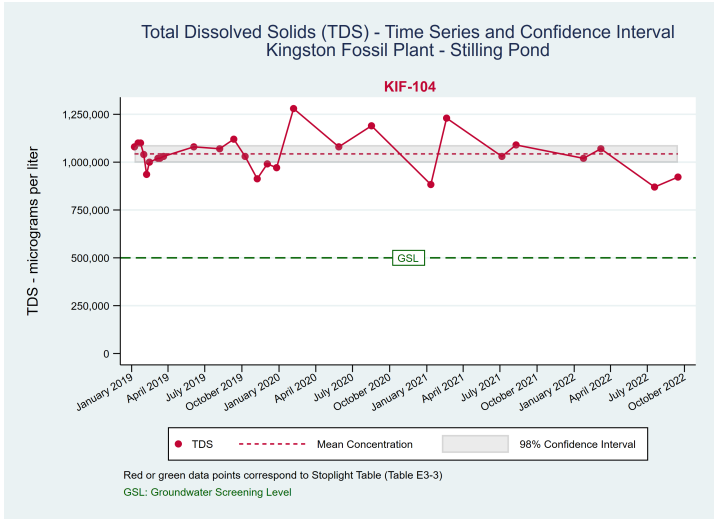












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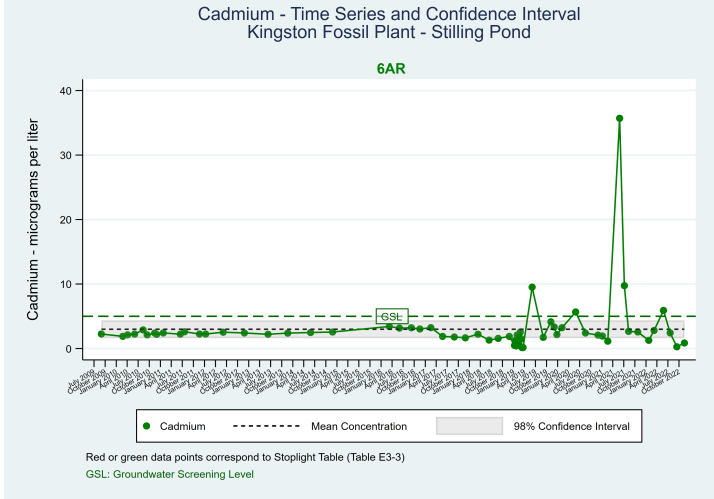
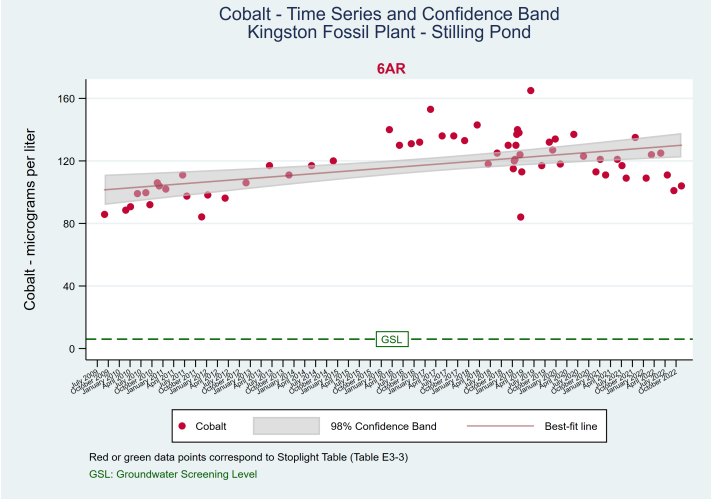
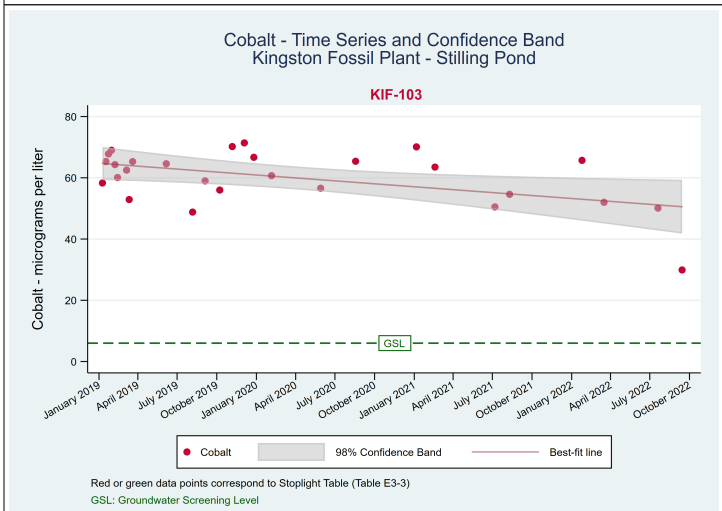
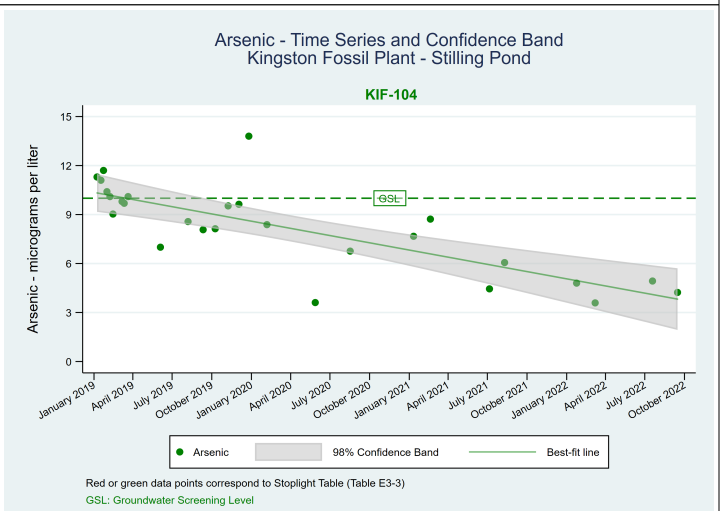
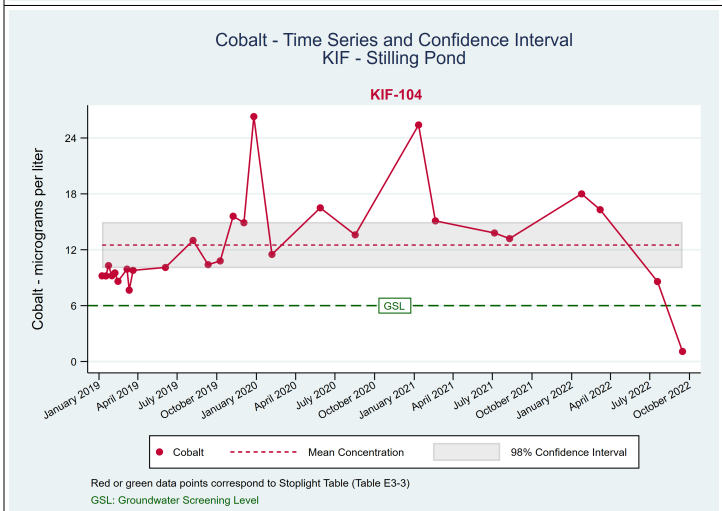
Regression Plots
Stilling Pond Wells
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee











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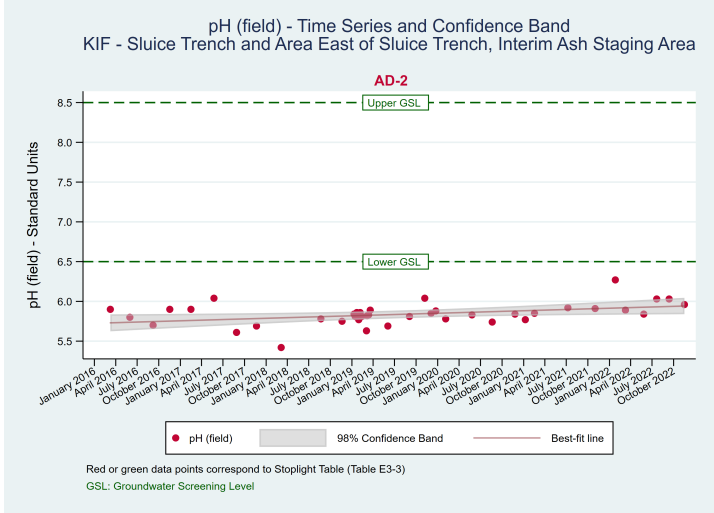
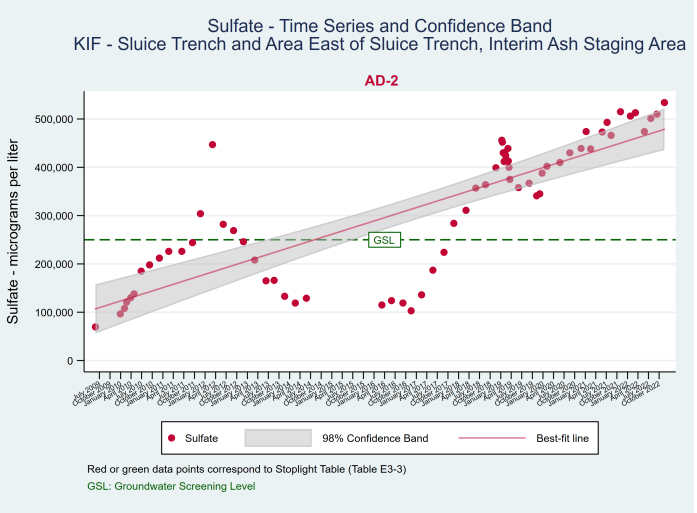
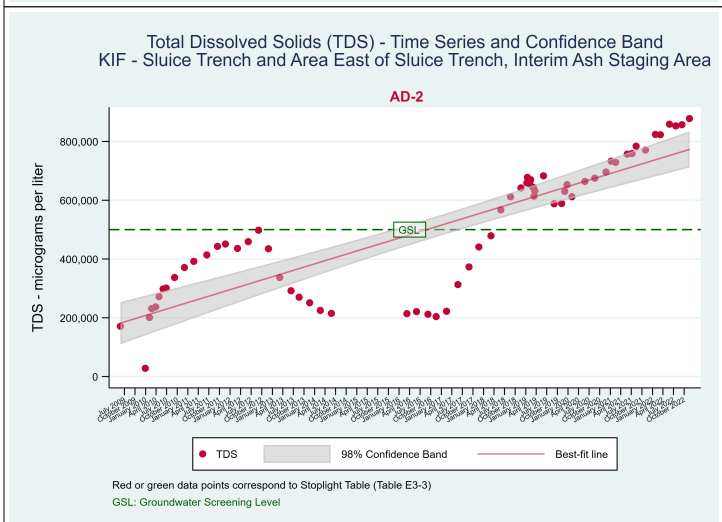
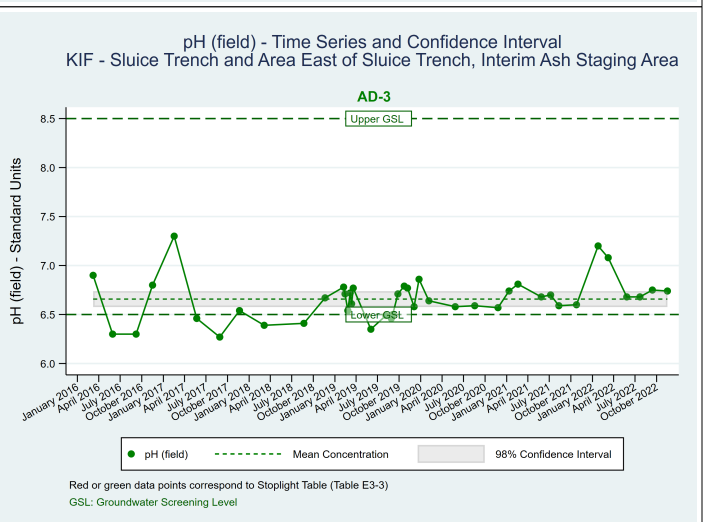
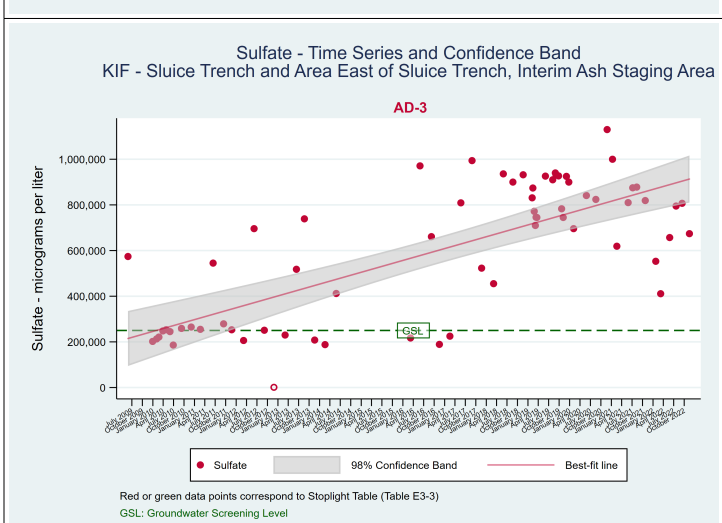
Regression Plots
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area Wells
CCR Rule Appendix III Parameters
Kingston Fossil Plant - Harriman, Tennessee

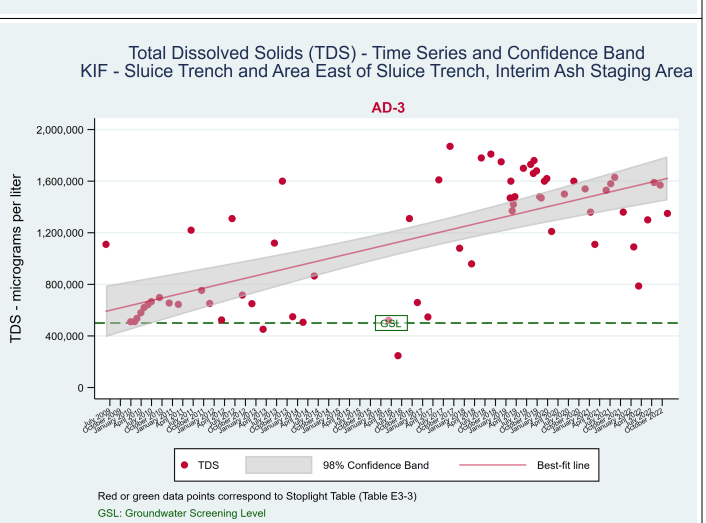




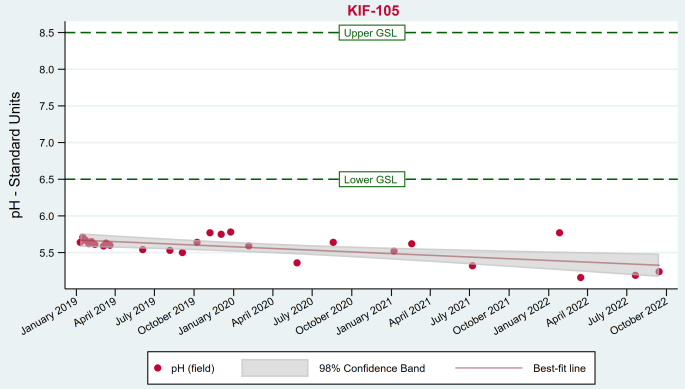






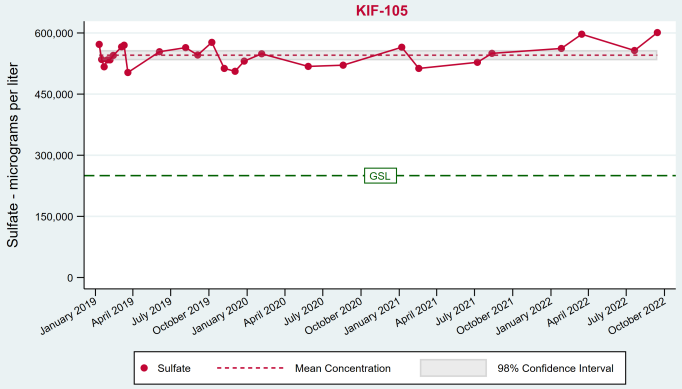


pH (field) - Time Series and Confidence Band
KIF - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



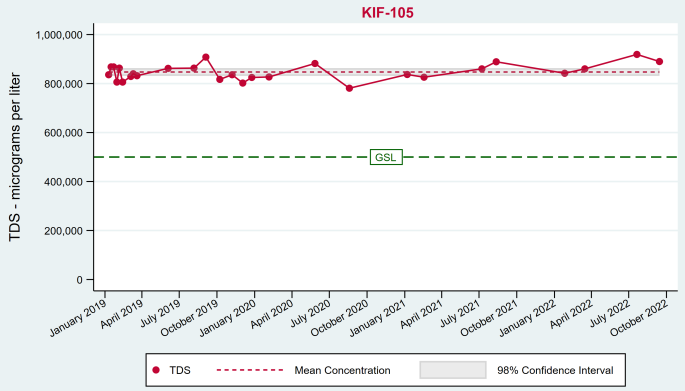
Red or green data points correspond to Stoplight Table (Table E3-3)
GSL: Groundwater Screening Level

Sulfate - Time Series and Confidence Interval
KIF - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



Red or green data points correspond to Stoplight Table (Table E3-3)
GSL: Groundwater Screening Level

Total Dissolved Solids (TDS) - Time Series and Confidence Interval
KIF - Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area



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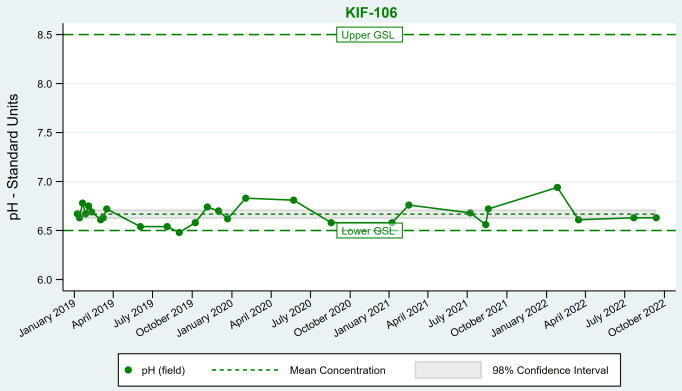

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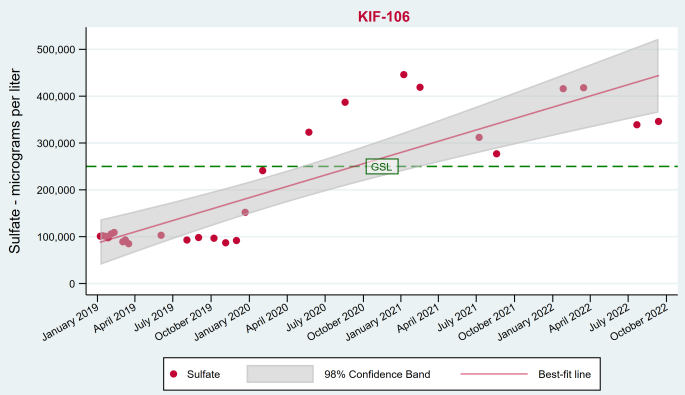

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Total Dissolved Solids (TDS) - Time Series and Confidence Band
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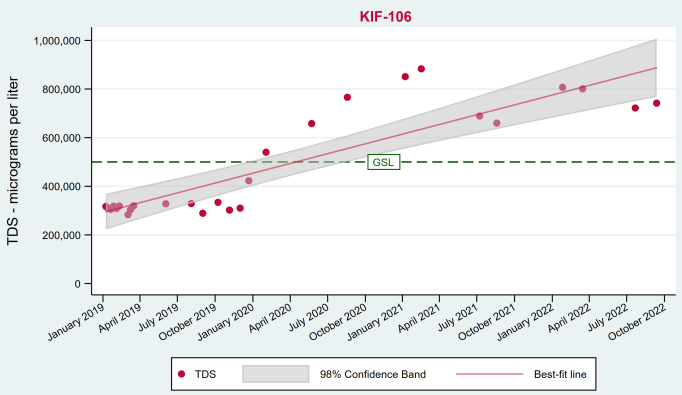

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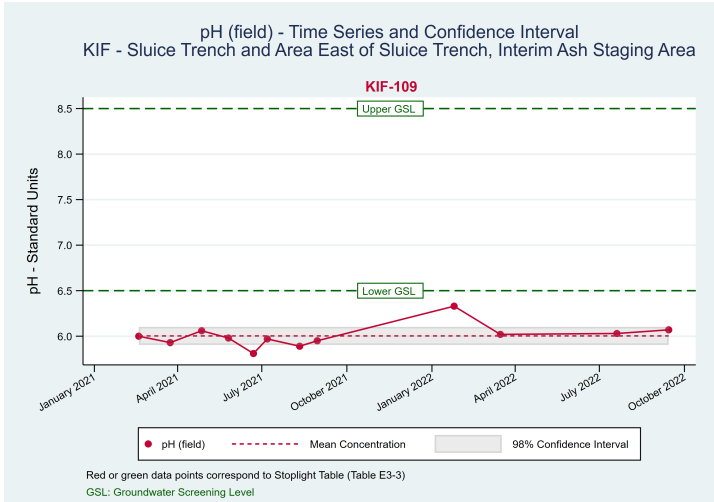

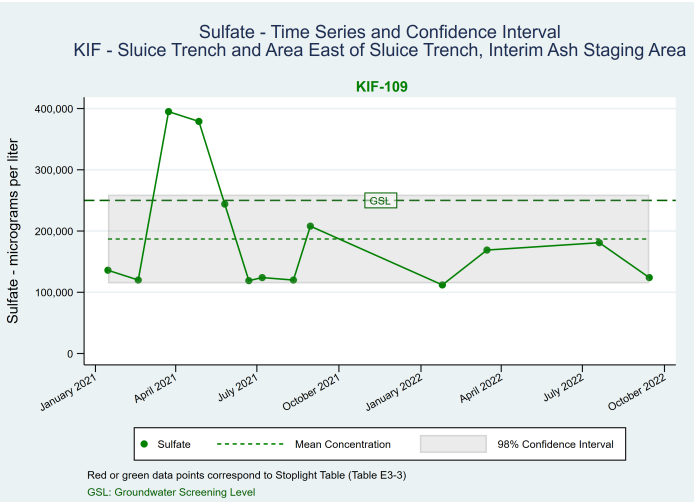

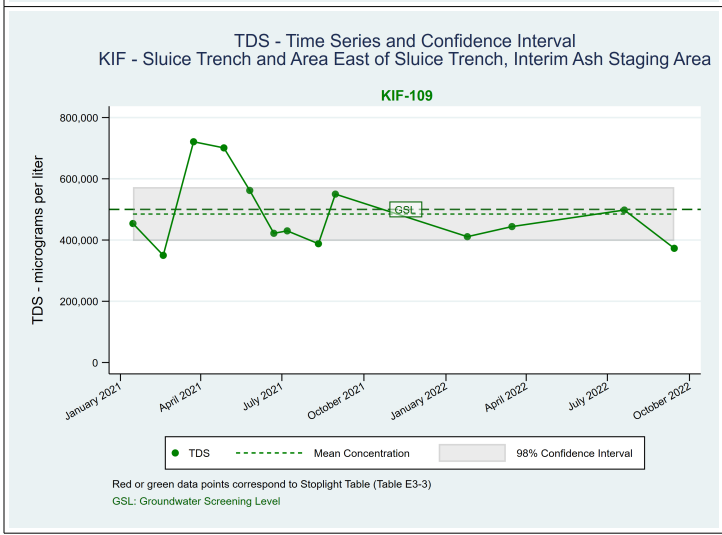

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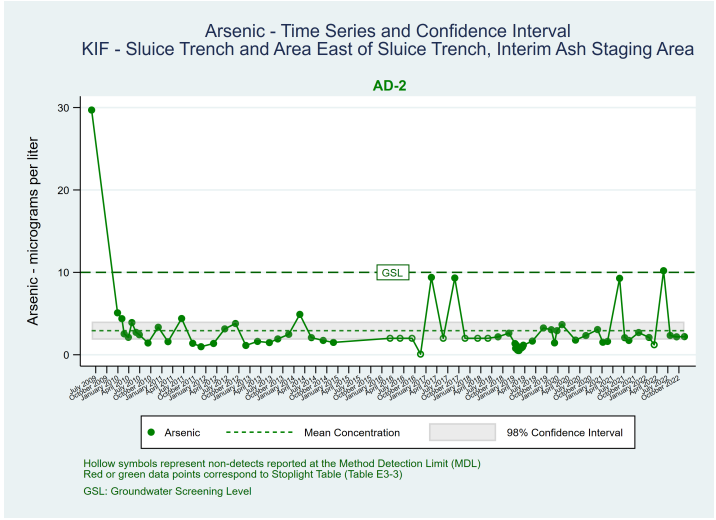
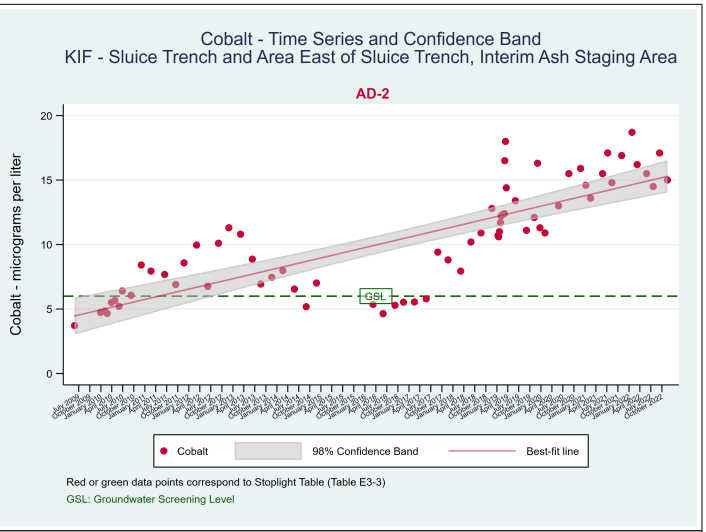
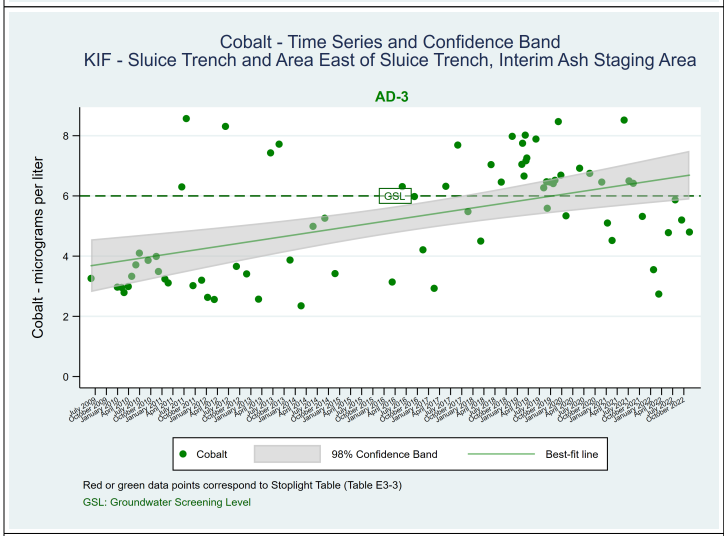
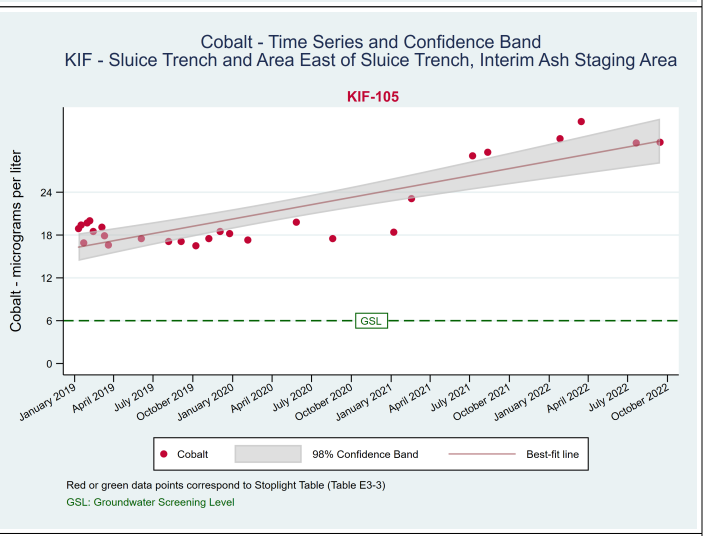
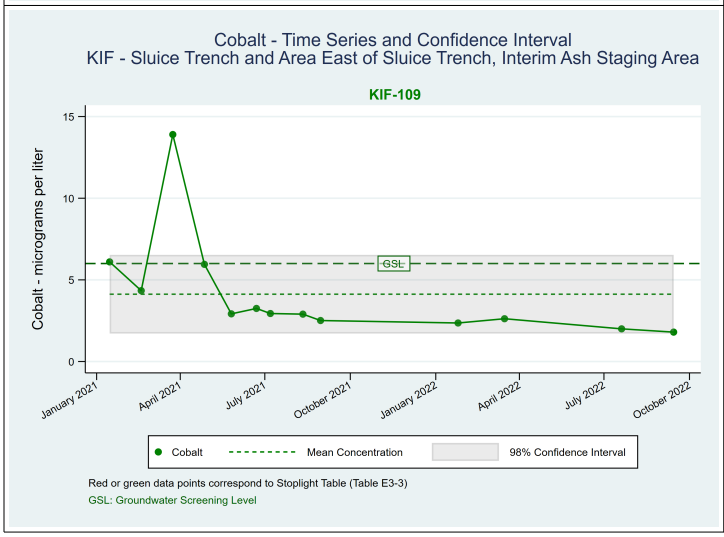
Regression Plots
Sluice Trench and Area East of Sluice Trench, Interim Ash Staging Area Wells
CCR Rule Appendix IV Parameters
Kingston Fossil Plant - Harriman, Tennessee











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ATTACHMENT E.3-E
LINEAR REGRESSION RESULTS

Attachment E.3-E - Linear Regression Results
Groundwater Investigation - Kingston Fossil Plant - Harriman, Tennessee

Well	Constituent Type	Constituent	p-value	Trend summary[1]
AD-1	CCR Rule Appendix III Parameters	pH	0.7739	No trend detected
GW-2	CCR Rule Appendix III Parameters	pH	0.3113	No trend detected
6AR	CCR Rule Appendix III Parameters	pH	0.0003	Increasing
		Sulfate	0.0063	Increasing
		Total Dissolved Solids	<0.0001	Increasing
	CCR Rule Appendix IV Parameters	Cadmium	0.2433	No trend detected
		Cobalt	<0.0001	Increasing
KIF-103	CCR Rule Appendix III Parameters	pH	0.0047	Increasing
	CCR Rule Appendix IV Parameters	Cobalt	0.0065	Decreasing
KIF-104	CCR Rule Appendix III Parameters	pH	0.1734	No trend detected
		Sulfate	0.0614	No trend detected
		Total Dissolved Solids	0.395	No trend detected
	CCR Rule Appendix IV Parameters	Arsenic	<0.0001	Decreasing
		Cobalt	0.3969	No trend detected
AD-2	CCR Rule Appendix III Parameters	pH	0.0086	Increasing
		Sulfate	<0.0001	Increasing
		Total Dissolved Solids	<0.0001	Increasing
	CCR Rule Appendix IV Parameters	Arsenic	0.1271	No trend detected
		Cobalt	<0.0001	Increasing
AD-3	CCR Rule Appendix III Parameters	pH	0.072	No trend detected
		Sulfate	<0.0001	Increasing
		Total Dissolved Solids	<0.0001	Increasing
	CCR Rule Appendix IV Parameters	Cobalt	<0.0001	Increasing
KIF-105	CCR Rule Appendix III Parameters	pH	0.0005	Decreasing
		Sulfate	0.08	No trend detected
		Total Dissolved Solids	0.0579	No trend detected
	CCR Rule Appendix IV Parameters	Cobalt	<0.0001	Increasing
KIF-106	CCR Rule Appendix III Parameters	pH	0.6825	No trend detected
		Sulfate	<0.0001	Increasing
		Total Dissolved Solids	<0.0001	Increasing
KIF-109	CCR Rule Appendix III Parameters	pH	0.1758	No trend detected
		Sulfate	0.3135	No trend detected
		Total Dissolved Solids	0.2954	No trend detected
	CCR Rule Appendix IV Parameters	Cobalt	0.0535	No trend detected

Notes:

CCR Rule - Title 40, Code of Federal Regulations, Part 257

1. Trend evaluated using linear regression. Regression considered significant when $p<0.05$.

2. Fluoride is both a CCR Rule Appendix III and CCR Rule Appendix IV constituent. In this table, fluoride has been grouped with the Appendix III constituents only to avoid duplication of results.

APPENDIX E.4

STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

Originally Published as Appendix D of the Seep Sampling and Analysis Report

Appendix D – Statistical Analysis of Water Quality Parameters

Kingston Fossil Plant
Seep Investigation

June 17, 2020

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

Revision Record

Revision	Description	Author		Quality Check		Independent Review	
0	Initial draft	Chris LaLonde	10/10/2019	Melissa Aslund	10/18/2019	Carole Farr	3/26/2020

Sign-off Sheet

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Carole Farr, Senior Principal Geologist

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Abbreviations

AOC	Area of Concern
AOI	Area of Interest
CCR	Coal Combustion Residuals
DO	Dissolved Oxygen
KIF	Kingston Fossil Plant
M/AOC#2	Historic seep M/AOC#3
SAP	Sampling and Analysis Plan
SAR	Sampling and Analysis Report
Stantec	Stantec Consulting Services Inc.
USEPA	United States Environmental Protection Agency
UTL	Upper Tolerance Level

APPENDIX D – STATISTICAL ANALYSIS OF WATER QUALITY PARAMETERS

June 17, 2020

1.0 INTRODUCTION

A statistical analysis of water quality parameter data collected in Emory River adjacent to the Kingston Fossil Plant (KIF Plant) was conducted as part of the seep investigation. The statistical analysis was used to evaluate whether there are statistically significant differences between monitoring results collected "adjacent to" and "upstream of" historical seep/Areas of Concern (AOC) locations and between intermediate and upstream control areas. This appendix to the KIF Plant seep investigation sampling and analysis report (SAR) presents the statistical approach and methods used for this analysis and the analysis results.

2.0 OBJECTIVE

The objective of the statistical analysis is to identify statistically significant differences between water quality parameter results measured "adjacent" to inaccessible historical seep/AOC locations and results measured "upstream" of those locations. As described in Section 3.2.1 of this SAR, four historical seep/AOC locations were identified and targeted for monitoring at the KIF Plant for the seep investigation.

An Area of Interest (AOI) is identified when statistically significant evidence indicates that: 1) water quality parameter results collected "adjacent" to historical seep/AOC locations are different than water quality parameter results collected "upstream" of historical seep locations/AOC for all four parameters, or 2) intermediate areas differ significantly from upstream control areas for all four parameters.

3.0 DATASETS

In accordance with the Seep Sampling and Analysis Plan (SAP), datasets were generated consisting of water quality parameter measurements for each of the four field parameters for each historical seepage location/AOC identified by Tennessee Valley Authority for evaluation. The data used in the statistical analysis were obtained in spreadsheet format from the "*Seep Investigation/ Surface Stream Field Parameter Measurement Forms"*, which were prepared in real time as the field investigation was being conducted. Statistical datasets were established based on proximity to individual or combined historical seep/AOC locations. A summary of the measurement location identifications and the number of measurements is provided in Table D.1.

In addition to the measurements associated with each of the four historical seep/AOC locations, measurements were also collected in intermediate areas between these locations. The distance between these measurements was typically 200 feet. Overall, this resulted in the collection of a total of 17 intermediate measurements, collected over five intermediate areas (Exhibit A.1; Appendix A).

Finally, data were also collected from two ”upstream control areas” and placed into two groups for evaluation: UC24 (measurements collected on April 24, 2019) includes upstream control locations KIF-UC-98 through KIF-UC-117, and UC25 (measurements collected on April 25, 2019) includes upstream control measurement locations KIF-UC-153 through KIF-UC-172 (Exhibit A.1; Appendix A). A total of 20 measurements were collected from each “upstream control area”. The distance between these measurements was approximately five feet.

Measurements collected from the intermediate areas were combined by location and compared statistically to measurements collected from the upstream control areas to identify statistically significant differences between each of the four parameters.

4.0 STATISTICAL ANALYSIS METHODS

In accordance with the Seep SAP, the following statistical analysis methods were used to evaluate the water quality parameter measurement results:

- Formal hypothesis testing was used to identify statistically significant differences between adjacent and upstream monitoring data for historic seep/AOC locations by comparison of mean parameter concentrations between the datasets; and
- Formal hypothesis testing was used to identify statistically significant differences between intermediate area data and control area data for intermediate area locations. Tolerance interval methods were utilized to assess differences between monitoring data collected in intermediate areas compared to control area(s).

The statistical analysis was conducted in three phases: 1) exploratory data analysis/outlier screening, 2) testing of statistical assumptions, and 3) formal hypothesis testing. These phases are discussed below. Analyses were conducted using United States Environmental Protection Agency (USEPA) ProUCL (version 5.1.002) and STATA Statistics and Data Analysis (version 15.1).

4.1 EXPLORATORY DATA ANALYSIS/OUTLIER SCREENING

Initially, the monitoring data associated with historical seep areas were plotted on time-series graphs and in box plots. Time-series graphs allow for the identification of trends, outliers, and to visually identify differences between water quality parameter measurements that were collected in a downstream to upstream direction. Box plots allow for the identification of outliers and provide a basic sense of the potential underlying statistical distributions. The time-series and box plots are presented in Attachment D.1. In addition to graphical analysis, descriptive statistics were calculated for each water quality parameter for each historical seep/AOC location, intermediate areas, and upstream control areas. A summary of the descriptive statistics is presented in Attachment D.2.

Following the calculation of descriptive statistics, the data was screened for possible outliers. Outliers are data points that are abnormally high or low as compared to the rest of the measurements and may represent anomalous data and/or data errors. Outliers may also represent natural variation of constituent concentrations in environmental systems. During the seep investigation, water quality parameters were measured at intermediate area locations, upstream control locations and downstream, adjacent and upstream of historical seeps/AOC locations. Utilizing the complete set of data to screen for the presence of outliers allowed for evaluation of potential spatial variation in the natural ecosystem. Screening for outliers is a critical step as outliers can bias the statistical testing results.

Outliers are identified graphically using side by side box plots and time-series graphs (Attachment D.1). Suspect visual outliers were further analyzed to determine if they are extreme outliers. The Tukey's procedure (Tukey, 1977) as outlined in the USEPA document*: "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance"* (USEPA 2009) – (Unified Guidance) was used to identify extreme outliers. The Tukey's procedure is briefly outlined below:

***Lower extreme outlier*:** The value is less than: 25^{th} percentile – (3 x interquartile range)

or

Upper extreme outlier: The value is greater than: 75^{th} percentile + (3 x interquartile range)

where:

Interquartile Range = 75^{th} percentile value – 25^{th} percentile value

If an outlier was identified visually and considered extreme (Tukey's procedure), then formal statistical testing (Dixon's and/or Rosner tests) was conducted to confirm that the data point is a statistically significant outlier. Utilizing the procedures outlined above, no outliers were identified or removed from the analytical dataset.

4.2 TEST OF STATISTICAL ASSUMPTIONS

In environmental applications, formal hypothesis testing is commonly used to compare mean values between two "populations". In the case of the investigation of historical seep/AOCs locations at the KIF Plant, the populations can be defined as monitoring results collected ***adjacent*** to the historical seep/AOC and monitoring results collected immediately ***upstream*** of the historical seep/AOC location. In the case of the investigation of intermediate areas, the population can be defined as monitoring results collected in the ***intermediate areas*** and monitoring results collected in the ***upstream control areas***.

Two sample t-tests were used to identify statistically significant differences between monitoring data collected adjacent to historical seeps/AOCs and data collected immediately upstream. As with most statistical tests, t-tests must meet statistical assumptions in order to produce reliable statistical conclusions. T-tests have two statistical assumptions: 1) the data "fit" or can be transformed to fit the normal distribution, and 2) the variance of each population being compared are equal (homoscedasticity).

The assumption of normality was tested visually using Normal Q-Q plots and statistically using the Shapiro-Wilks Test (alpha 0.01). Data for each parameter in adjacent and upstream measurements were normally distributed. Normal Q-Q plots are presented in Attachment D.3. The assumption of homoscedasticity was tested using the F-Test for the Equality of Two-Variances. In instances where variances were not equal, the Satterthwaite's degrees of freedom were used to adjust for unequal variances. The results of the evaluation of normality and equality of variances between the upstream and adjacent measurement locations are presented in Table D.2.

4.3 FORMAL HYPOTHESIS TESTING

The objective of formal hypothesis testing is to determine whether mean water quality parameter monitoring results for the "adjacent" datasets are statistically different than the results for the "upstream" datasets. Hypothesis tests are standard statistical methods used to decide between two competing alternatives based on available data. Uncertainties arise when sample statistics are used as estimates of "true" but unknown population parameters (mean, standard deviation). Hypothesis testing provides the framework for managing these uncertainties and controlling potential decision errors (Ofungwu, 2014).

Hypothesis tests are set up based on two competing alternatives. The null hypothesis (H_o) represents baseline conditions or conditions of no effects/differences. The null hypothesis can be represented mathematically as:

H_o: Mean Adjacent – Mean Upstream = 0; or Mean Adjacent = Mean Upstream

The alternative hypothesis is simply the opposite of the null hypothesis and can be written as:

H_a: Mean Adjacent – Mean Upstream ≠ 0

If there is an *a priori* idea that a parameter's mean may be greater than or less than the upstream mean the alternative hypothesis can be written as:

H_a: Mean Adjacent – Mean Upstream < 0 or Mean Adjacent – Mean Upstream > 0

The former alternative hypothesis is considered a two-sided test (e.g., it is unknown if the difference will be higher or lower and therefore, need to account for both possibilities). The later alternative hypotheses are considered a one-sided test (e.g., there is *a priori* knowledge of the direction of change – the parameter measurement is expected to be higher or lower when comparing adjacent to upstream monitoring data).

Appropriate hypothesis tests were established prior to examining the data. Two-sided tests were used to evaluate pH and temperature as there is no *a priori* knowledge that these parameters are expected to be higher or lower when comparing adjacent to upstream monitoring data. However, one-sided tests were used to evaluate specific conductance and DO based on the following assumptions: 1) the specific conductance would be expected to be higher adjacent to an active seep as opposed to upstream due to expected higher concentrations of metals in water emanating from a Coal Combustion Residuals (CCR) unit and 2) the DO would be expected to be lower adjacent to an active seep in a similar area as opposed to DO in a surface stream.

The null and alternative hypotheses for the seep investigation are presented below:

- Specific Conductance (SC - microSiemens/centimeter)
  - H_o: Mean $SC_{Adjacent}$ - Mean $SC_{Upstream} = 0$
  - H_a: Mean $SC_{Adjacent}$ – Mean $SC_{Upstream} > 0$
- pH (Standard Units)
  - H_o: Mean $pH_{Adjacent}$ – Mean $pH_{Upstream} = 0$
  - H_a: Mean $pH_{Adjacent}$ – Mean $pH_{Upstream} \neq 0$
- Temperature (Temp – degrees Celsius)
  - H_o: Mean $Temp_{Adjacent}$ – Mean $Temp_{Upstream} = 0$
  - H_a: Mean $Temp_{Adjacent}$ – Mean $Temp_{Upstream} \neq 0$
- DO (milligrams/Liter)
  - H_o: Mean $DO_{Adjacent}$ – Mean $DO_{Upstream} = 0$
  - H_a: Mean $DO_{Adjacent}$ – Mean $DO_{Upstream} < 0$

Statistical hypothesis tests produce a p-value (probability value). The p-value represents the probability that the mean of the adjacent measurements is equal to the mean of the upstream measurements. If the p-value of a statistical test is ***small*** *(i.e., below the significance level)*, the normal procedure is to reject the null (Ho), accept the alternative (Ha), and conclude there is a ***statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance.***

The statistician establishes the "significance level" (α), which is typically set between 0.01 and 0.10. This can be thought of as an acceptable false positive rate (e.g., rejecting the null when the null is true, which is equivalent to finding a statistically significant difference between adjacent and upstream monitoring data, when in fact one does not exist).

The significance level for a single test needs to be adjusted in situations where multiple hypothesis tests are going to be conducted at a site. Conducting multiple statistical tests on a site increases the chances of getting a significant result simply by chance (e.g. false positive statistical test result). For example, 16 statistical tests were conducted at the KIF Plant to identify differences in adjacent and upstream water quality parameter monitoring data for the seep investigation; if alpha is set at 0.1 and the multiple testing is ignored, then the cumulative error rate can be calculated:

Cumulative error rate = $1-(1-0.1)^{16}$ = 81% chance of making false positive error

The Bonferroni correction was utilized to adjust the significance level to control the site-wide false positive rate described above. This method simply divides the desired overall significance level (0.10) by the number of hypothesis tests conducted site-wide (4 parameters x 4 historic seeps/AOCs = 16 tests). For the KIF Plant, the adjustment yields an individual test significance level of 0.1/16 tests = 0.00625. Therefore, to reject the null and determine that there is a statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance, the p-value of the test needs to be less than 0.00625.

All data followed the normal distribution parametric T-tests utilized. In the case where variances were not equal between adjacent and upstream measurements, the Satterthwaite two-sample T-test was used to account for unequal variances.

4.4 TOLERANCE INTERVALS

Tolerance limits consist of two values expected to contain a pre-specified proportion of the underlying data population with a specified level of confidence. For example, for a 95% tolerance interval with a 95% confidence level, there is 95% confidence that, on average, 95% of the data population is contained within the interval. The one-sided Upper Tolerance Level (UTL) is commonly used in environmental monitoring and is constructed using background data (Ofungwu, 2014).

The calculation of the UTL is straightforward:

$$UTL = \overline{x} + \tau s$$

Where:

$\overline{x}$ = mean constituent concentration in background dataset

s = standard deviation of constituent in background dataset

τ = tau multiplier - based on size of dataset, confidence (95%) and desired coverage (95%)

Two sets of tolerance intervals were calculated for each parameter using data collected from control area UC24 (n=20) and UC25 (n=20), respectively. Prior to calculating tolerance intervals, the data were tested for normality and for outliers using methods described previously. All control area datasets were free of outliers and were normally distributed.

The statistical null hypothesis (H_o) is that mean parameter measurements collected from intermediate areas lie within the tolerance interval, and the alternate hypothesis (H_a) is that the mean parameter measurements are outside of the tolerance interval. In order to test these hypotheses, 95% confidence intervals around the mean parameter measurements from the intermediate area data were estimated and compared to the upstream control area tolerance intervals. Prior to calculating confidence intervals, the intermediate area monitoring data were pooled and tested for normality and for outliers using methods described previously. The intermediate area dataset was free of outliers and was normally distributed.

Confidence intervals were calculated based on the following equation:

$$Confidence\ Interval = \overline{x} +/- t_{1-\propto/2,n-1} * s/\sqrt{n}$$

Where,

$\overline{x}$ = mean parameter measurement in intermediate area

s = standard deviation of parameter measurement in intermediate area

n = number of measurements in intermediate area dataset

$t_{(1-\propto/2,n-1)}$ = two tailed t value, with n-1 degrees of freedom (where α = 0.05)

Statistically significant differences were identified if the confidence interval calculated using the intermediate area dataset falls outside of the applicable upstream control area tolerance interval.

5.0 STATISTICAL ANALYSIS RESULTS

The following sections describe the results of 1) the hypothesis testing comparing the water quality parameter results between the adjacent and upstream measurements at each of the four historical seep/AOC locations, and 2) the interval testing comparing the water quality parameter results from intermediate areas to two upstream control areas.

5.1 HYPOTHESIS TESTING RESULTS: ADJACENT AND UPSTREAM MEASUREMENT COMPARISONS AT HISTORIC SEEP/AOC LOCATIONS

A historic seep/AOC is considered an AOI when the mean values of all four water quality parameters (DO, pH, specific conductance and temperature) are found to be statistically different when comparing adjacent to upstream monitoring data. For pH and temperature, the difference between upstream and adjacent measurements may be either positive or negative. However, it is expected that an active seep would increase specific conductance (due to higher concentrations of metals in water emanating from a CCR unit) and decrease DO (as seep water from a similar area would have decreased DO relative to a surface stream). Therefore, only significant increases in specific conductance and significant decreases in DO in the adjacent areas, relative to the upstream areas were evaluated. Table D.3 provides a summary of the hypothesis testing, including the p-values obtained using procedures described in preceding sections to identify significant differences between adjacent and upstream water quality parameter monitoring data at the four identified historical seep/AOC locations. None of the evaluated historical seep locations/AOCs were observed to have statistically significant values across all four prescribed parameters. Therefore, no AOIs were identified for further investigation or data collection.

5.2 INTERVAL TESTING RESULTS: INTERMEDIATE AREA COMPARISON TO UPSTREAM CONTROL AREAS

Water quality parameter monitoring results collected from intermediate areas were evaluated against monitoring data collected from upstream control location groups (UC24 and UC25) to identify any AOIs. A visual comparison of the upstream control data suggests that there is a difference between water quality parameter readings between the two upstream control locations. Box plots comparing the distributions of the two upstream control areas are presented in Attachment D.1. The visual observations were confirmed using hypothesis testing; all four parameters were statistically significantly different when comparing UC24 to UC25. The differences are possibly due to physical location (i.e., UC25 is further north and located 'around the bend' of the river from investigated historical seep/AOC locations except for historic seep M/AOC#3 (M/AOC#3)).

To account for potential differences between upstream control locations, water quality parameter readings for intermediate areas north of M/AOC#3 were compared to the results from UC25; all other intermediate area readings were compared to the results from UC24. For an intermediate area to be considered an AOI, the mean values of all four water quality parameters (DO, pH, specific conductance and temperature) are required to be statistically different when monitoring data collected from intermediate areas are compared to data collected in the upstream control areas. Table D.4 presents a summary of the interval testing results used to identify significant differences between intermediate areas and upstream control location monitoring data. This analysis did not identify any additional AOIs for further investigation.

6.0 REFERENCES

Ofungwu, J., 2014. *Statistical Applications for Environmental Analysis and Risk Assessment*. Hoboken, New Jersey: John Wiley and Sons, Inc.

Tukey, J.W., 1977. *Exploratory Data Analysis*. Reading, Massachusetts: Addison-Wesely, 1977

U.S. Environmental Protection Agency, 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*.

TABLES

TABLE D.1 – Summary of Water Quality Parameter Measurement Locations
Kingston Fossil Plant
April 2019

Historical Seep / AOC Locations	Measurement Location IDs	Number of Measurements		
		Downstream	Adjacent	Upstream
L/AOC#2	KIF-LAOC2-D-2 through KIF-LAOC2-U-30	10	8	11
HSK	KIF-HSK-D-35 through KIF-HSK-U-63	10	9	10
HSCluster-(C,R)	KIF-HSCR-D-69 through KIF-HSCR-U-96	10	8	10
M/AOC#3,HSD	KIF-MAOC3HSD-D-119 through KIF-MAOC3HSD-U-147	10	9	10

Notes:

1. Historic Seep (HS) and Area of Concern (AOC) locations and measurement location identications (IDs) are shown on Exhibits A.1 through A.3.

TABLE D.2 – Tests of Normality and Equality of Variances between Adjacent and Upstream Monitoring Results
Kingston Fossil Plant
April 2019

	Historical Seep/AOC Location			
Monitoring Parameters	**L/AOC#2**	**HSK**	**HS Cluster-(C,R)**	**M/AOC#3,HSD**
Number of Samples (Adjacent / Upstream)	8 / 11	9 / 10	8 / 10	9 / 10
Dissolved Oxygen	Normal / =	Normal / =	Normal / ≠	Normal / ≠
pH	Normal / ≠	Normal / =	Normal / =	Normal / ≠
Specific Conductance	Normal / =	Normal / =	Normal / =	Normal / =
Temperature	Normal / =	Normal / ≠	Normal / =	Normal / =

Notes:

=	Variances are equal when comparing adjacent and upstream data sets
≠	Variances are not equal when comparing adjacent and upstream data sets
AOC	Historical Area of Concern
HS	Historical Seep
Normal	Data Sets (adjacent and upstream) are normally distributed (alpha=0.01)

TABLE D.3 – Summary of Statistical Hypothesis Testing
Kingston Fossil Plant
April 2019

Historical Seep/ AOC Location	Number of Samples	p-value			
		DO	pH	Specific Conductance	Temperature
	Adjacent / Upstream	mg/L	SU	uS/cm	DEG C
L/AOC#2	8 / 11	0.9911	0.0699	0.1115	*0.0043*
HSK	9 / 10	0.0968	*0.0024*	0.1032	*0.0032*
HS Cluster-(C,R)	8 / 10	0.8677	0.3919	0.1039	*0.0026*
M/AOC#3, HSD	9 / 10	0.9926	*0.0000*	0.6558	*0.0004*

Notes:

AOC	Historical Area of Concern
DEG C	degrees Celsius
DO	Dissolved Oxygen
HS	Historical Seep
mg/L	milligrams per Liter
SU	Standard Units
SWFPR	site-wide false positive rate
uS/cm	microSiemens per centimeter

1. The p-value represents the probability that the mean of the adjacent measurements is equal to the mean of the upstream measurements. If a p-value is small (i.e., below the significance level), it is indicative that there is a statistically significant difference between adjacent and upstream monitoring results that is unlikely to have occurred by chance.

2. Adjusted Significance Level (SWFPR/No. of Statistical Tests): 0.10/16 = 0.00625

3. Shaded values indicate a statistically significant difference between measurements at relative locations to historical seeps/AOCs (p-value is below adjusted significance level, reject null hypothesis).

TABLE D.4 – Summary of Intermediate Area Statistical Testing
Kingston Fossil Plant
April 2019

Parameter	Confidence Interval Intermediate Area 1 [a]	Tolerance Interval UC 25	Tolerance Interval Significant?	Confidence Interval Intermediate Area 2 [b]	Tolerance Interval UC 24	Tolerance Interval Significant?
Dissolved Oxygen	(7.482 - 8.51)	(7.164 - 9.11)	No	(7.961 - 8.657)	(7.209 - 8.375)	No
pH	*(7.718 - 7.89)*	*(7.278 - 7.514)*	*Yes*	(6.813 - 7.149)	(7.071 - 7.251)	No
Specific Conductance	*(57.68 - 62.88)*	*(48.17 - 52.19)*	*Yes*	*(51.03 - 56.87)*	*(46.24 - 47.8)*	*Yes*
Temperature	(19.34 - 19.82)	(18.77 - 19.65)	No	(15.02 - 16.18)	(15.97 - 18.47)	No

Notes:

%	percent
UC	Upstream Control

[a] Confidence Interval: 95% confidence interval from intermediate areas north of M/AOC#3.

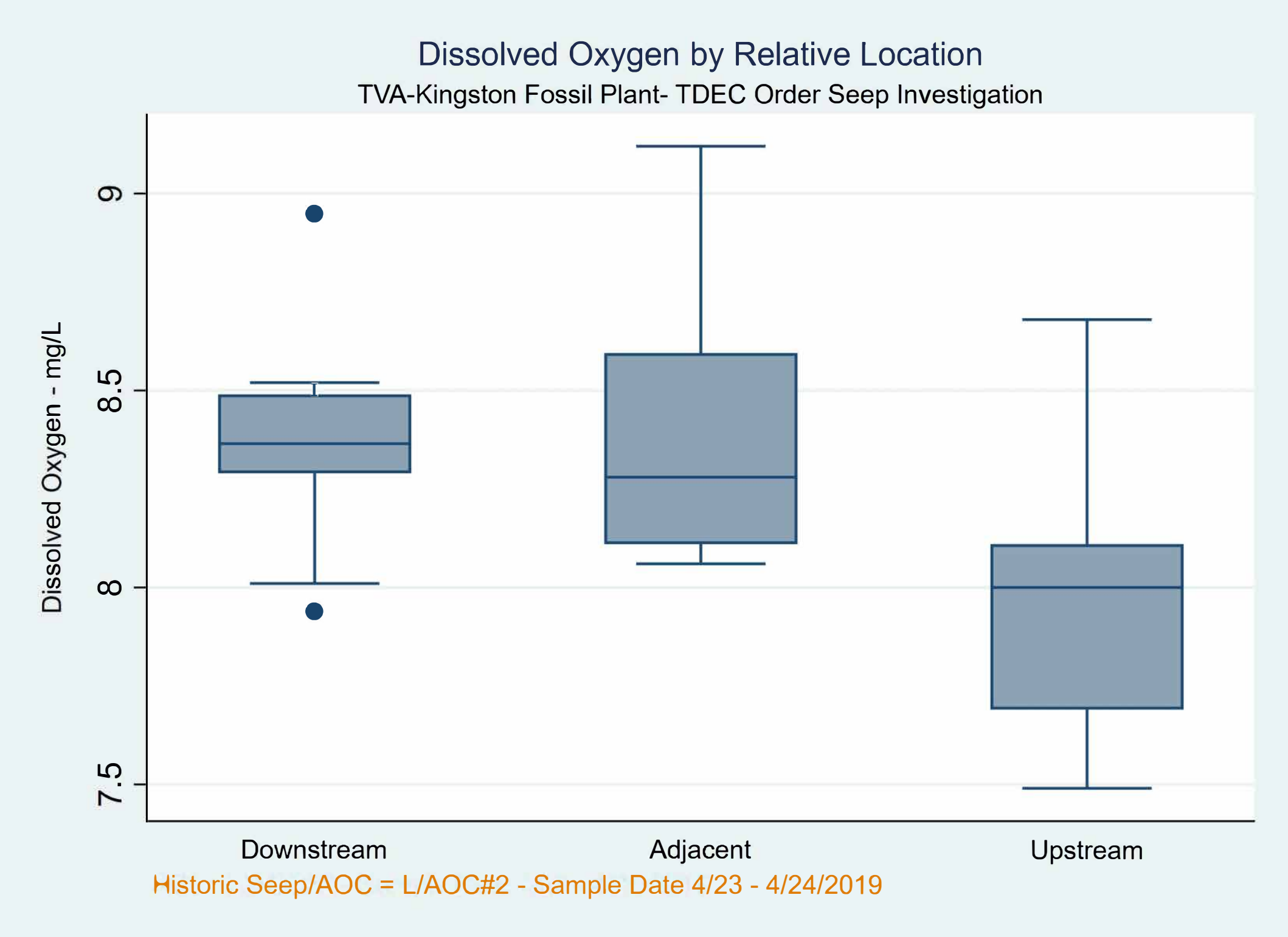
[b] Confidence Interval: 95% confidence interval from intermediate areas south of M/AOC#3.

1. Tolerance Interval: 95% tolerance interval with 95% coverage.
2. Shaded values are statistically significant differences if the confidence interval calculated using the intermediate area data set falls outside of the tolerance interval.

ATTACHMENTS

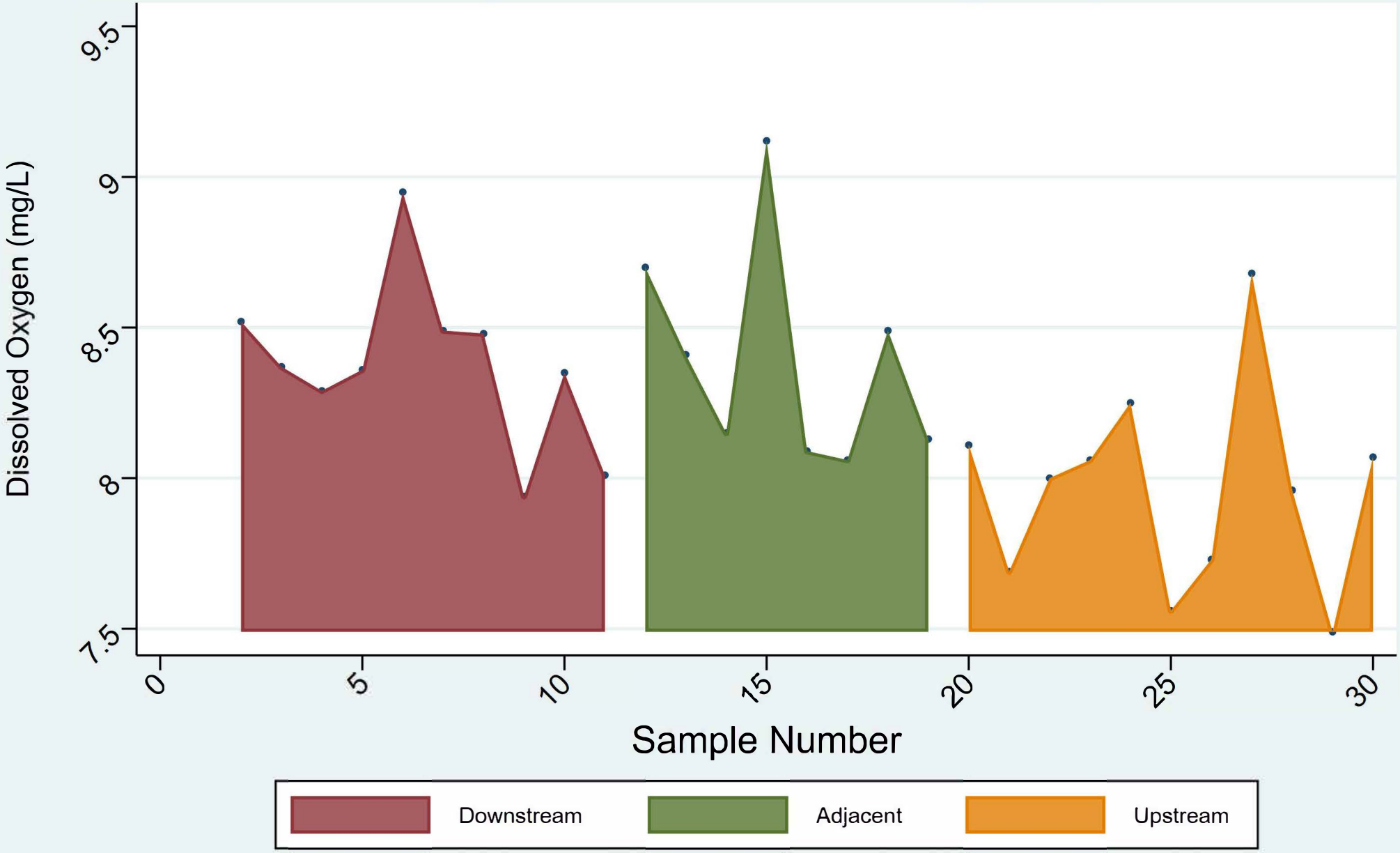
ATTACHMENT D.1

Time-Series and Box Plots

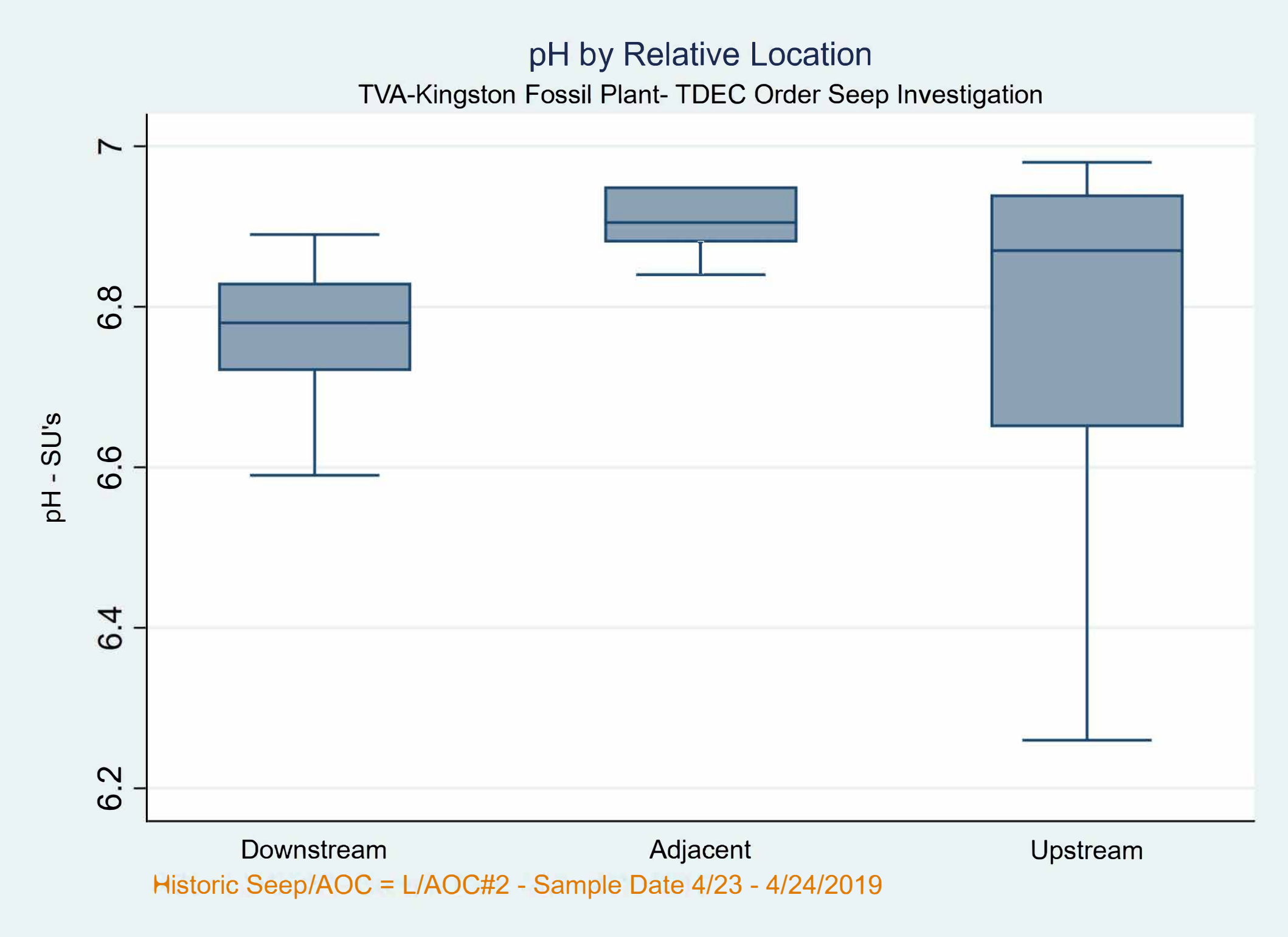

Dissolved Oxygen by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Dissolved Oxygen - mg/L
9
8.5
8
7.5
Downstream
Adjacent
Upstream
Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

Time Series - Dissolved Oxygen

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

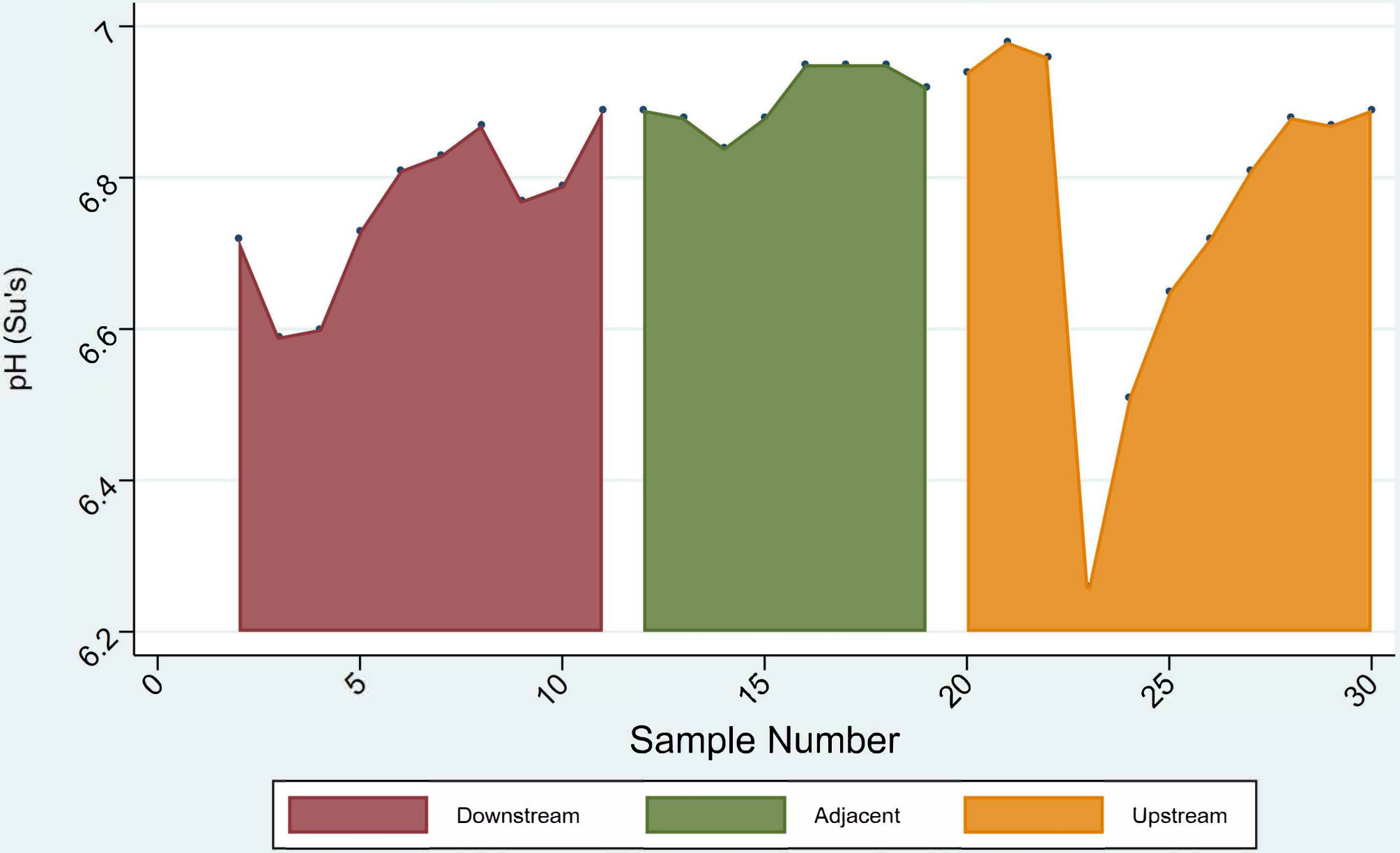


Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

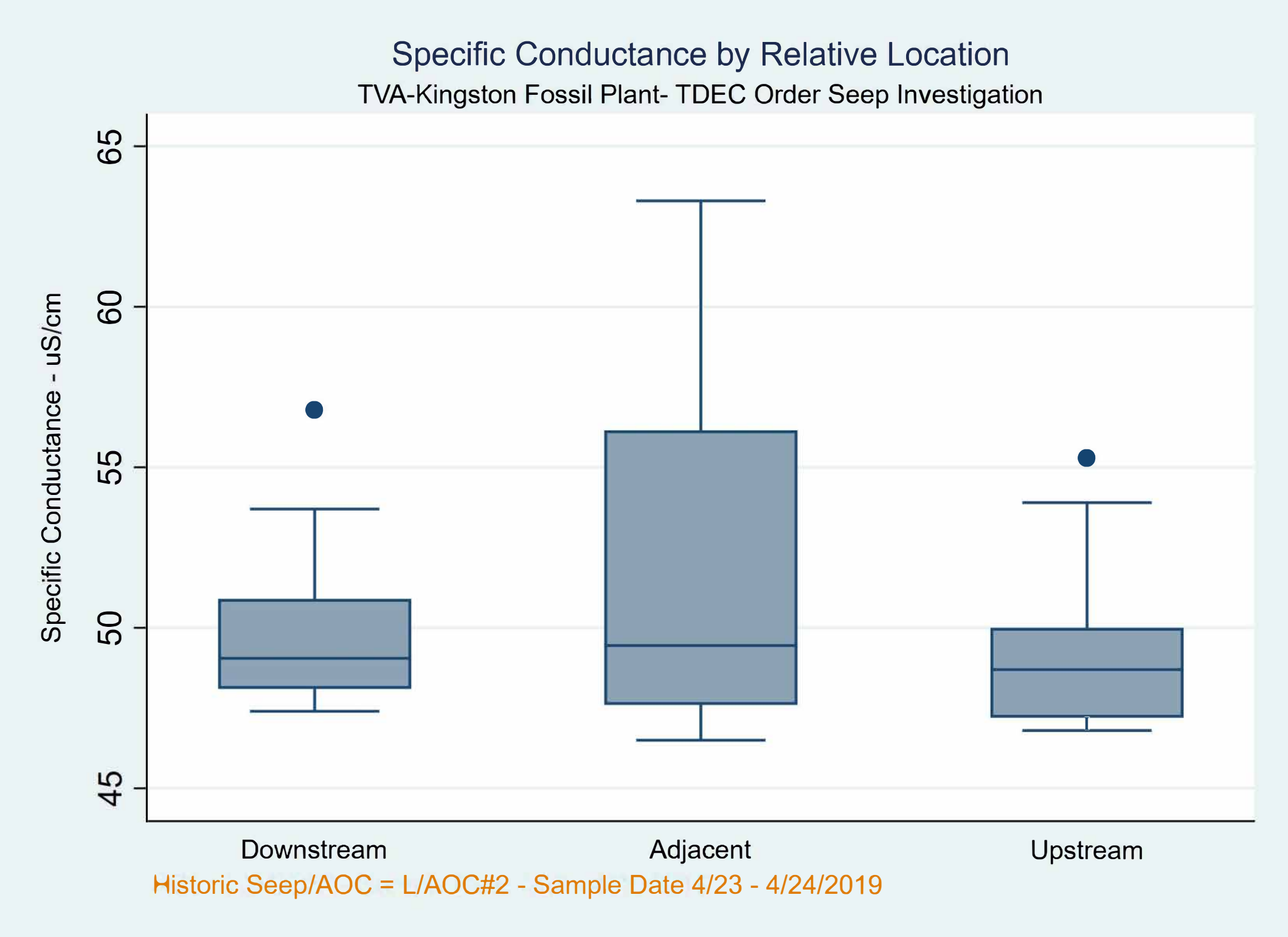

pH by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
pH - SU's
7
6.8
6.6
6.4
6.2
Downstream
Adjacent
Upstream
Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

Time Series - pH

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

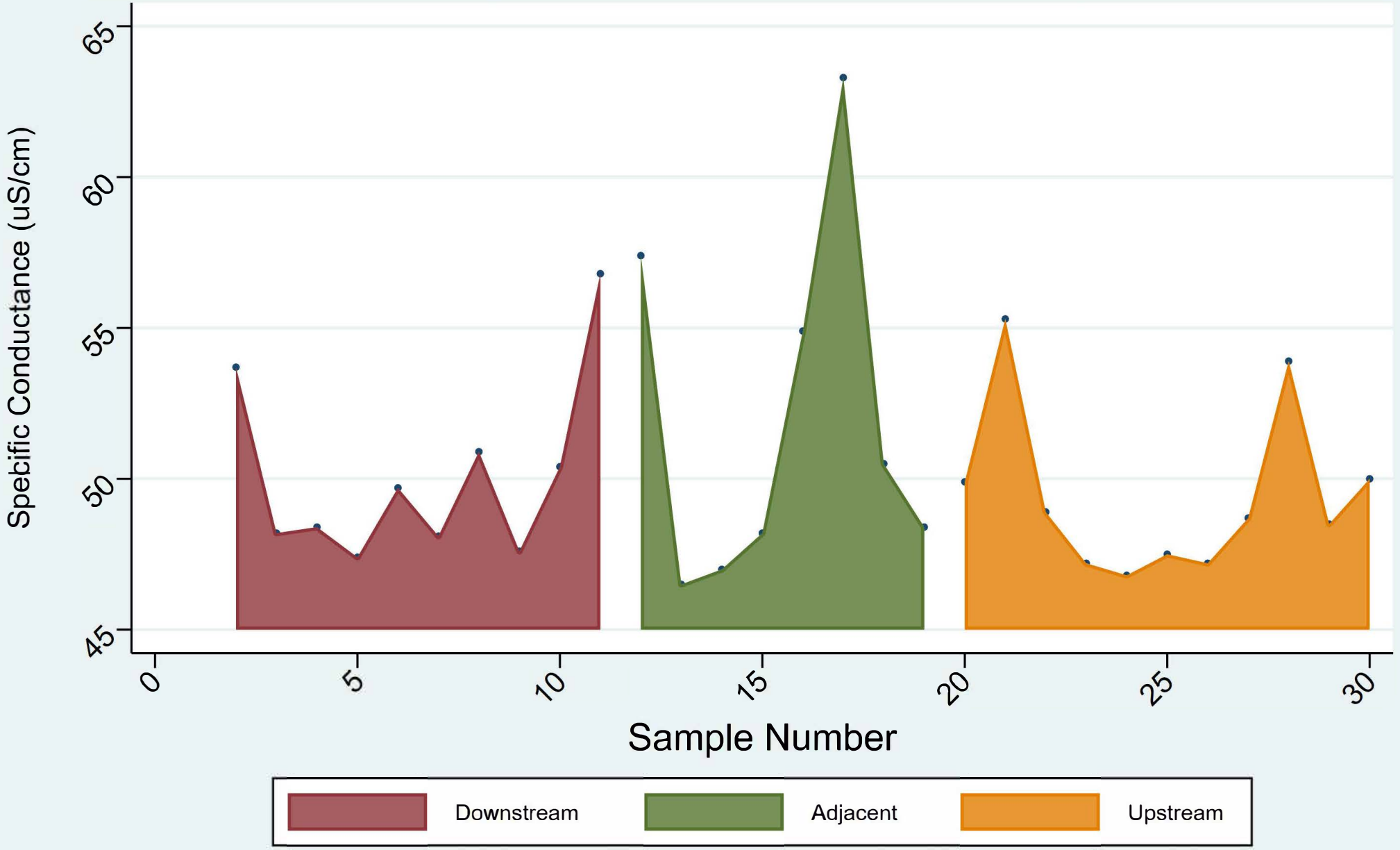


Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

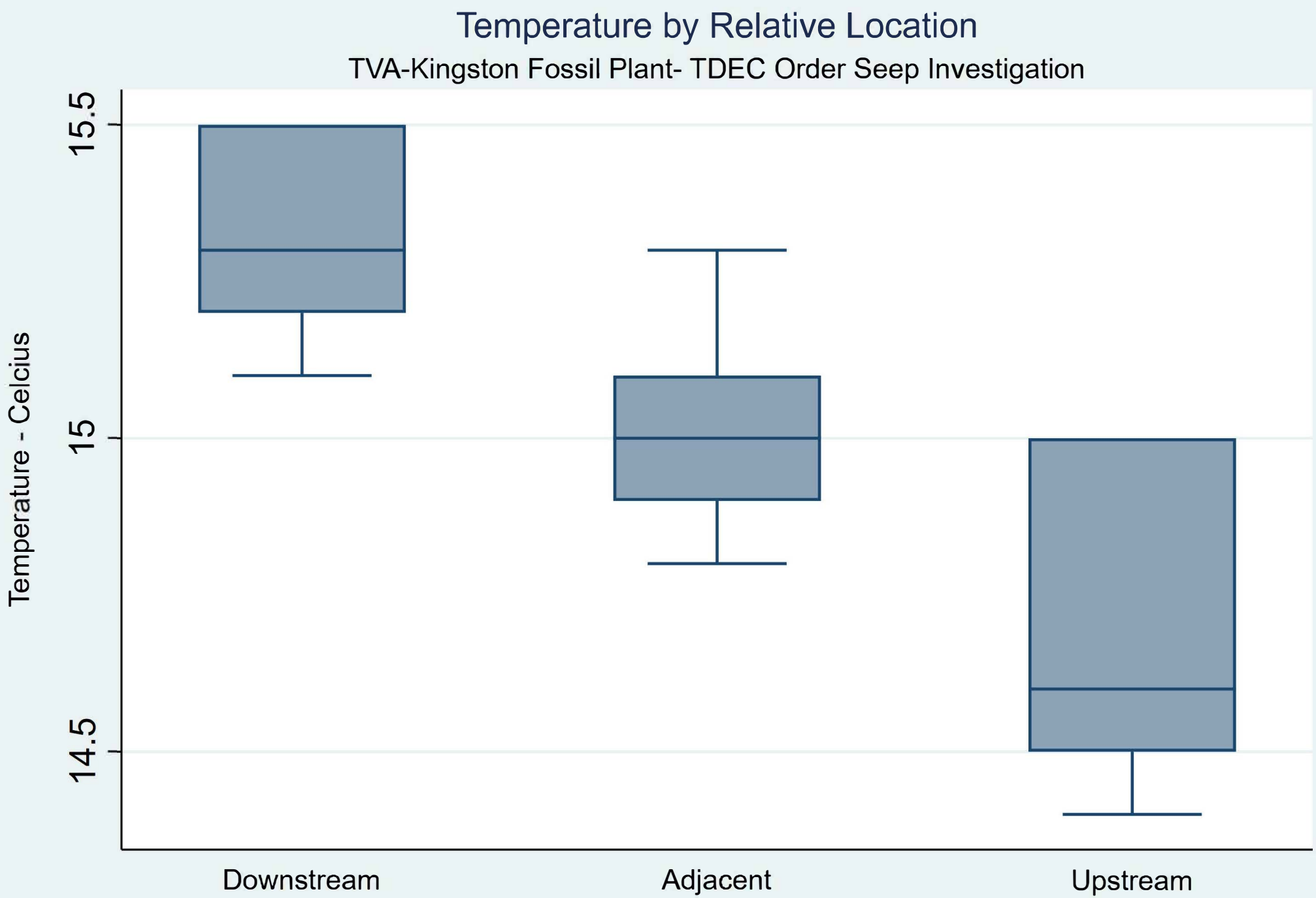

Specific Conductance by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Specific Conductance - uS/cm
65
60
55
50
45
Downstream
Adjacent
Upstream
Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

Time Series - Specific Conductance

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

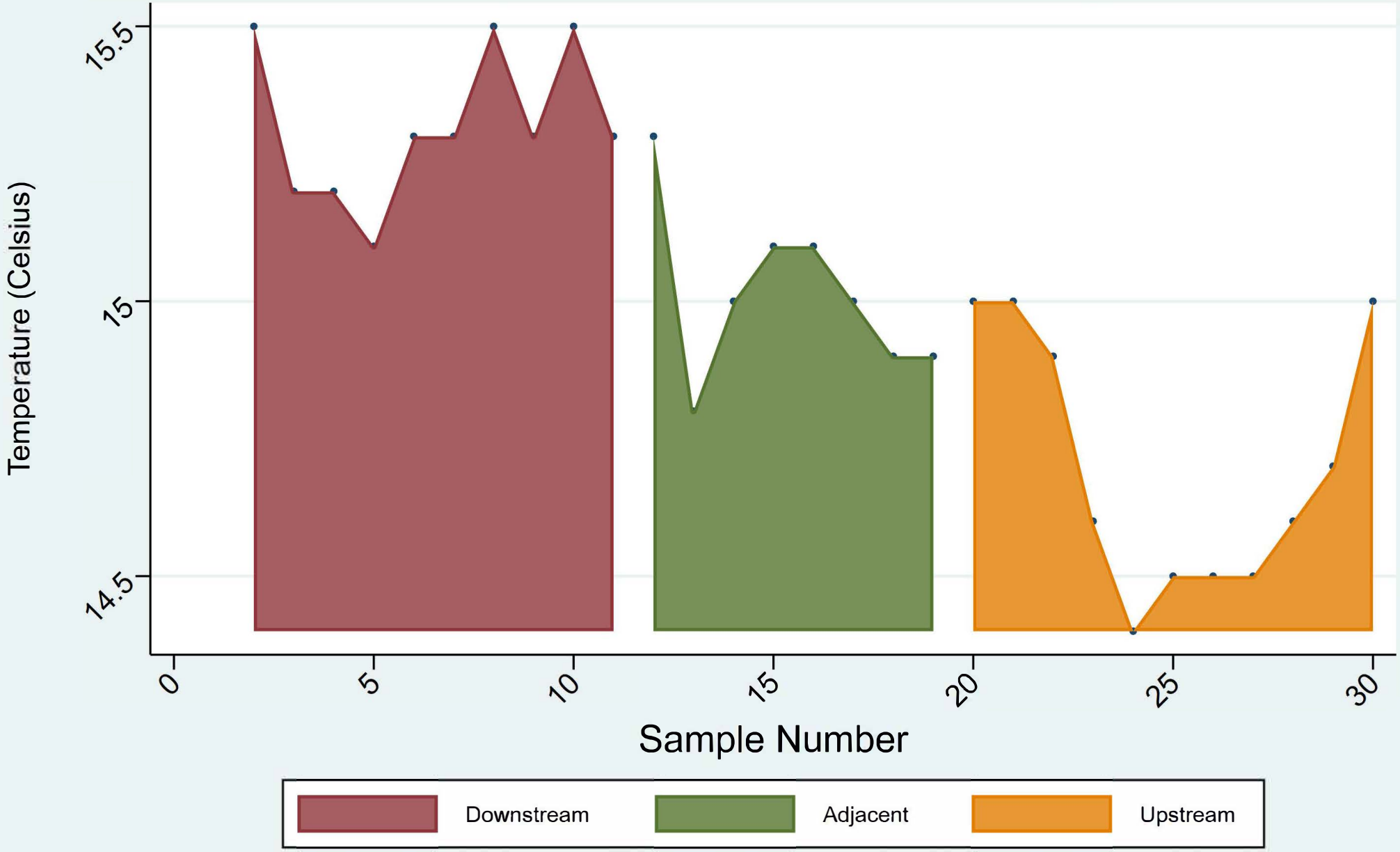


Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

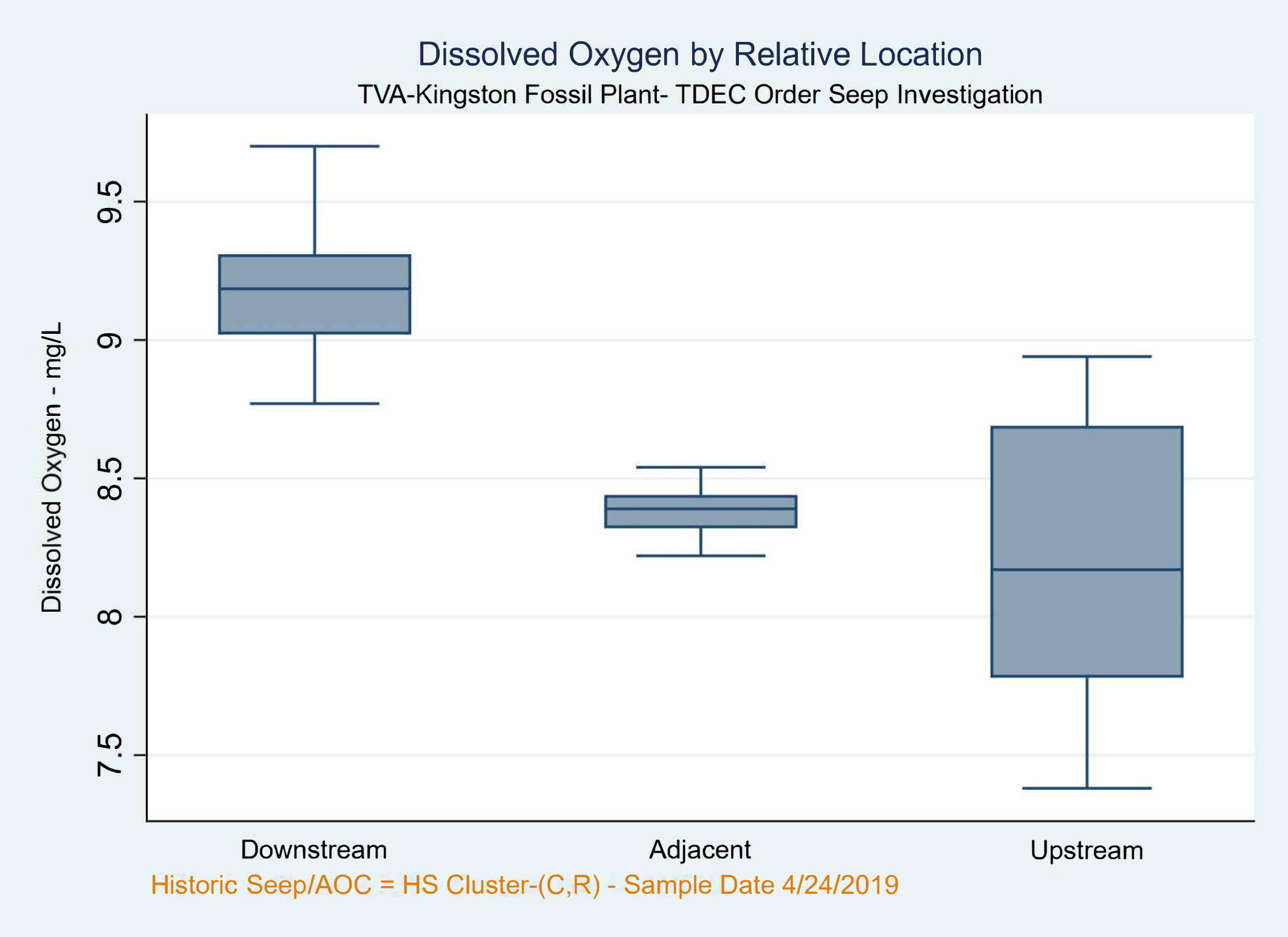

Temperature by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Temperature - Celcius
15.5
15
14.5
Downstream
Adjacent
Upstream
AHistoric Seep/OC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

Time Series - Temperature

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

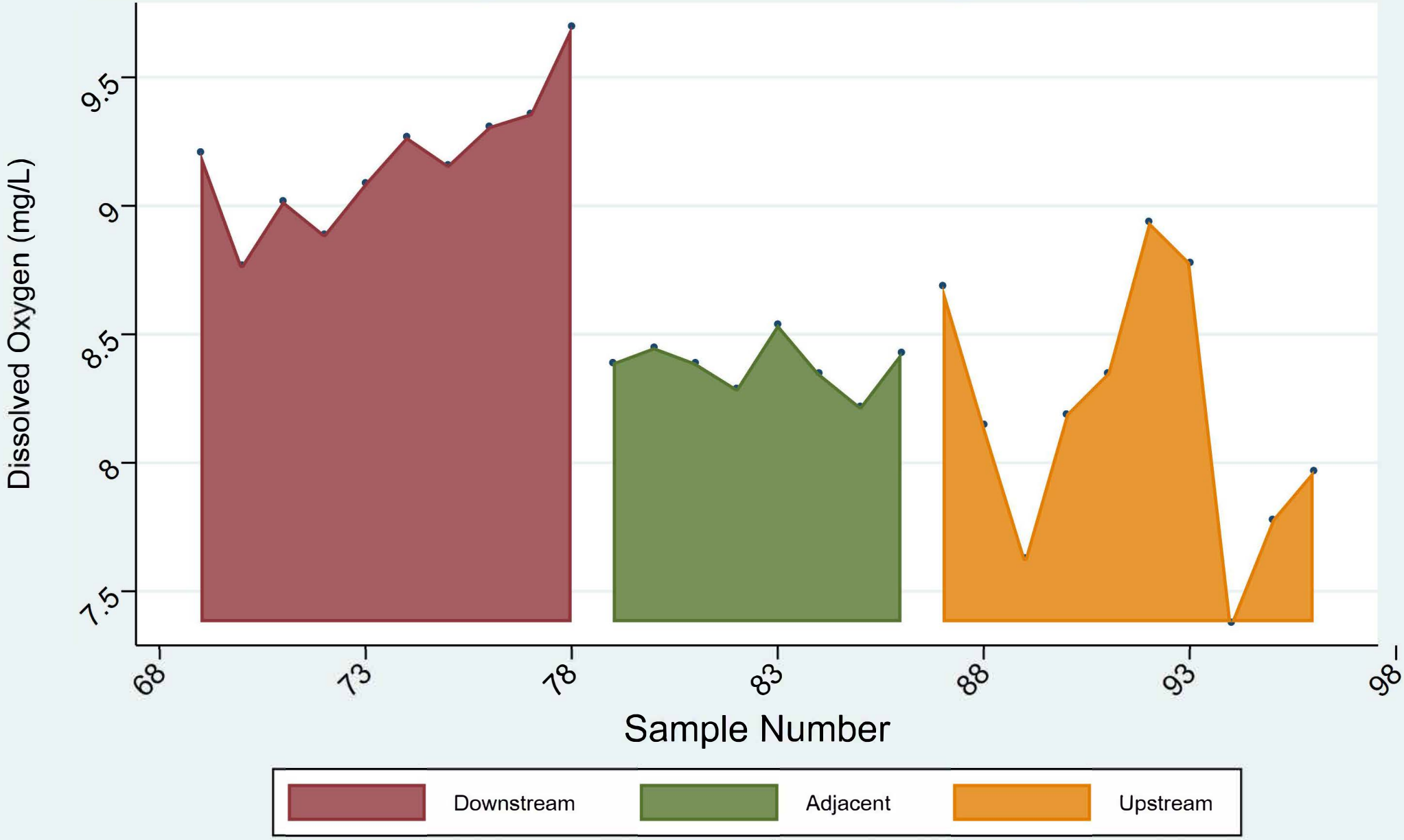


Historic Seep/AOC = L/AOC#2 - Sample Date 4/23 - 4/24/2019

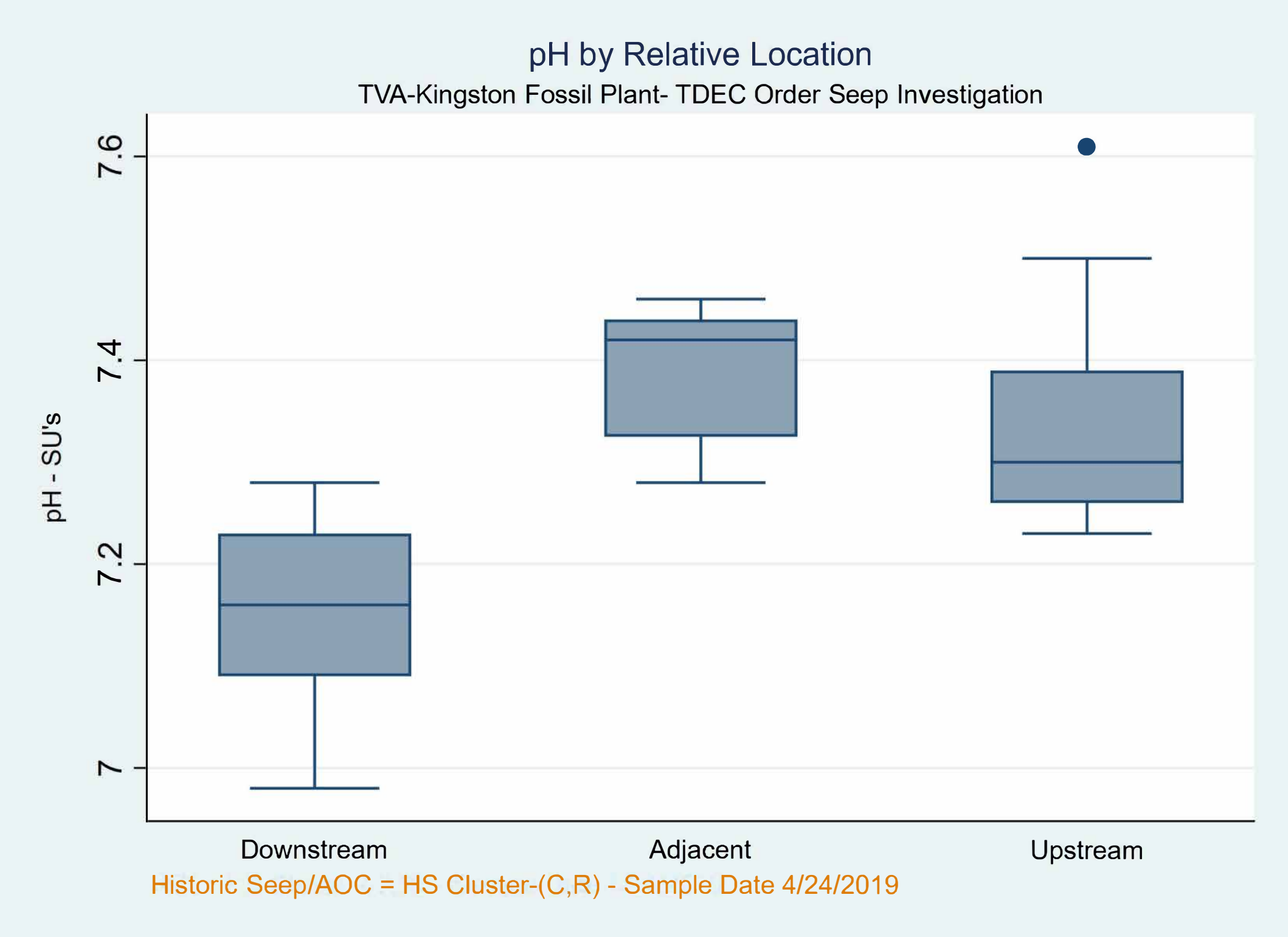

Dissolved Oxygen by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Dissolved Oxygen - mg/L
9.5
9
8.5
8
7.5
Downstream
Adjacent
Upstream
Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

Time Series - Dissolved Oxygen

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

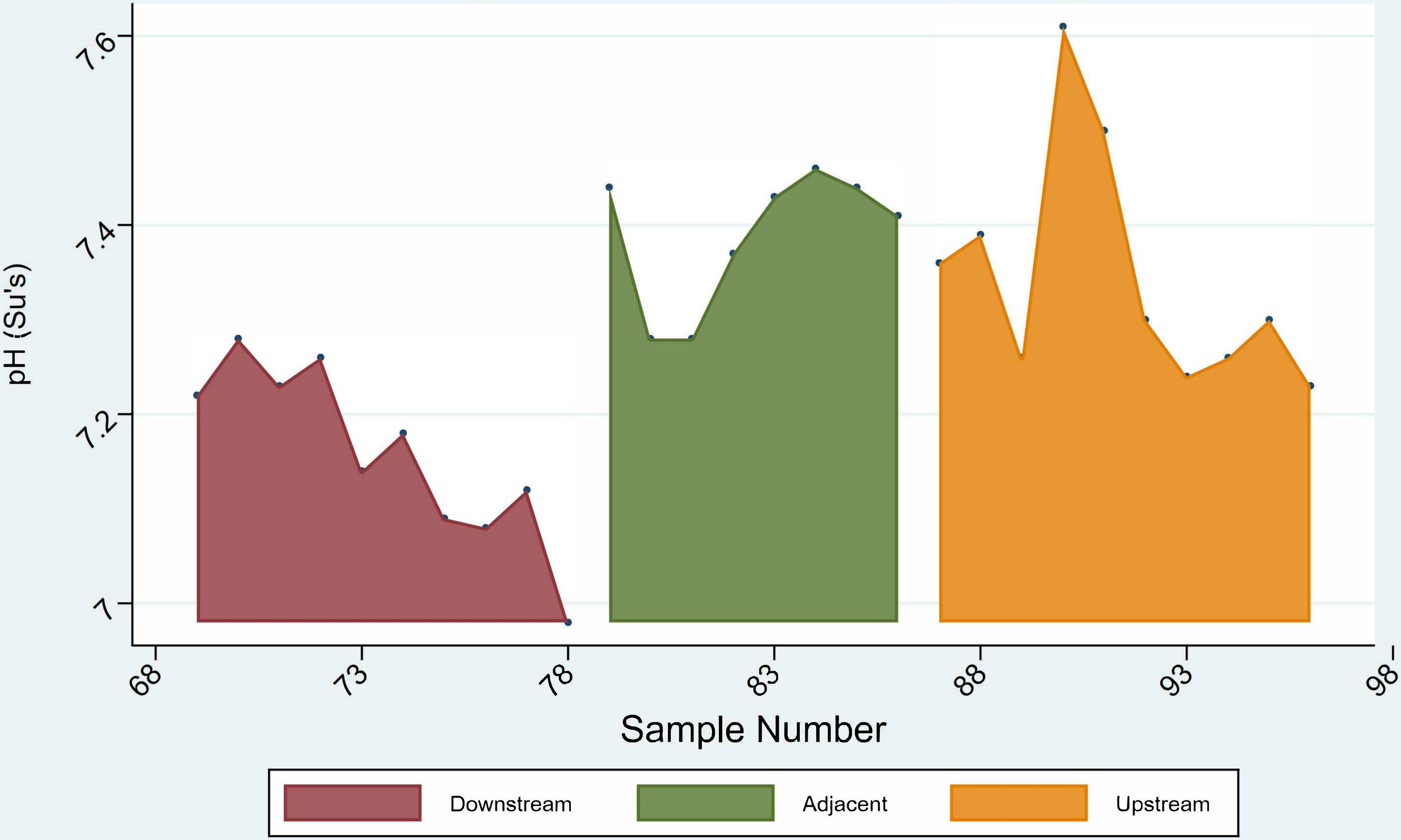


Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

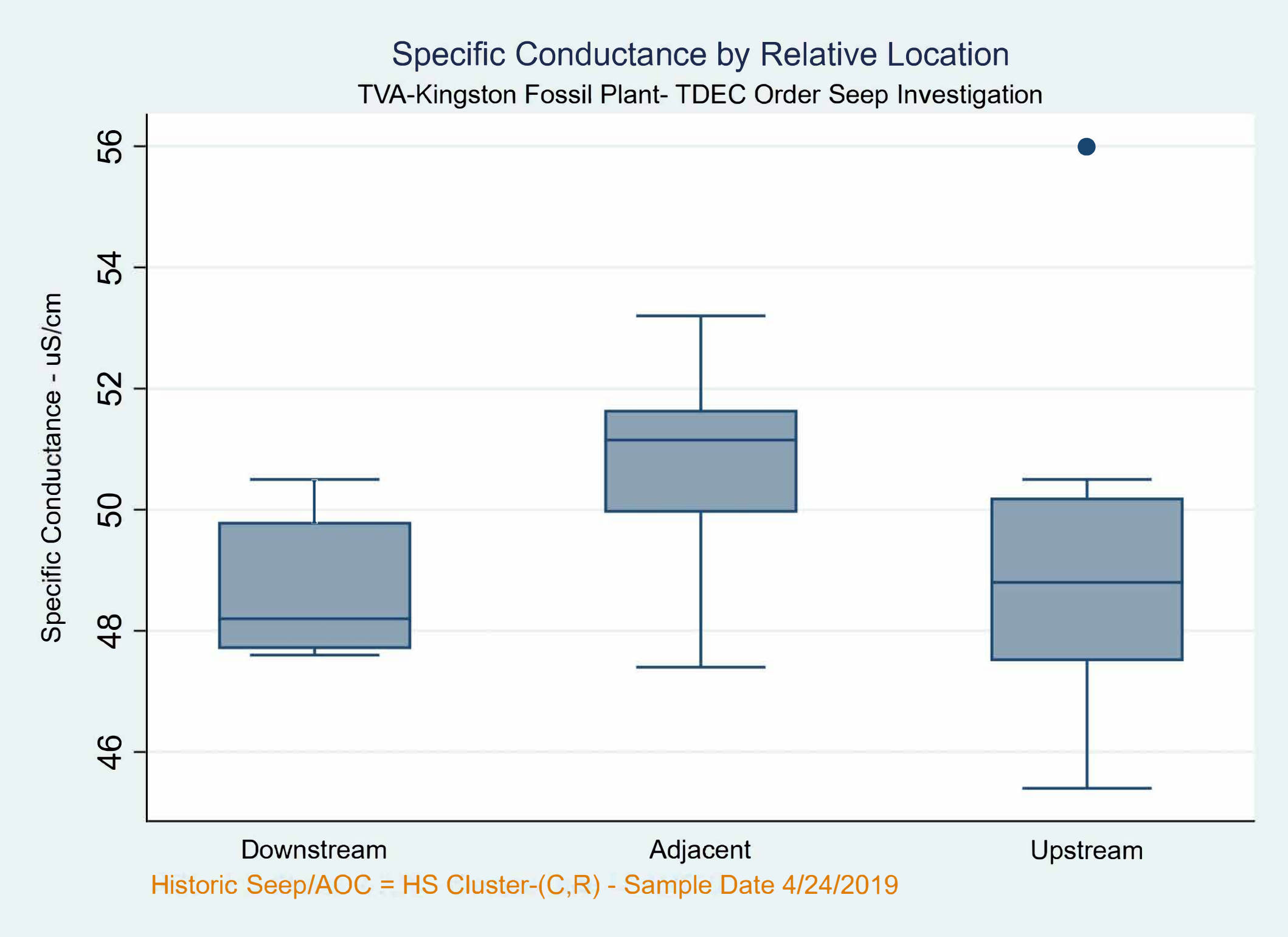

pH by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
pH - SU's
7.6
7.4
7.2
7
Downstream
Adjacent
Upstream
Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

Time Series - pH

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

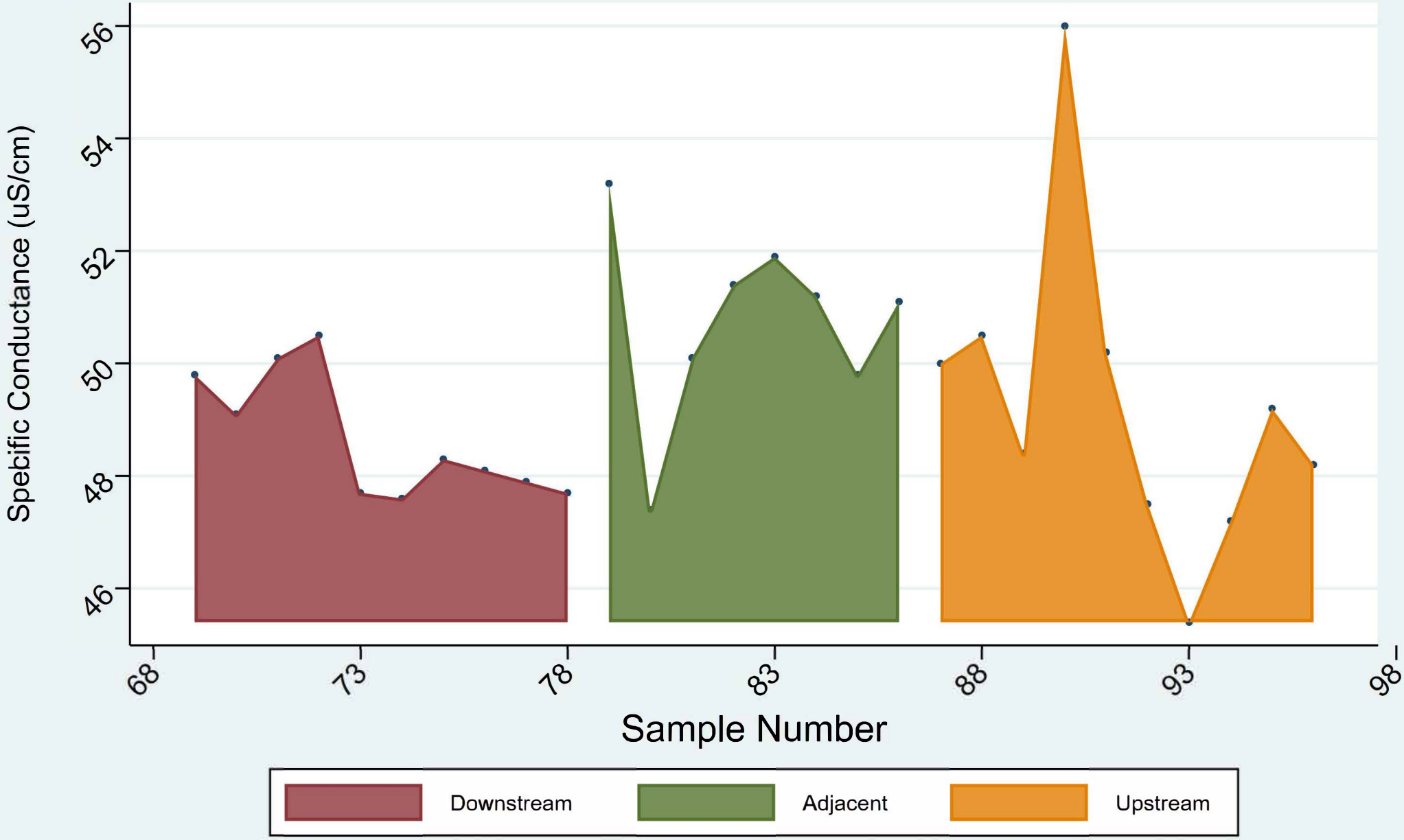


Historic Seep/AOC – HS Cluster-(C,R) - Sample Date 4/24/2019

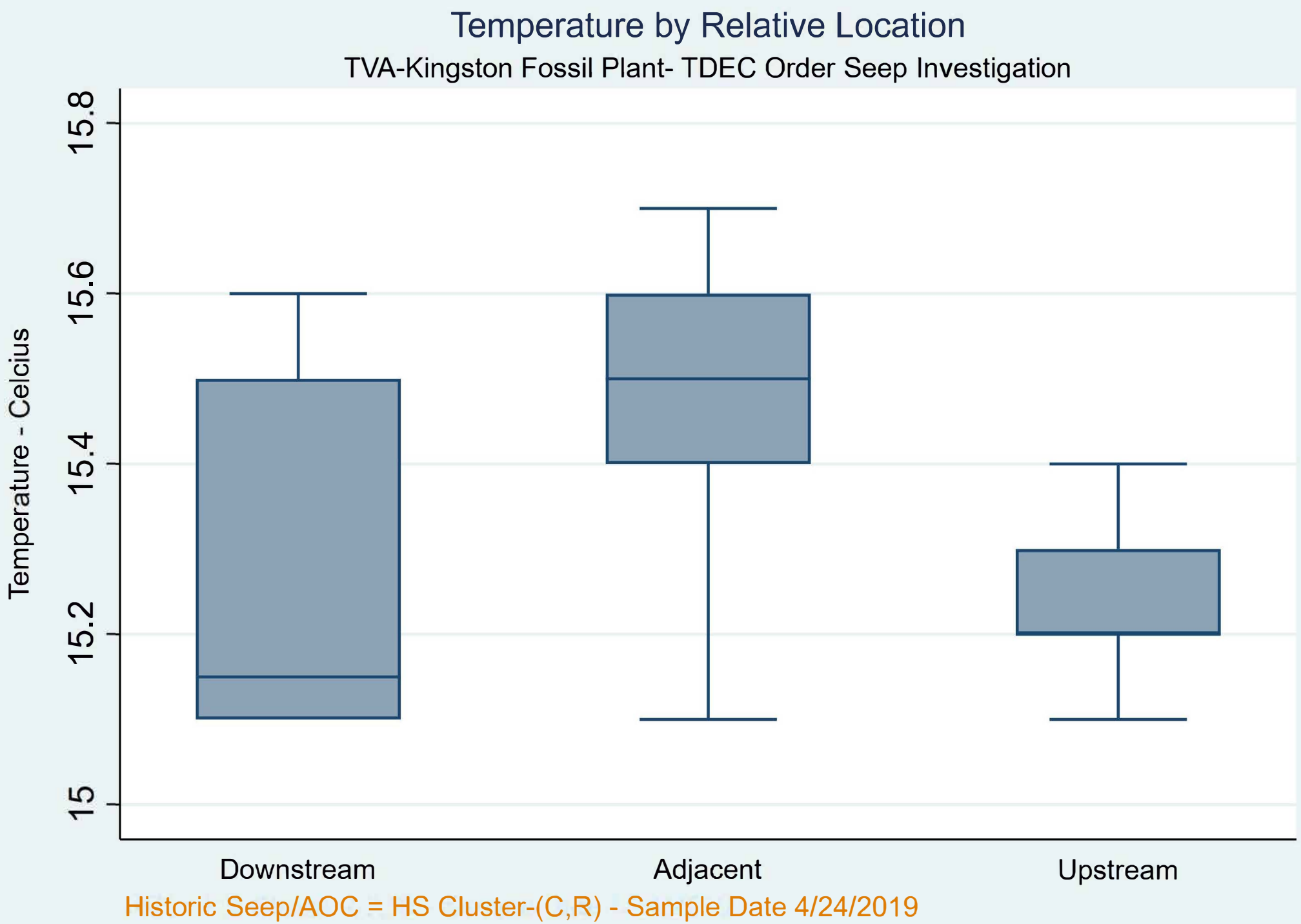

Specific Conductance by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Specific Conductance - uS/cm
46
48
50
52
54
56
Downstream
Adjacent
Upstream
Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

Time Series - Specific Conductance

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

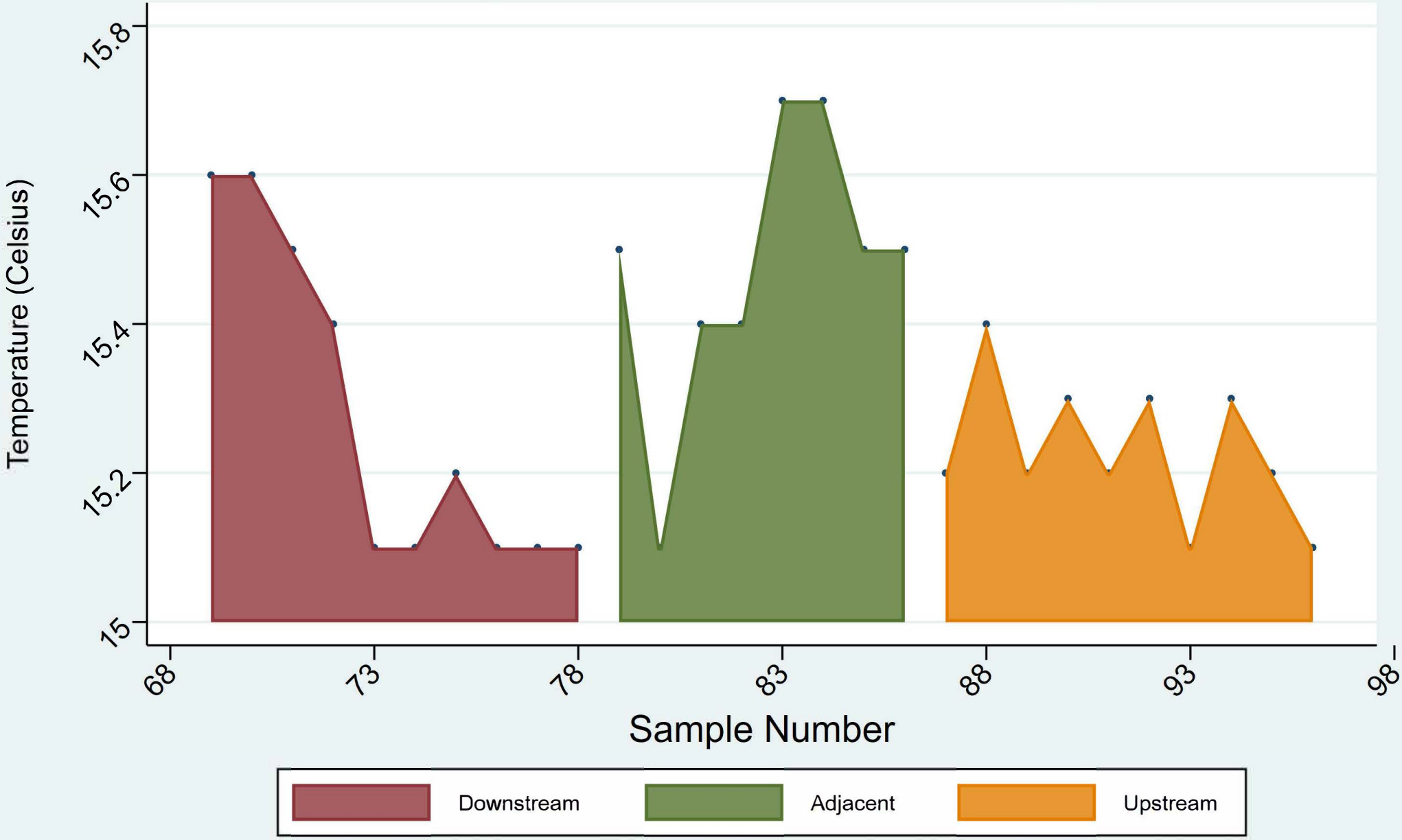


Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

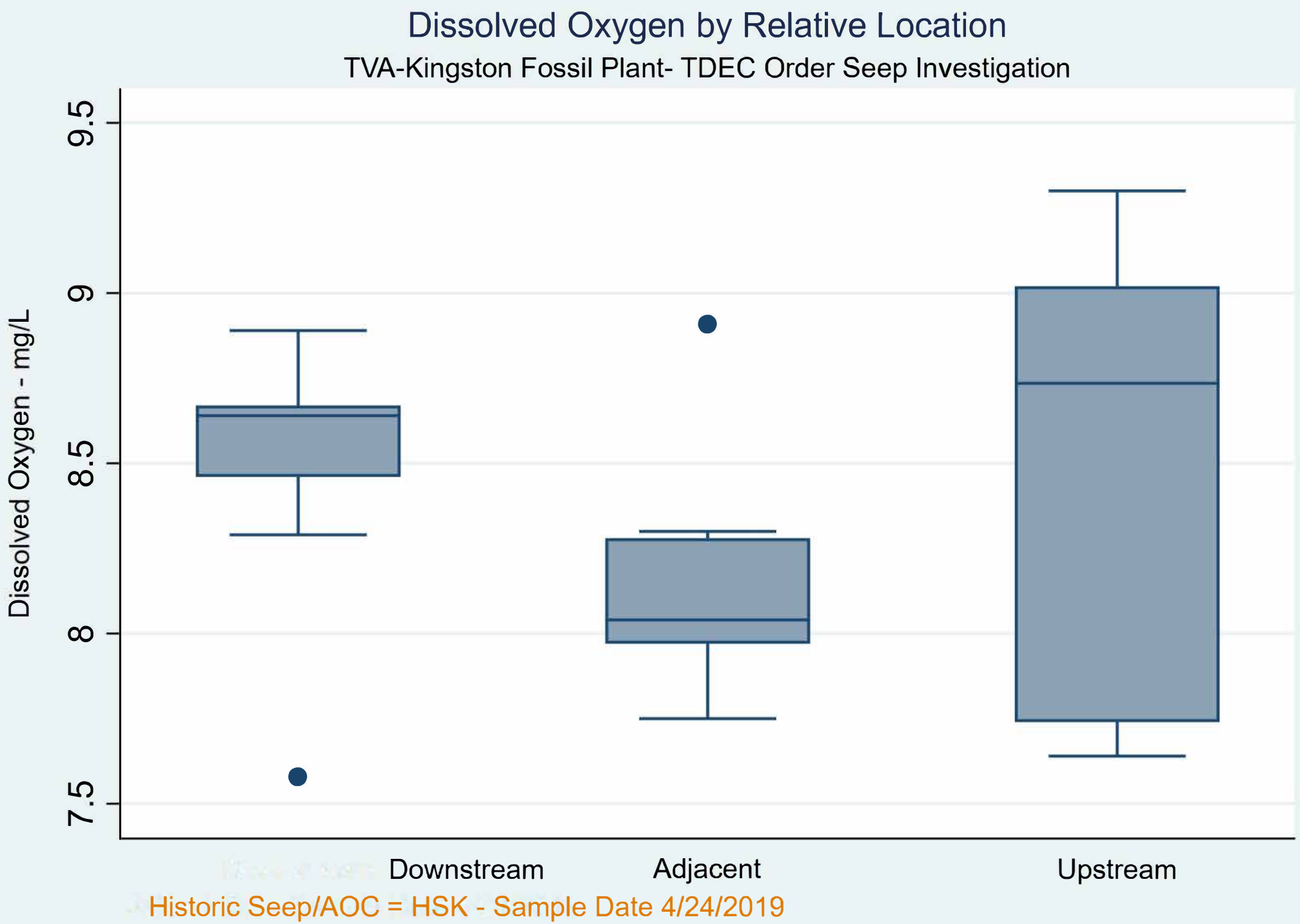

Temperature by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Temperature - Celcius
15.8
15.6
15.4
15.2
15
Downstream
Adjacent
Upstream
Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

Time Series - Temperature

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

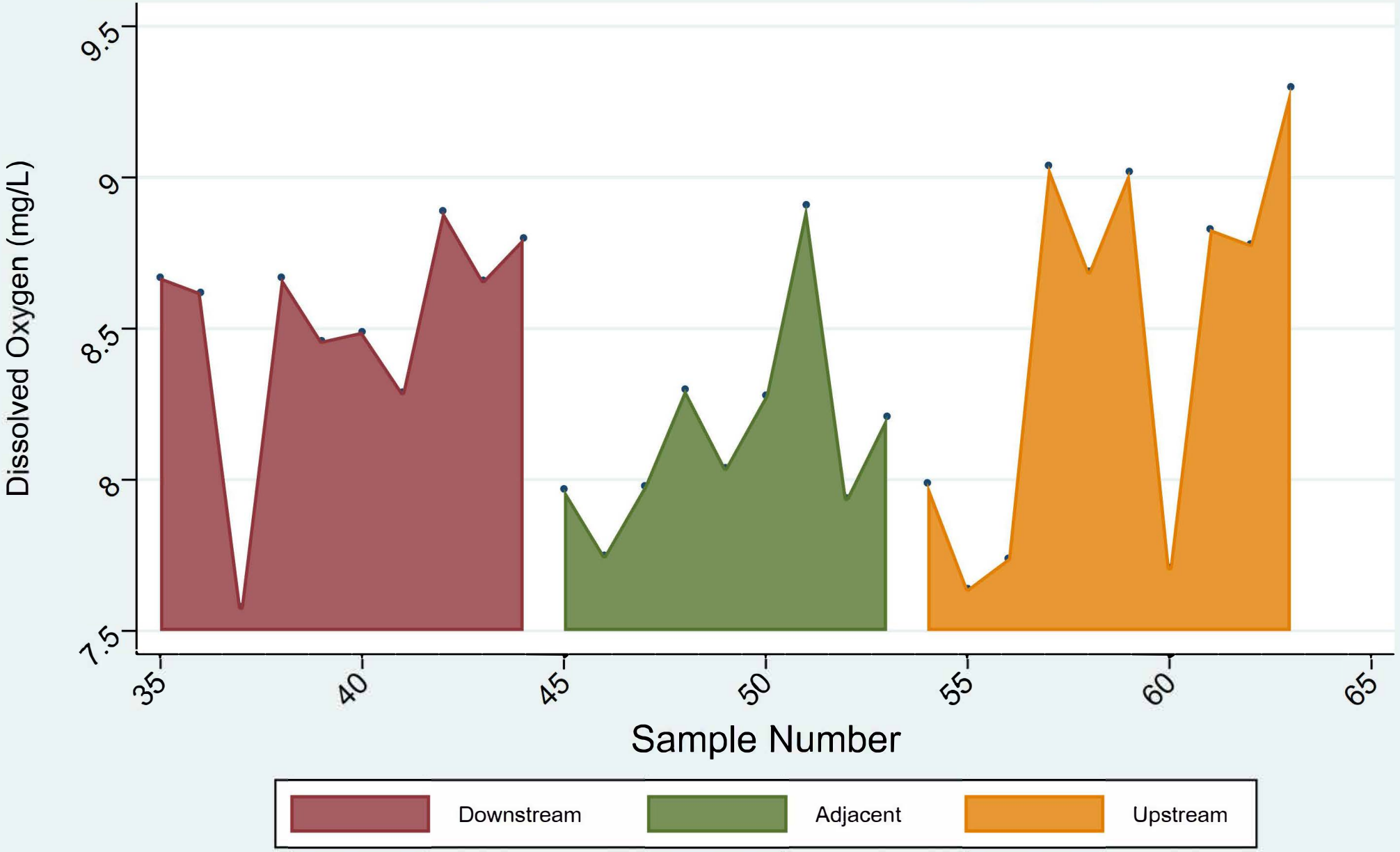


Historic Seep/AOC = HS Cluster-(C,R) - Sample Date 4/24/2019

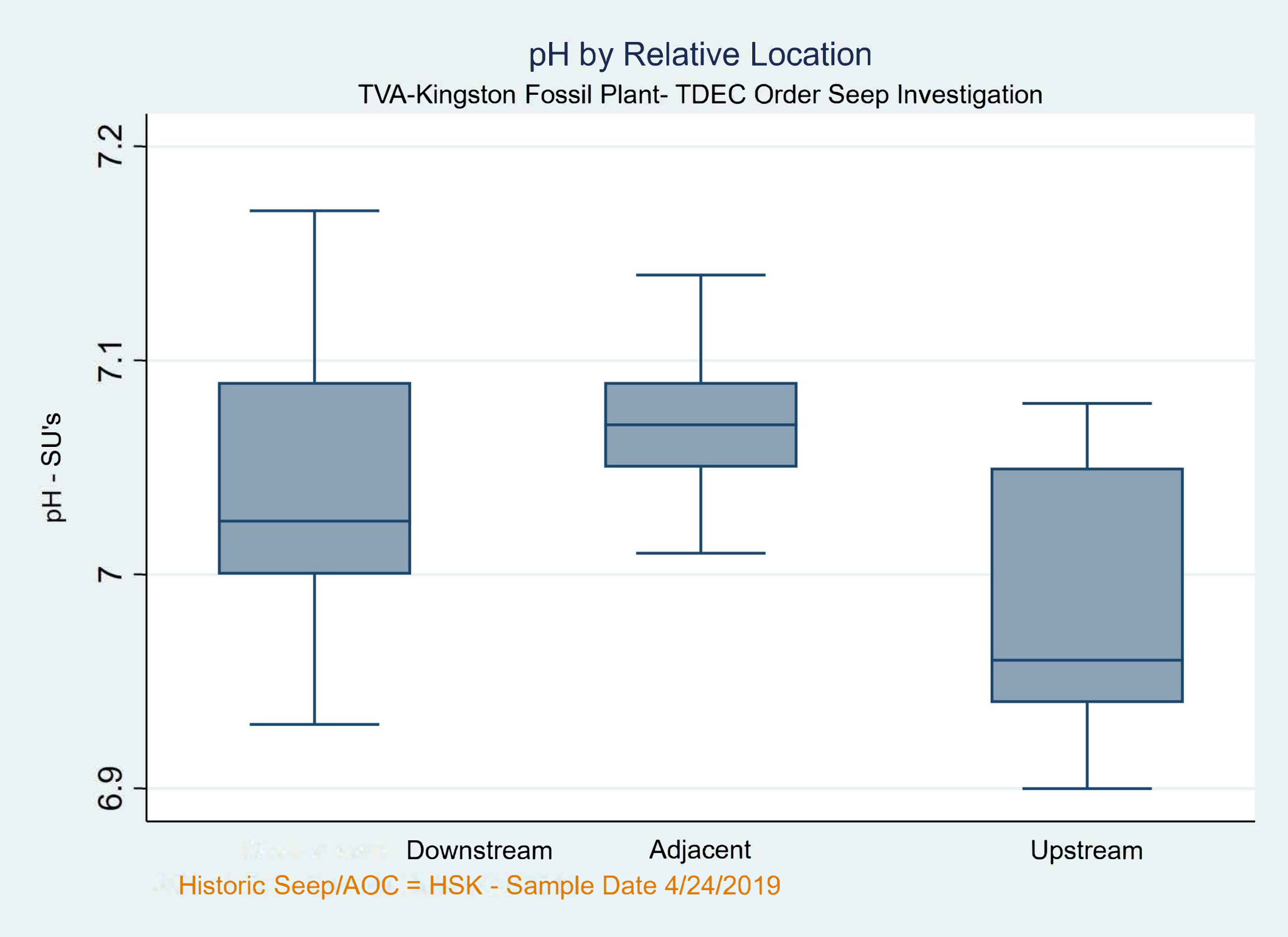

Dissolved Oxygen by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Dissolved Oxygen - mg/L
9.5
9
8.5
8
7.5
Downstream
Adjacent
Upstream
Historic Seep/AOC = HSK - Sample Date 4/24/2019

Time Series - Dissolved Oxygen

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

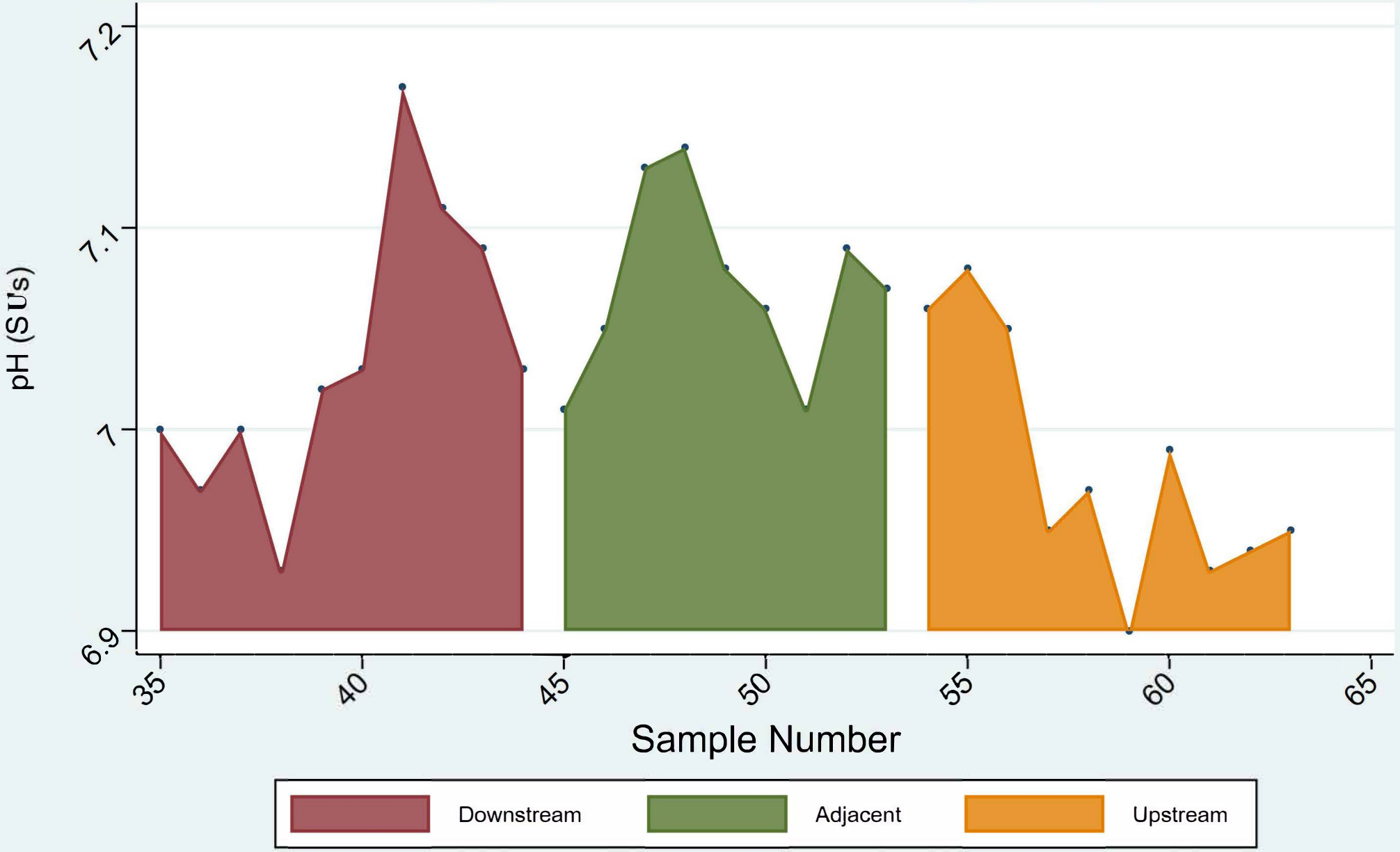


Historic Seep/AOC = HSK - Sample Date 4/24/2019

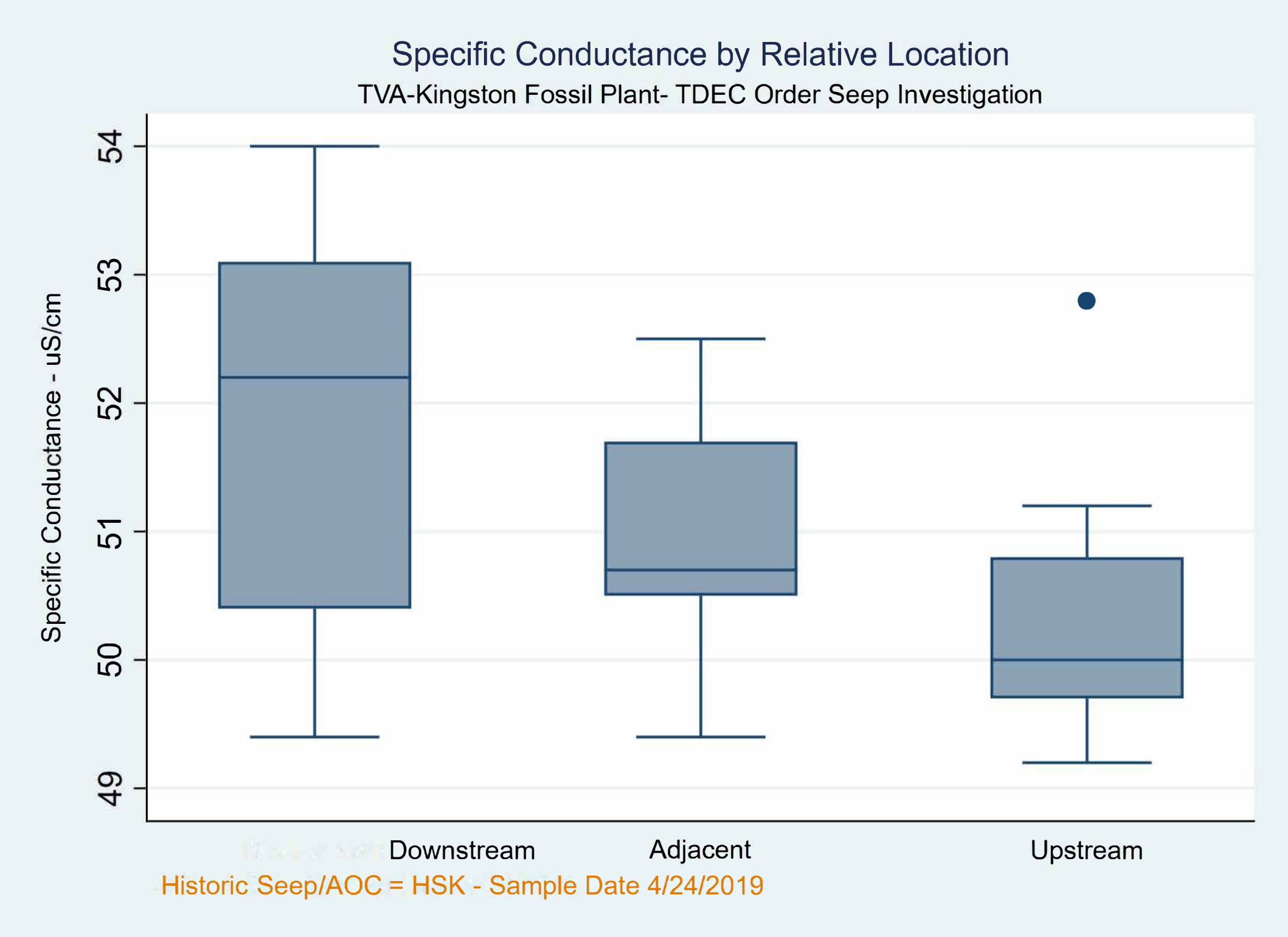

pH by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
pH - SU's
7.2
7.1
7
6.9
Downstream
Adjacent
Upstream
Historic Seep/AOC = HSK - Sample Date 4/24/2019

Time Series - pH

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

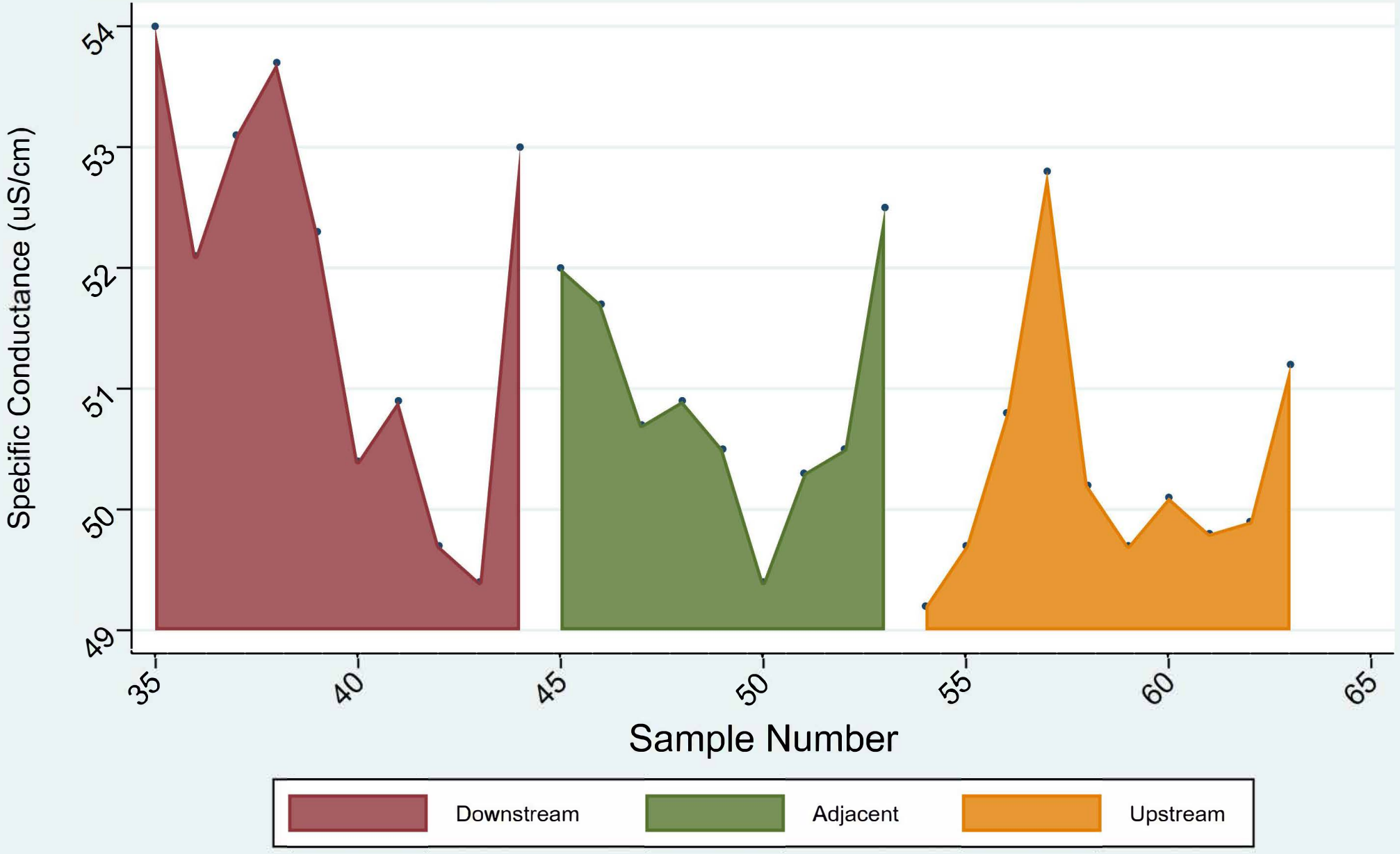


Historic Seep/AOC = HSK - Sample Date 4/24/2019

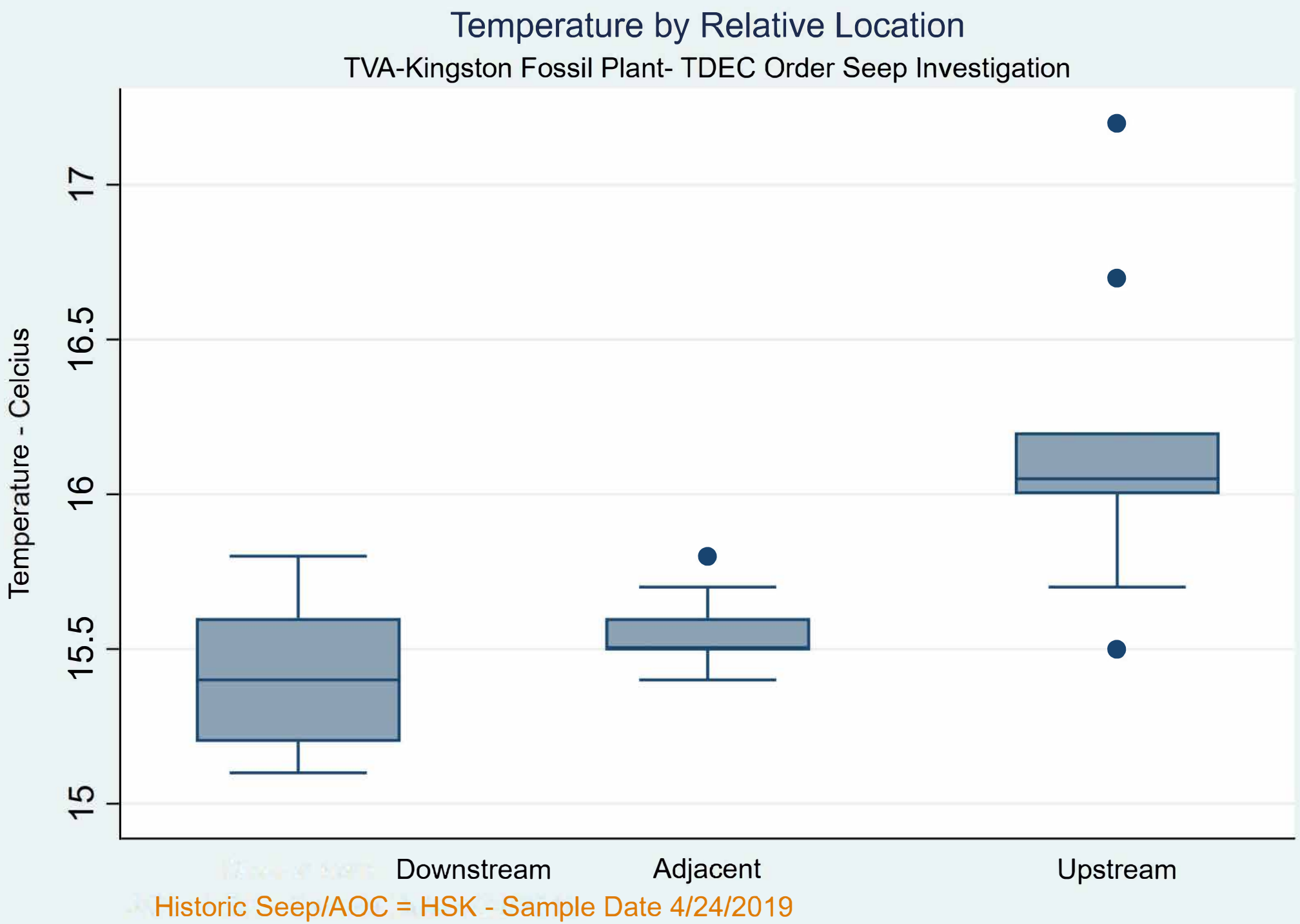

Specific Conductance by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Specific Conductance - uS/cm
54
53
52
51
50
49
Downstream
Adjacent
Upstream
Historic Seep/AOC = HSK - Sample Date 4/24/2019

Time Series - Specific Conductance

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

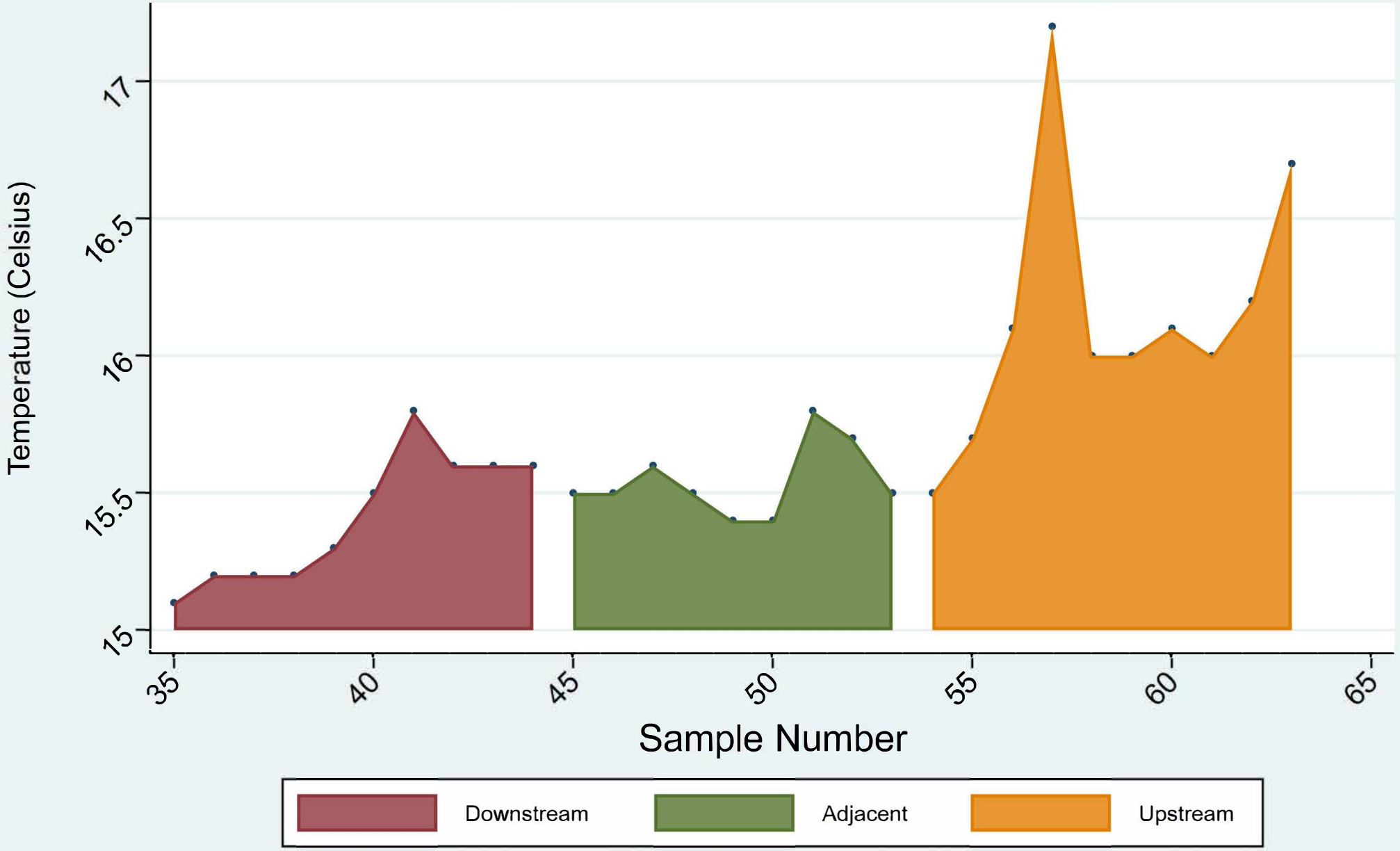


Historic Seep/AOC = HSK - Sample Date 4/24/2019


Temperature by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Temperature - Celcius
15
15.5
16
16.5
17
Downstream
Adjacent
Upstream
Historic Seep/AOC = HSK - Sample Date 4/24/2019

Time Series - Temperature

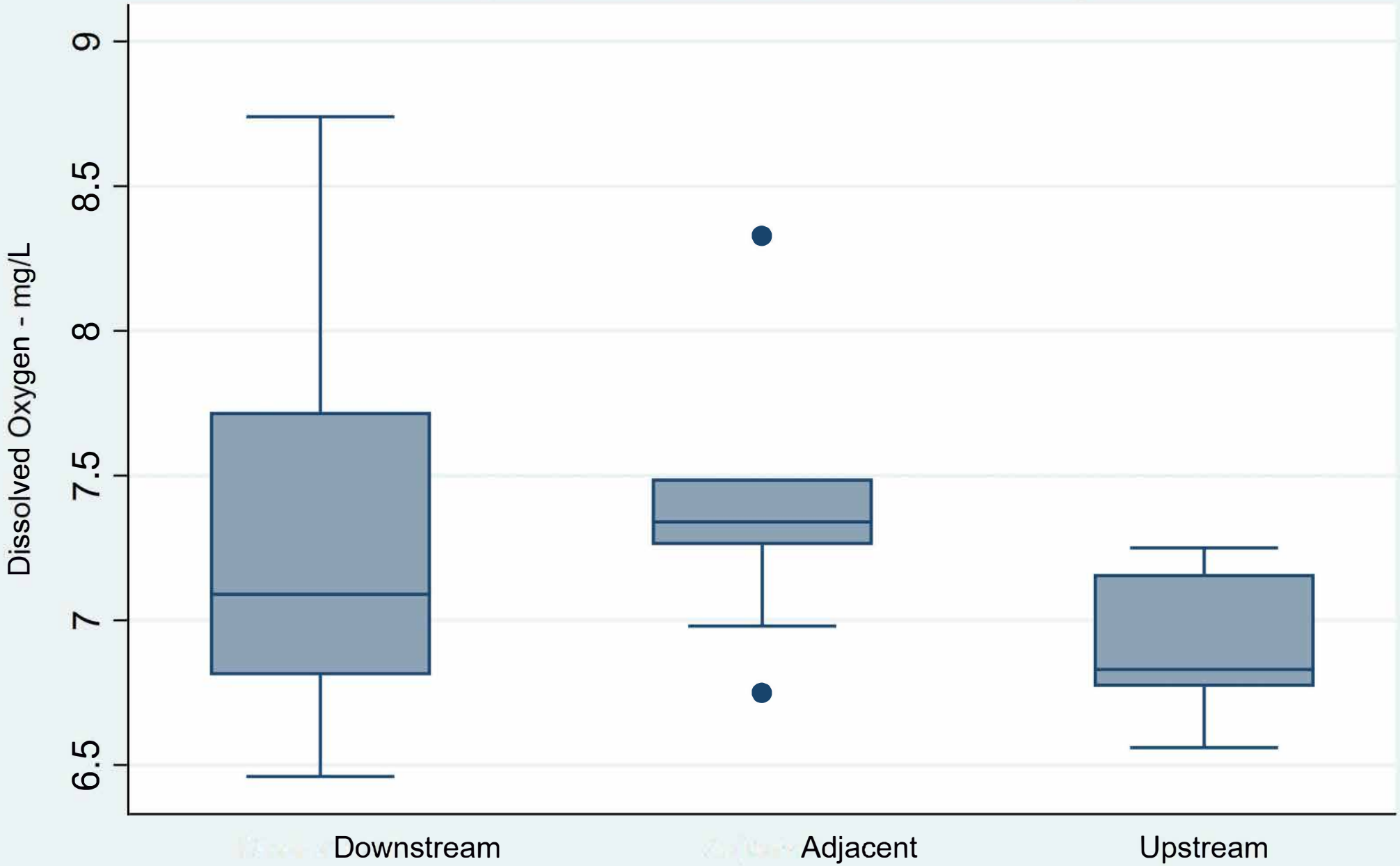
TVA-Kingston Fossil Plant - TDEC Order Seep Investigation



Historic Seep/AOC = HSK - Sample Date 4/24/2019

Dissolved Oxygen by Relative Location

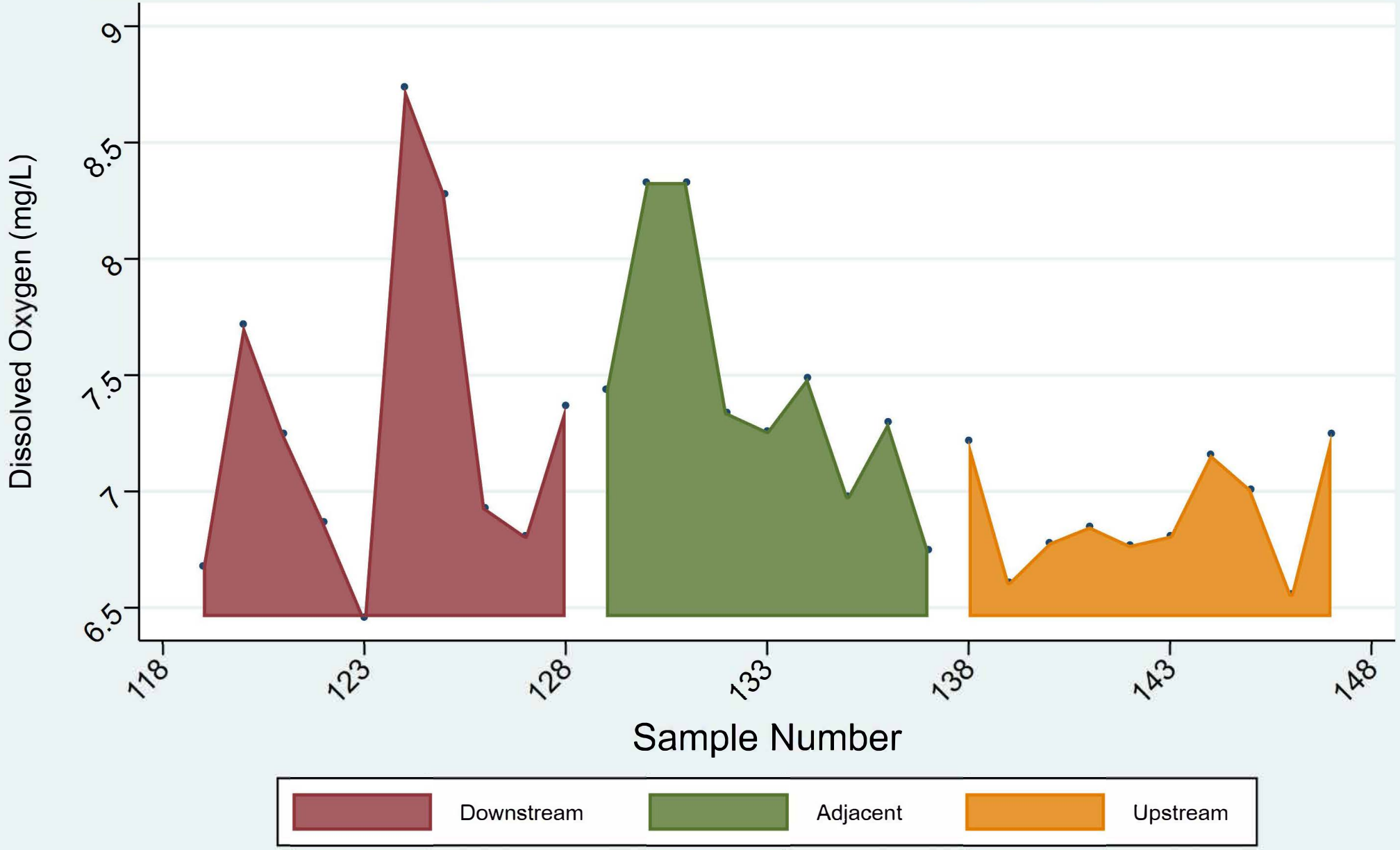
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation



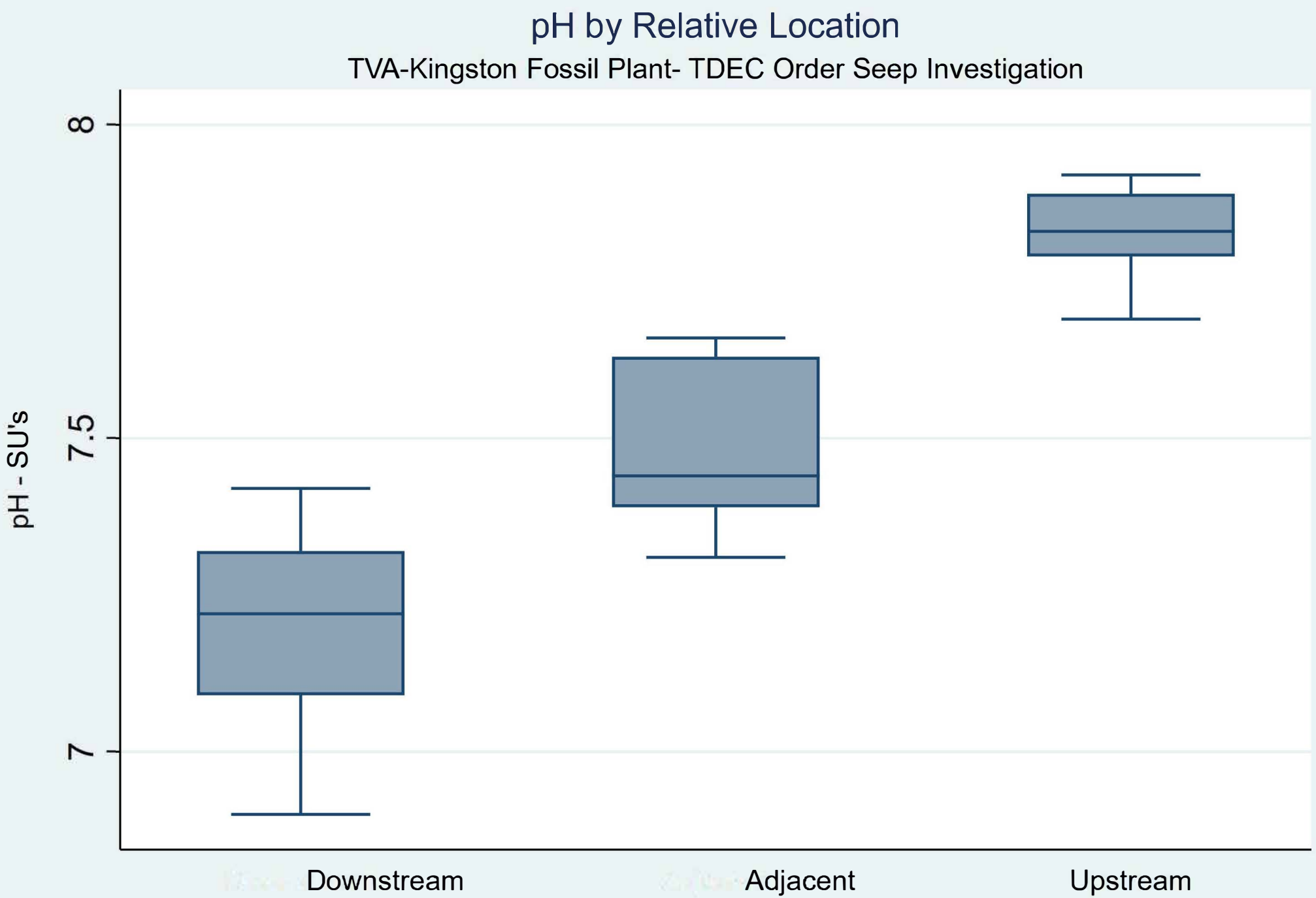
Historic Seep/AOC = Cluster-(M/AOC#3,HSD) - Sample Date 4/25/2019

Time Series - Dissolved Oxygen

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

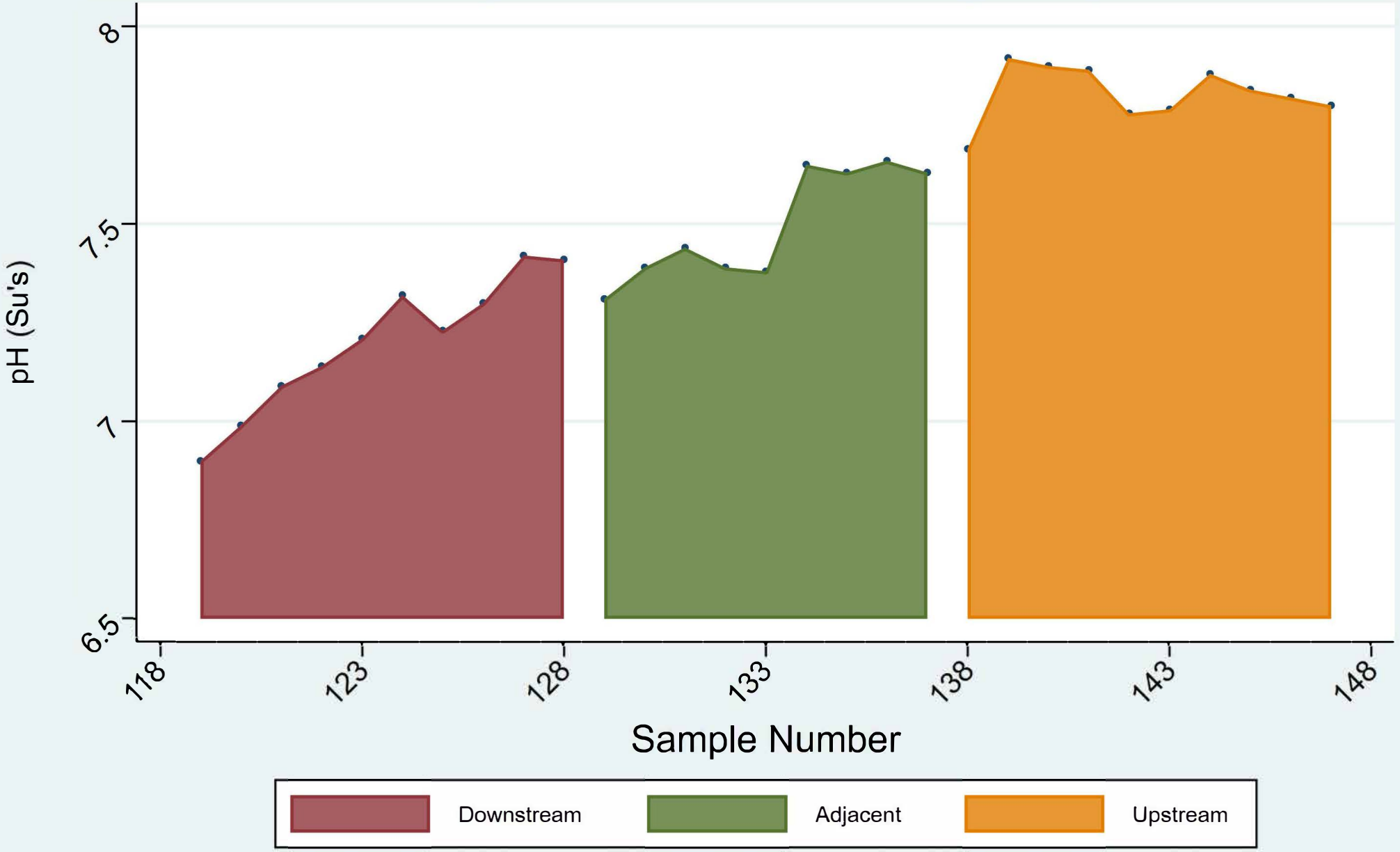


Historic Seep/AOC = Cluster-(M/AOC#3,HSD) - Sample Date 4/25/2019

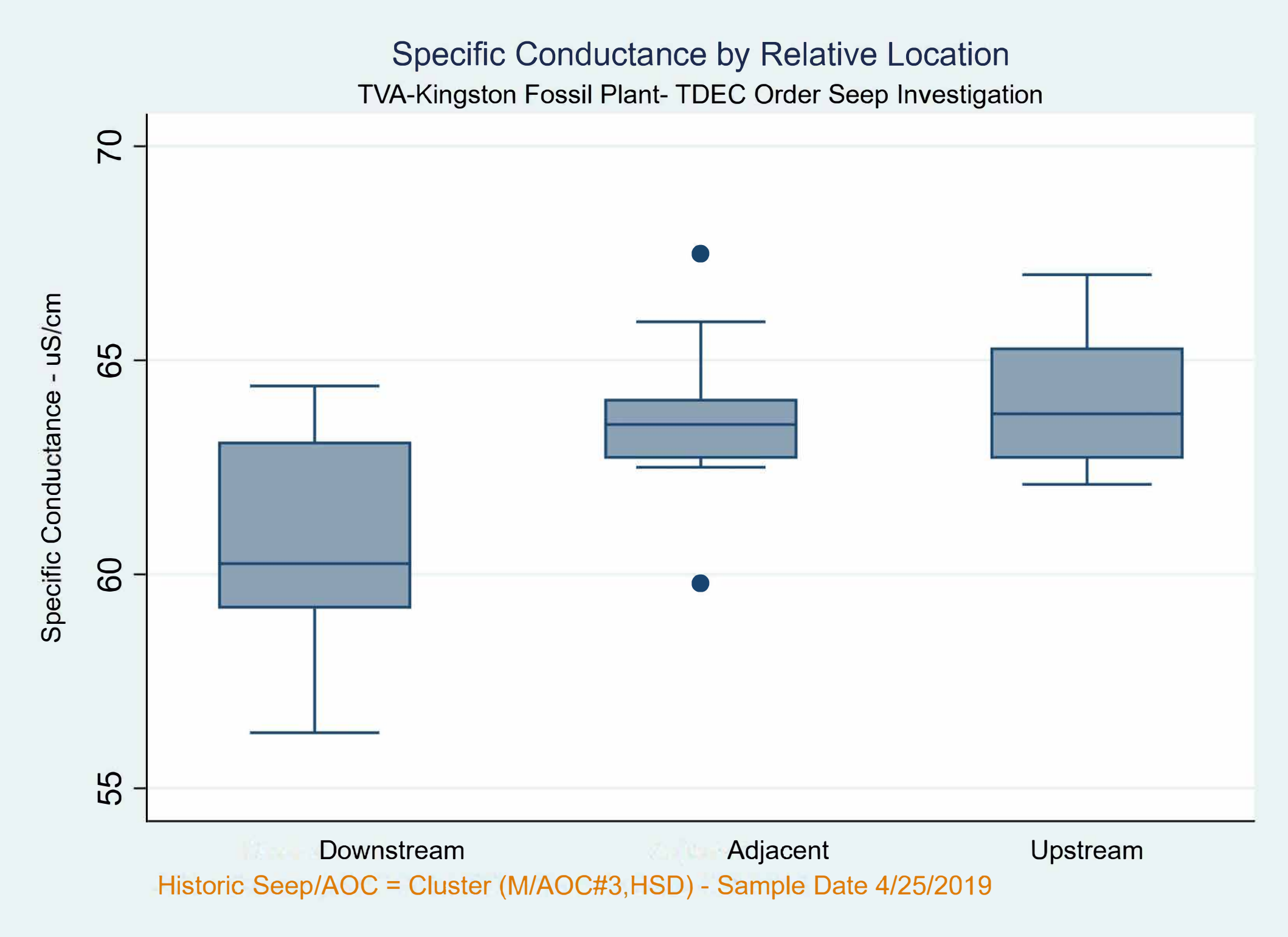

pH by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
pH - SU's
8
7.5
7
Downstream
Adjacent
Upstream
Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019

Time Series - pH

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

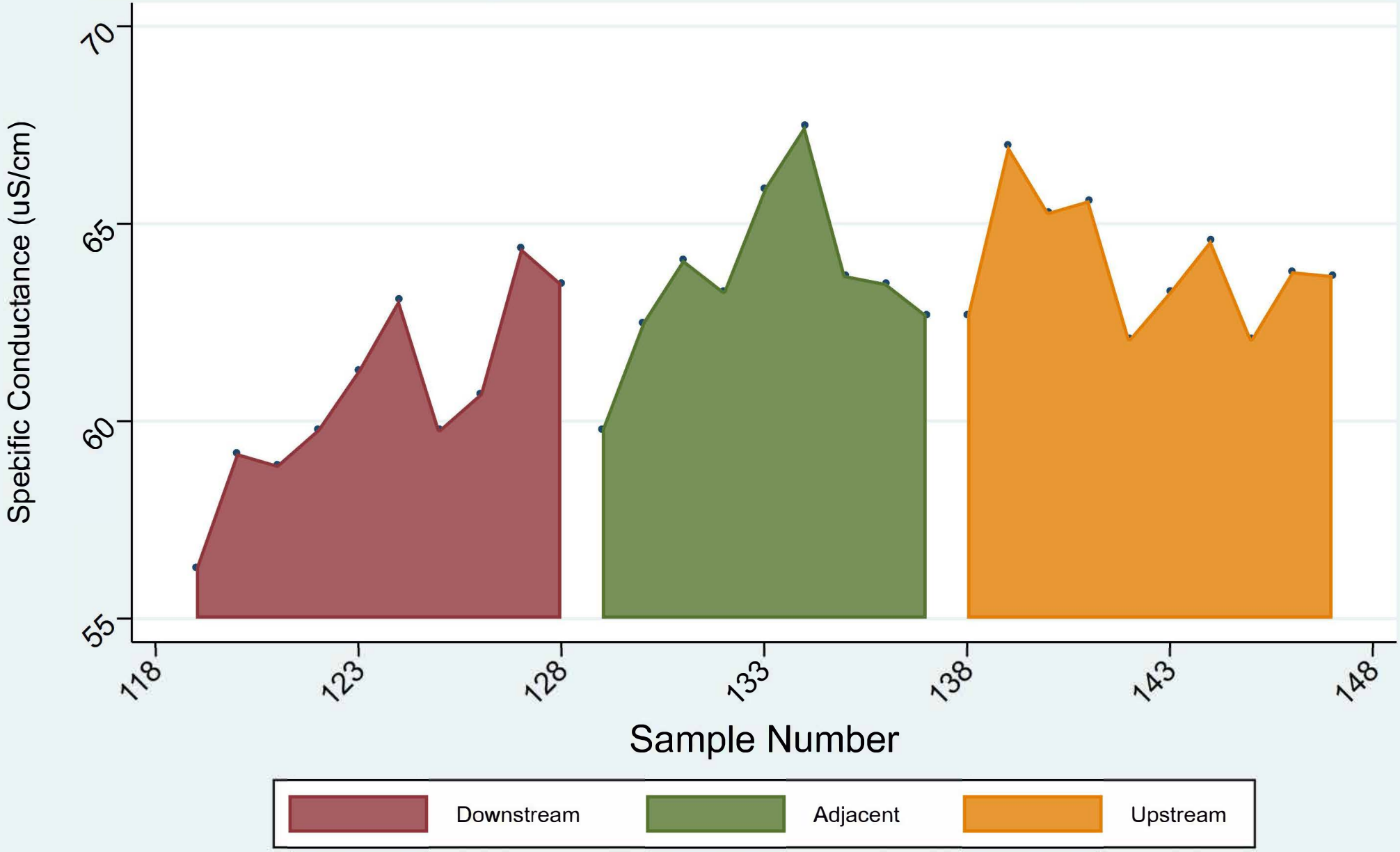


Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019

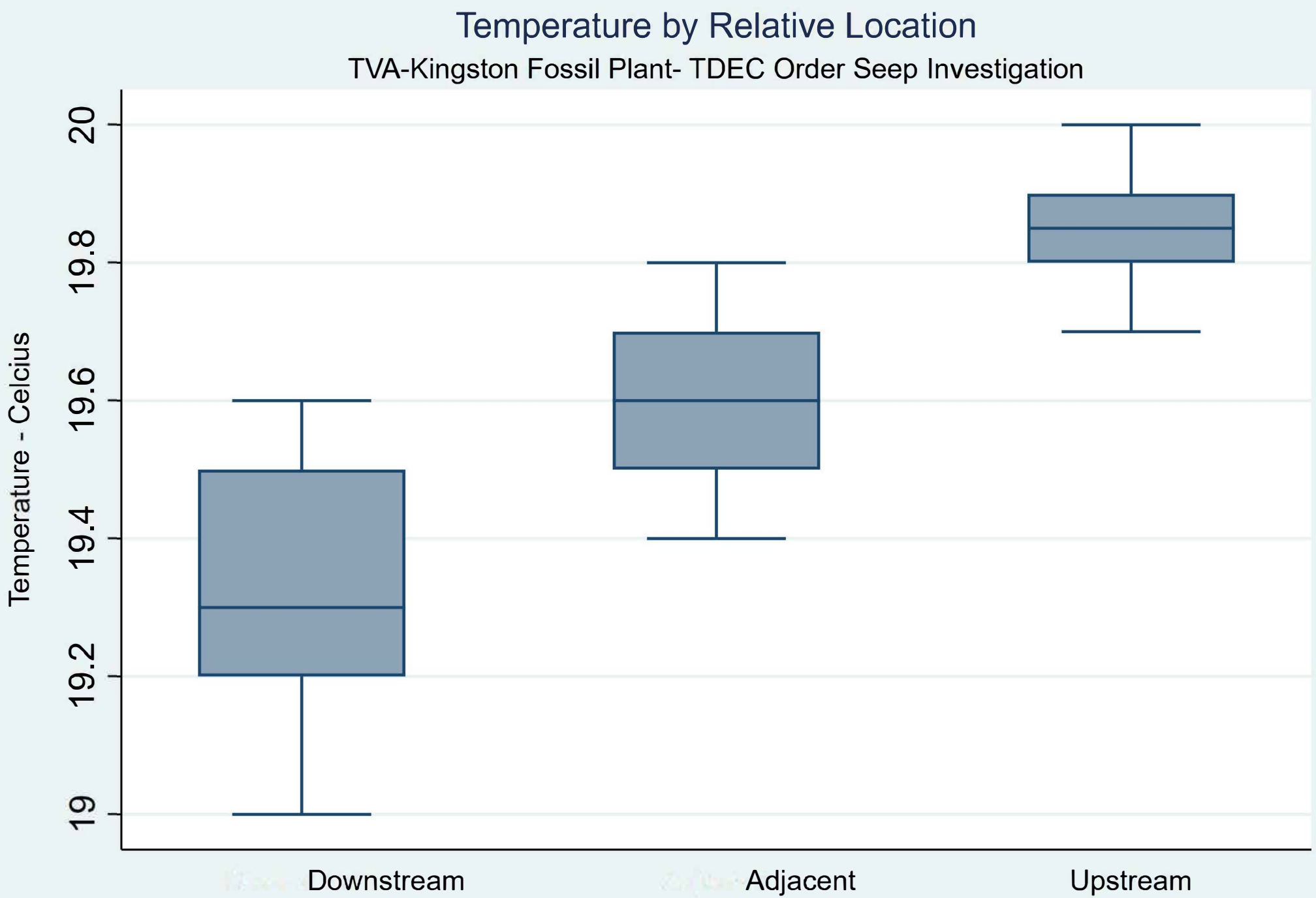

Specific Conductance by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Specific Conductance - uS/cm
70
65
60
55
Downstream
Adjacent
Upstream
Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019

Time Series - Specific Conductance

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation

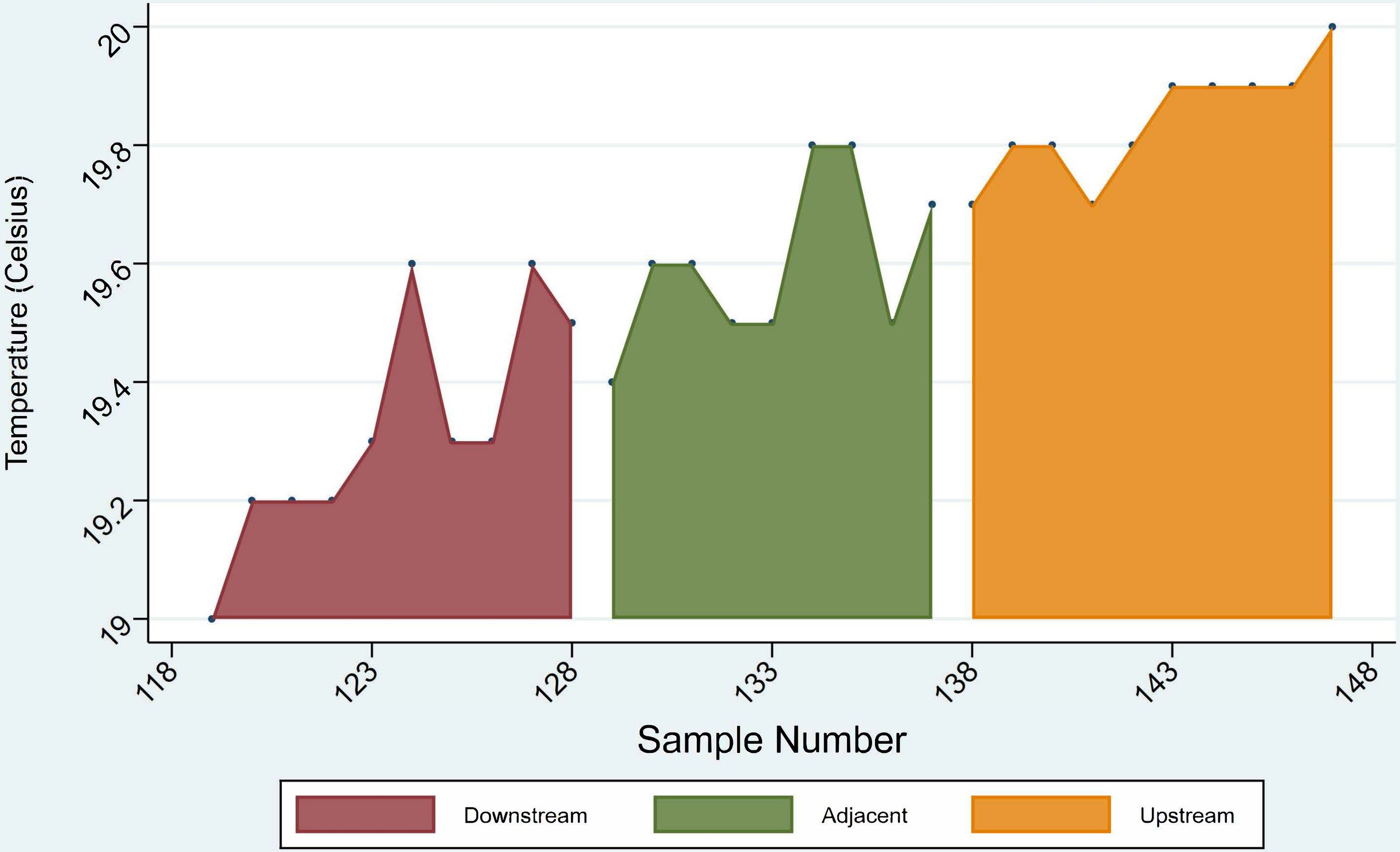


Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019


Temperature by Relative Location
TVA-Kingston Fossil Plant- TDEC Order Seep Investigation
Temperature - Celcius
19
19.2
19.4
19.6
19.8
20
Downstream
Adjacent
Upstream
Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019

Time Series - Temperature

TVA-Kingston Fossil Plant - TDEC Order Seep Investigation



Historic Seep/AOC = Cluster (M/AOC#3,HSD) - Sample Date 4/25/2019

ATTACHMENT D.2

Summary of Descriptive Statistics

KIF Seep Investigation –Summary Statistics for Areas of Concern (AOCs)

Kingston Fossil Plant - Seep Investigation - Summary Statistics Dissolved Oxygen - milligrams per liter (mg/L)								
Historical Seep/ AOC Location	**Relative Location to AOC**	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Median**	**95th Percentile**
L/AOC#2	Downstream	10	7.94	8.95	8.38	0.28	8.37	8.95
	Adjacent	8	8.06	9.12	8.39	0.37	8.28	9.12
	Upstream	11	7.49	8.68	7.96	0.34	8.00	8.68
HS Cluster-(C,R)	Downstream	10	8.77	9.70	9.18	0.26	9.19	9.70
	Adjacent	8	8.22	8.54	8.38	0.10	8.39	8.54
	Upstream	10	7.38	8.94	8.19	0.51	8.17	8.94
HSK	Downstream	10	7.58	8.89	8.51	0.37	8.64	8.89
	Adjacent	9	7.75	8.91	8.15	0.34	8.04	8.91
	Upstream	10	7.64	9.30	8.47	0.63	8.74	9.30
M/AOC#3,HSD	Downstream	10	6.46	8.74	7.31	0.74	7.09	8.74
	Adjacent	9	6.75	8.33	7.47	0.54	7.34	8.33
	Upstream	10	6.56	7.25	6.90	0.25	6.83	7.25
Control (4/24/2019)		20	7.22	8.29	7.79	0.24	7.80	8.17
Control (4/25/2019)		20	7.27	8.68	8.14	0.41	8.22	8.67
Intermediate Areas		17	7.01	9.21	8.21	0.65	8.09	9.21

KIF Seep Investigation –Summary Statistics for Areas of Concern (AOCs)

Kingston Fossil Plant - Seep Investigation - Summary Statistics pH (Standard Units)								
Historical Seep/ AOC Location	**Relative Location to AOC**	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Median**	**95th Percentile**
L/AOC#2	Downstream	10	6.59	6.89	6.76	0.10	6.78	6.89
	Adjacent	8	6.84	6.95	6.91	0.04	6.91	6.95
	Upstream	11	6.26	6.98	6.77	0.22	6.87	6.98
HS Cluster-(C,R)	Downstream	10	6.98	7.28	7.16	0.09	7.16	7.28
	Adjacent	8	7.28	7.46	7.39	0.07	7.42	7.46
	Upstream	10	7.23	7.61	7.35	0.12	7.30	7.61
HSK	Downstream	10	6.93	7.17	7.04	0.07	7.03	7.17
	Adjacent	9	7.01	7.14	7.07	0.05	7.07	7.14
	Upstream	10	6.90	7.08	6.98	0.06	6.96	7.08
M/AOC#3,HSD	Downstream	10	6.90	7.42	7.20	0.17	7.22	7.42
	Adjacent	9	7.31	7.66	7.50	0.14	7.44	7.66
	Upstream	10	7.69	7.92	7.83	0.07	7.83	7.92
Control (4/24/2019)		20	7.10	7.24	7.16	0.04	7.15	7.23
Control (4/25/2019)		20	7.29	7.48	7.40	0.05	7.40	7.47
Intermediate Areas		17	6.29	7.88	7.22	0.47	7.23	7.88

KIF Seep Investigation –Summary Statistics for Areas of Concern (AOCs)

Kingston Fossil Plant - Seep Investigation - Summary Statistics Specific Conductance - microsiemens per centimeter (µS/cm)								
Historical Seep/ AOC Location	**Relative Location to AOC**	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Median**	**95th Percentile**
L/AOC#2	Downstream	10	47.4	56.8	50.1	3.03	49.1	56.8
	Adjacent	8	46.5	63.3	52.0	5.98	49.5	63.3
	Upstream	11	46.8	55.3	49.4	2.78	48.7	55.3
HS Cluster-(C,R)	Downstream	10	47.6	50.5	48.7	1.10	48.2	50.5
	Adjacent	8	47.4	53.2	50.8	1.72	51.2	53.2
	Upstream	10	45.4	56.0	49.3	2.84	48.8	56.0
HSK	Downstream	10	49.4	54.0	51.9	1.66	52.2	54.0
	Adjacent	9	49.4	52.5	50.9	0.96	50.7	52.5
	Upstream	10	49.2	52.8	50.3	1.04	50.0	52.8
M/AOC#3,HSD	Downstream	10	56.3	64.4	60.7	2.45	60.3	64.4
	Adjacent	9	59.8	67.5	63.7	2.16	63.5	67.5
	Upstream	10	62.1	67.0	64.0	1.60	63.8	67.0
Control (4/24/2019)		20	46.5	47.7	47.0	0.33	47.1	47.6
Control (4/25/2019)		20	48.7	52.3	50.2	0.84	50.1	52.0
Intermediate Areas		17	46.3	64.4	55.8	5.70	56.9	64.4

KIF Seep Investigation –Summary Statistics for Areas of Concern (AOCs)

Kingston Fossil Plant - Seep Investigation - Summary Statistics Temperature (Celsius)								
Historical Seep/ AOC Location	**Relative Location to AOC**	**Number of Samples**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Median**	**95th Percentile**
L/AOC #2	Downstream	10	15.1	15.5	15.3	0.14	15.3	15.5
	Adjacent	8	14.8	15.3	15.0	0.16	15.0	15.3
	Upstream	11	14.4	15.0	14.7	0.23	14.6	15.0
HS Cluster-(C,R)	Downstream	10	15.1	15.6	15.3	0.22	15.2	15.6
	Adjacent	8	15.1	15.7	15.5	0.19	15.5	15.7
	Upstream	10	15.1	15.4	15.2	0.09	15.2	15.4
HSK	Downstream	10	15.1	15.8	15.4	0.24	15.4	15.8
	Adjacent	9	15.4	15.8	15.5	0.13	15.5	15.8
	Upstream	10	15.5	17.2	16.2	0.48	16.1	17.2
M/AOC#3,HSD	Downstream	10	19.0	19.6	19.3	0.19	19.3	19.6
	Adjacent	9	19.4	19.8	19.6	0.14	19.6	19.8
	Upstream	10	19.7	20.0	19.8	0.10	19.9	20.0
Control (4/24/2019)		20	16.5	18.4	17.2	0.49	17.2	18.2
Control (4/25/2019)		20	18.8	19.5	19.2	0.17	19.2	19.5
Intermediate Areas		17	14.9	19.8	16.8	2.09	15.6	19.8

p-Values by Areas of Concern (AOCs)

Kingston Fossil Plant Seep Investigation - Summary of Hypothesis Testing						
Historical Seep/AOC Location	**Relative Location to Historical Seep**	**Number of Samples**	**Dissolved Oxygen (mg/L)**	**pH (Standard Units)**	**Specific Conductance (µS/cm)**	**Temperature (Celsius)**
			p-value	**p-value**	**p-value**	**p-value**
L/AOC#2	Adjacent v Upstream	8/11	0.9894	0.0699	0.1426	**0.0027**
HSK	Adjacent v Upstream	9/10	0.0921	**0.0022**	0.1023	**0.0032**
HS Cluster-(C,R)	Adjacent v Upstream	8/10	0.8677	0.3658	0.0928	0.0081
M/AOC#3,HSD	Adjacent v Upstream	9/10	0.9926	**0.0000**	0.6530	**0.0008**

Adjusted Significance Level (SWFPR/#Statistical Tests): 0.10/16 = 0.00625

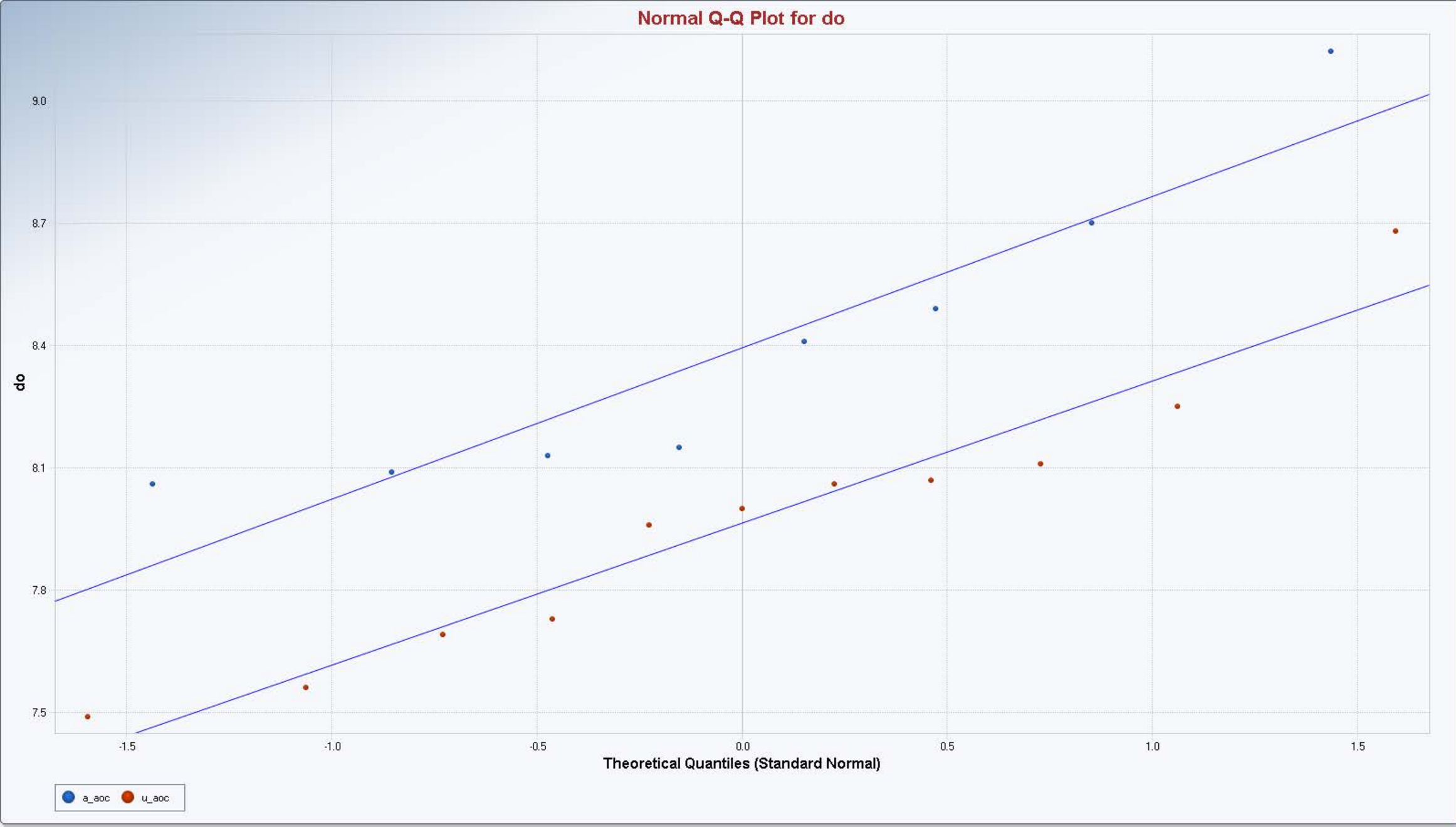
Bold and Highlight indicate that p-value is below adjusted significance level, reject null and conclude statistically significant difference.
(mg/L = milligrams per liter

µS/cm = microsiemens per centimeter
AOC = Area of Concern

ATTACHMENT D.3

Normal Q-Q Plots

Key to Normal Quantile – Quantile (Q-Q Plots)		
Parameter Abbreviations	**Parameter**	**Units**
do	Dissolved Oxygen	milligrams per liter (mg/L)
ph	pH	standard units (SU's)
sc	Specific Conductance	microsiemens per centimeter (µS/cm)
temp	Temperature	Celsius (°C)
Additional Abbreviations		
"a_"	Measurements collected adjacent to Historic Seep or Area of Concern	
"u_"	Measurements collected upstream of Historic Seep or Area of Concern	

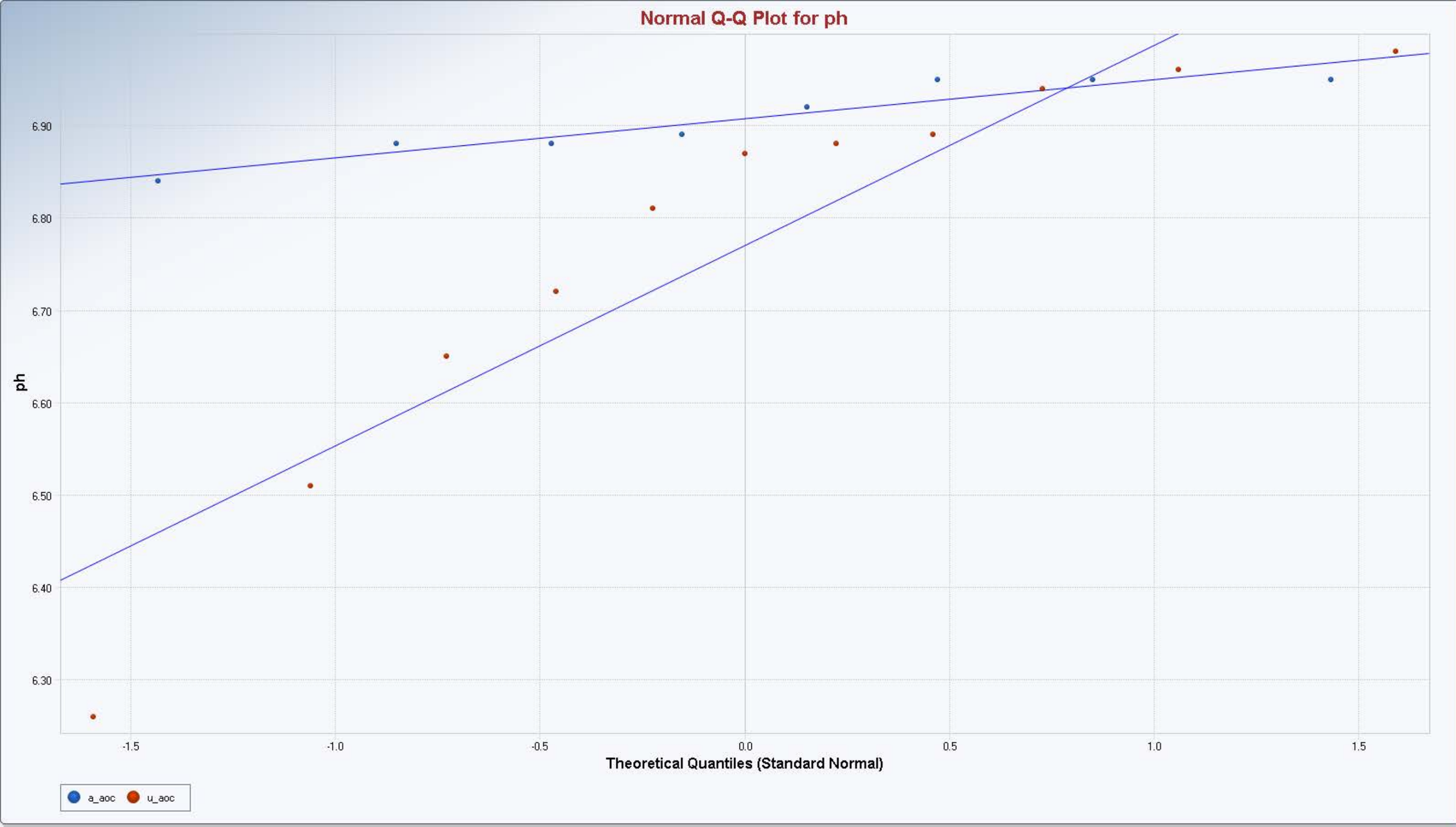


a_aoc

n = 8
Mean = 8.394
Sd = 0.371
Slope = 0.371
Intercept = 8.394
Correlation, R = 0.931
Shapiro-Wilk Test
Exact Test Value = 0.863
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.867
p-Value = 0.144

u_aoc

n = 11
Mean = 7.964
Sd = 0.34
Slope = 0.349
Intercept = 7.964
Correlation, R = 0.97
Shapiro-Wilk Test
Exact Test Value = 0.947
Critical Val(0.05) = 0.850
Data Appear Normal
Approx. Test Value = 0.944
p-Value = 0.543
Best Fit Line



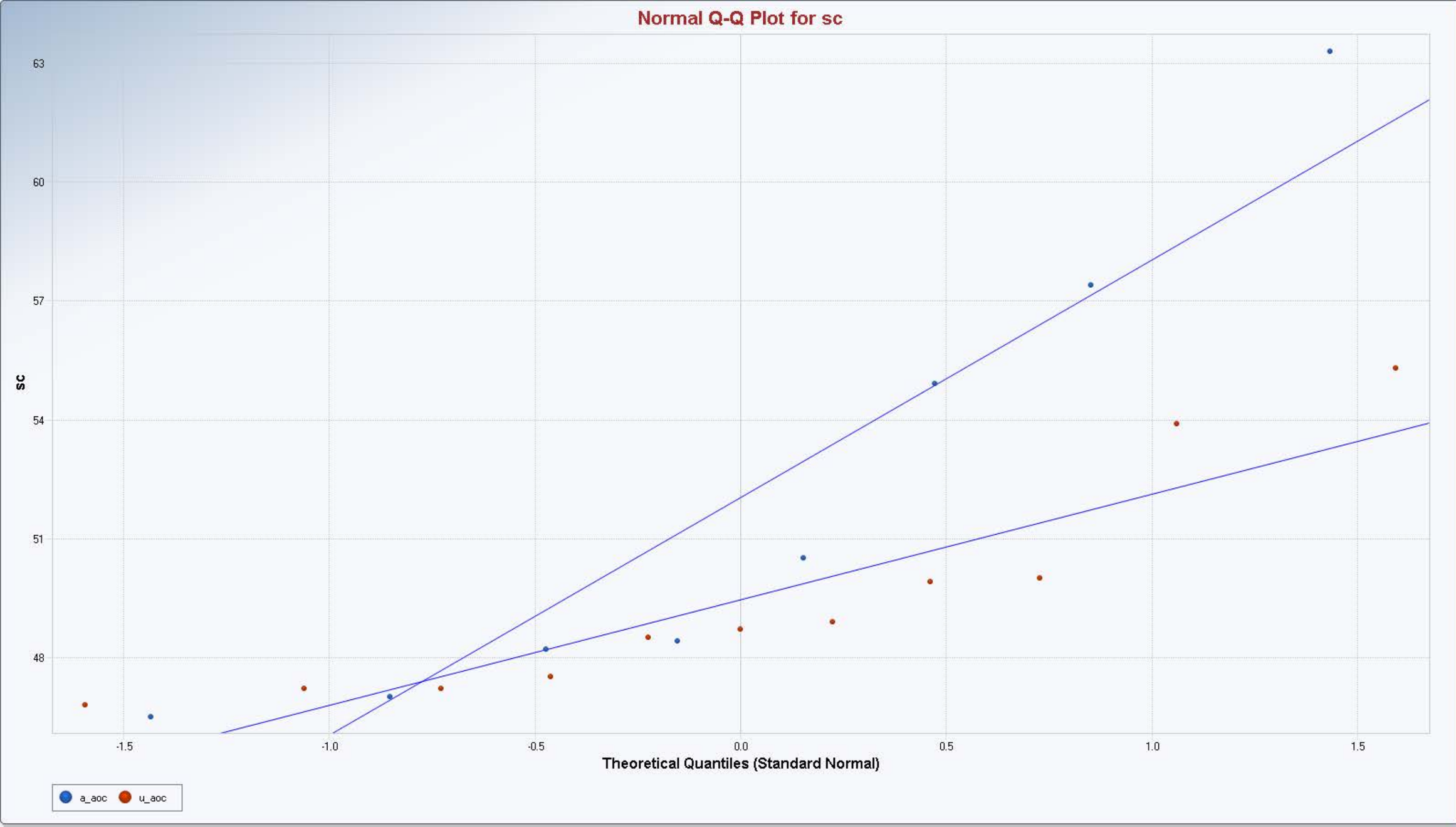
a_aoc

n = 8
Mean = 6.908
Sd = 0.0413
Slope = 0.0421
Intercept = 6.908
Correlation, R = 0.948
Shapiro-Wilk Test
Exact Test Value = 0.881
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.897
p-Value = 0.275

u_aoc

n = 11
Mean = 6.77
Sd = 0.222
Slope = 0.217
Intercept = 6.77
Correlation, R = 0.922
Shapiro-Wilk Test
Exact Test Value = 0.852
Critical Val(0.05) = 0.850
Data Appear Normal
Approx. Test Value = 0.851
p-Value = 0.0444

Best Fit Line



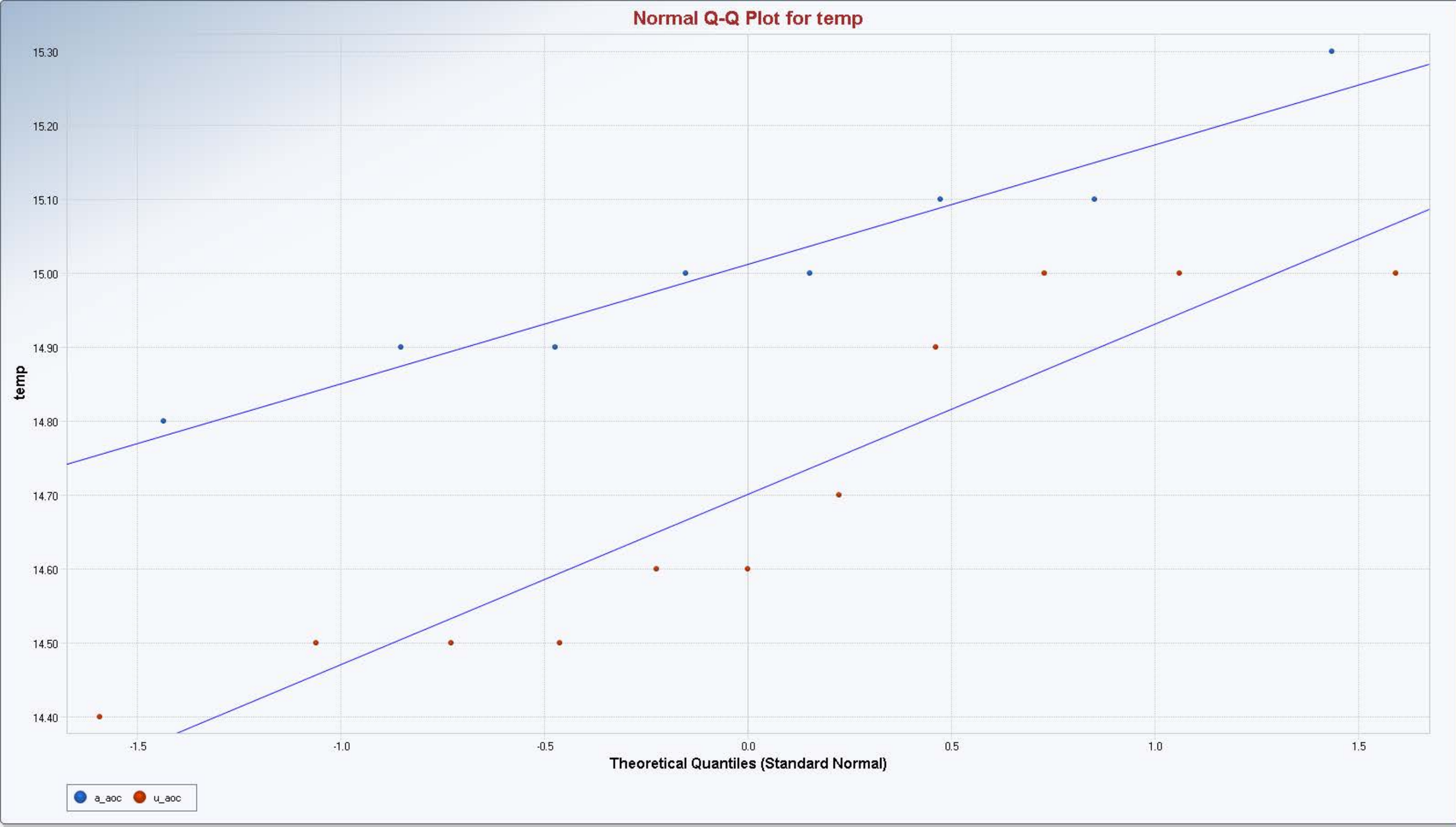
a_aoc

n = 8
Mean = 52.03
Sd = 5.978
Slope = 6.014
Intercept = 52.03
Correlation, R = 0.936
Shapiro-Wilk Test
Exact Test Value = 0.869
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.876
p-Value = 0.174

u_aoc

n = 11
Mean = 49.45
Sd = 2.779
Slope = 2.68
Intercept = 49.45
Correlation, R = 0.91
Shapiro-Wilk Test
Exact Test Value = 0.825
Critical Val(0.05) = 0.850
Data Not Normal
Approx. Test Value = 0.828
p-Value = 0.0233

Best Fit Line



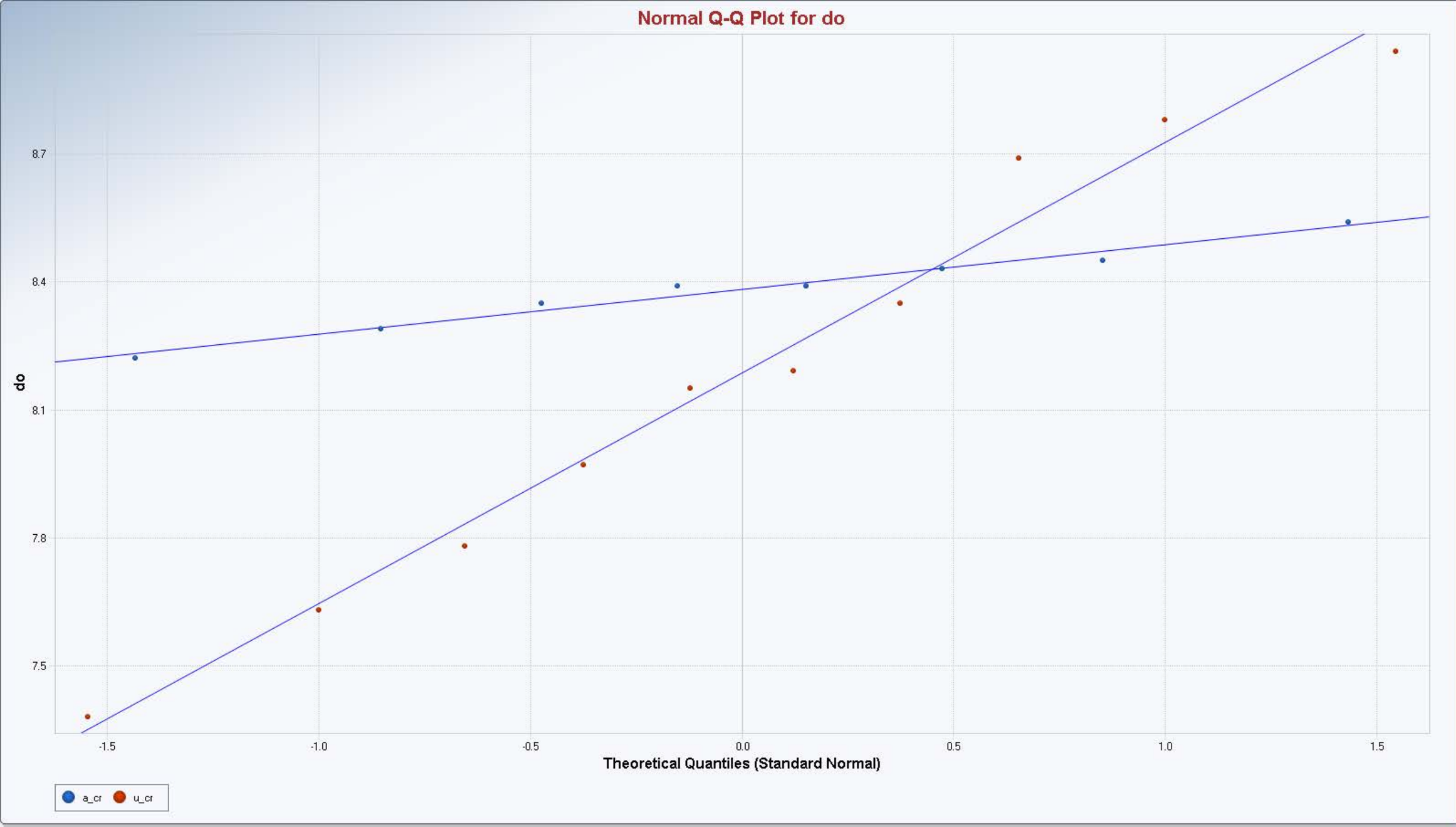
a_aoc

n = 8
Mean = 15.01
Sd = 0.155
Slope = 0.162
Intercept = 15.01
Correlation, R = 0.971
Shapiro-Wilk Test
Exact Test Value = 0.952
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.945
p-Value = 0.66

u_aoc

n = 11
Mean = 14.7
Sd = 0.232
Slope = 0.231
Intercept = 14.7
Correlation, R = 0.938
Shapiro-Wilk Test
Exact Test Value = 0.854
Critical Val(0.05) = 0.850
Data Appear Normal
Approx. Test Value = 0.871
p-Value = 0.0797

Best Fit Line



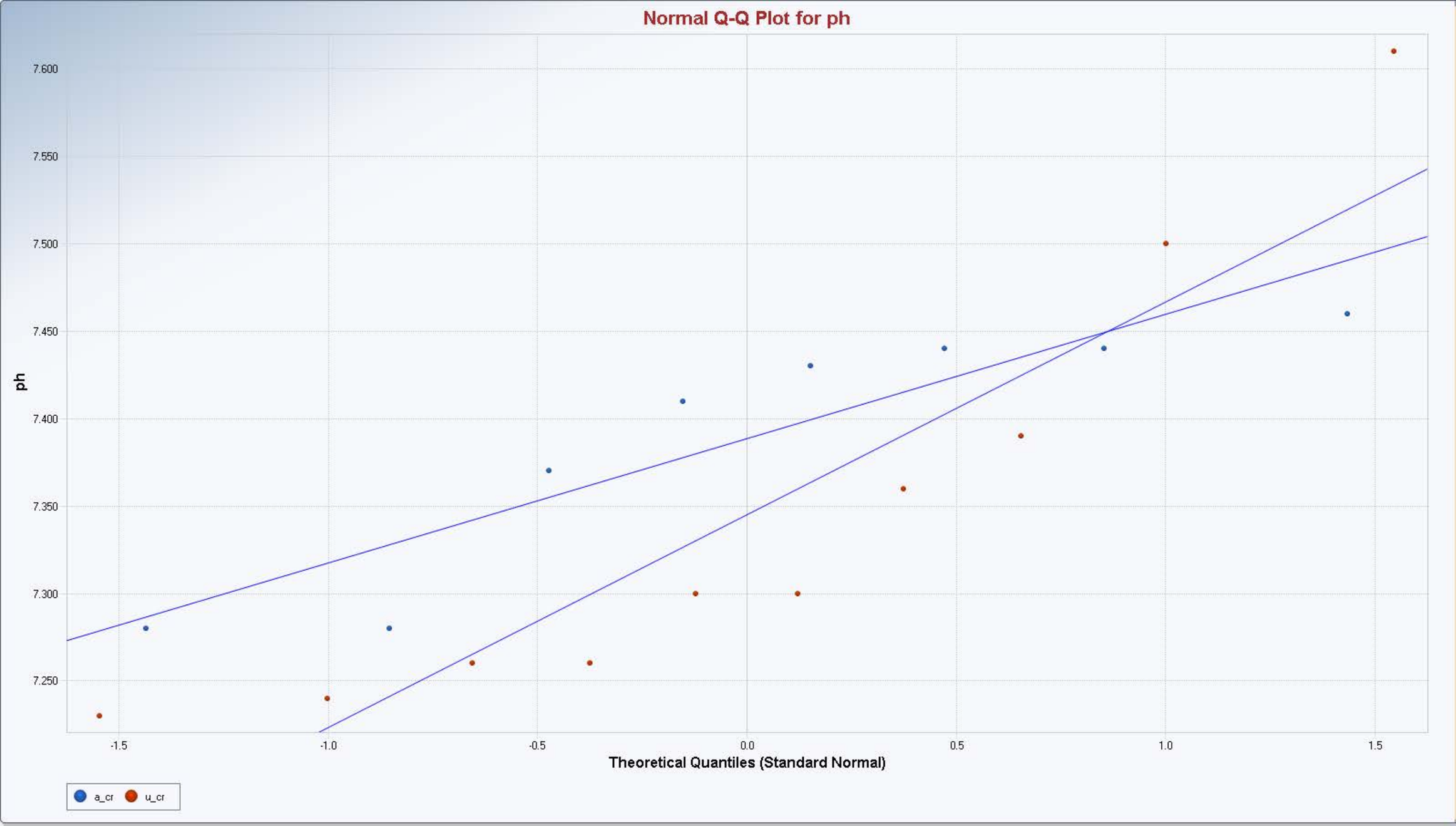
a_cr

- n = 8
- Mean = 8.383
- Sd = 0.0984
- Slope = 0.104
- Intercept = 8.383
- Correlation, R = 0.988
- Shapiro-Wilk Test
- Exact Test Value = 0.984
- Critical Val(0.05) = 0.818
- Data Appear Normal
- Approx. Test Value = 0.978
- p-Value = 0.946

u_cr

- n = 10
- Mean = 8.186
- Sd = 0.514
- Slope = 0.541
- Intercept = 8.186
- Correlation, R = 0.991
- Shapiro-Wilk Test
- Exact Test Value = 0.969
- Critical Val(0.05) = 0.842
- Data Appear Normal
- Approx. Test Value = 0.979
- p-Value = 0.957

Best Fit Line

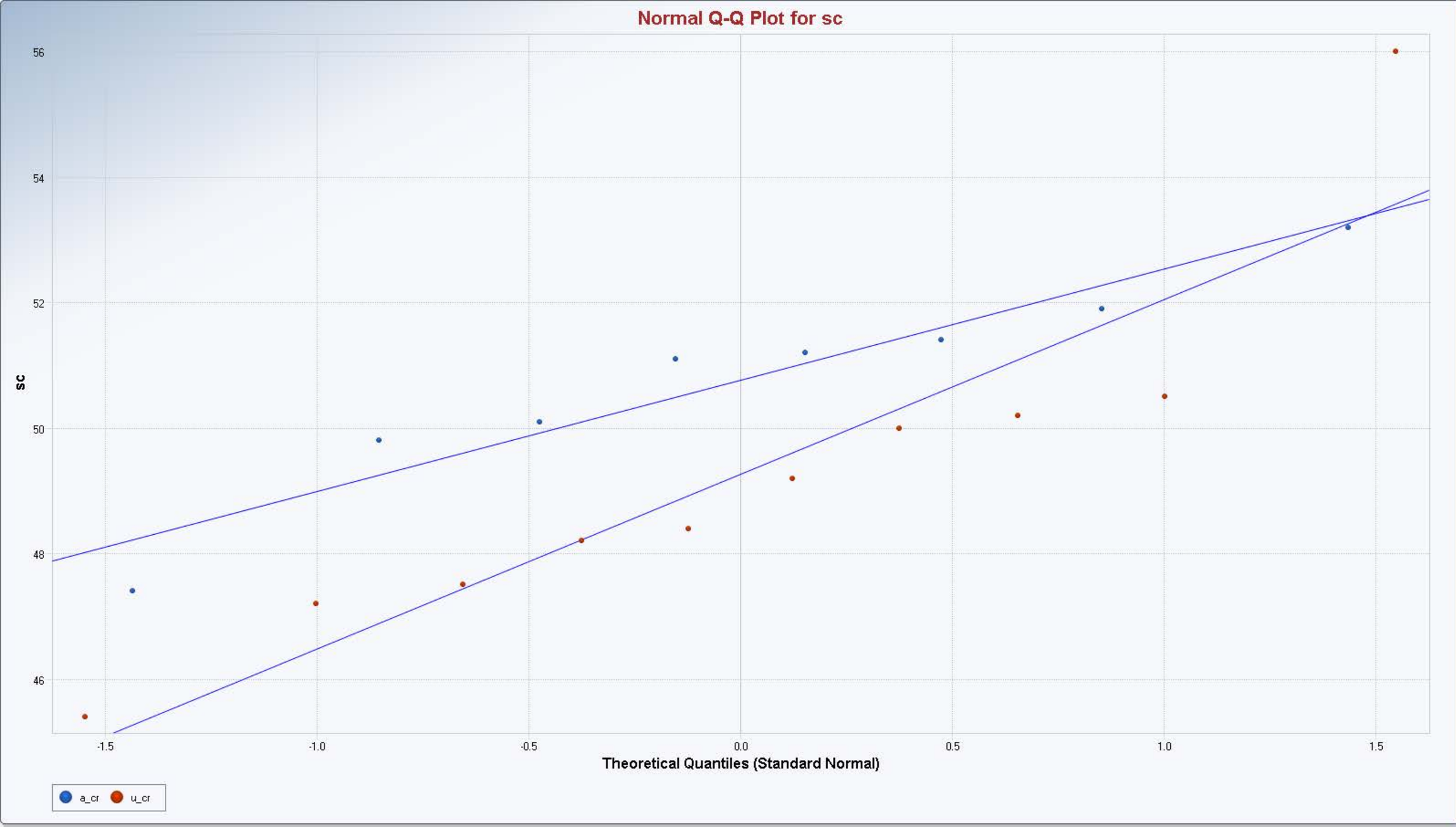


a_cr

n = 8
Mean = 7.389
Sd = 0.0722
Slope = 0.0711
Intercept = 7.389
Correlation, R = 0.916
Shapiro-Wilk Test
Exact Test Value = 0.819
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.837
p-Value = 0.0716

u_cr

n = 10
Mean = 7.345
Sd = 0.124
Slope = 0.122
Intercept = 7.345
Correlation, R = 0.922
Shapiro-Wilk Test
Exact Test Value = 0.848
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.850
p-Value = 0.0564
Best Fit Line

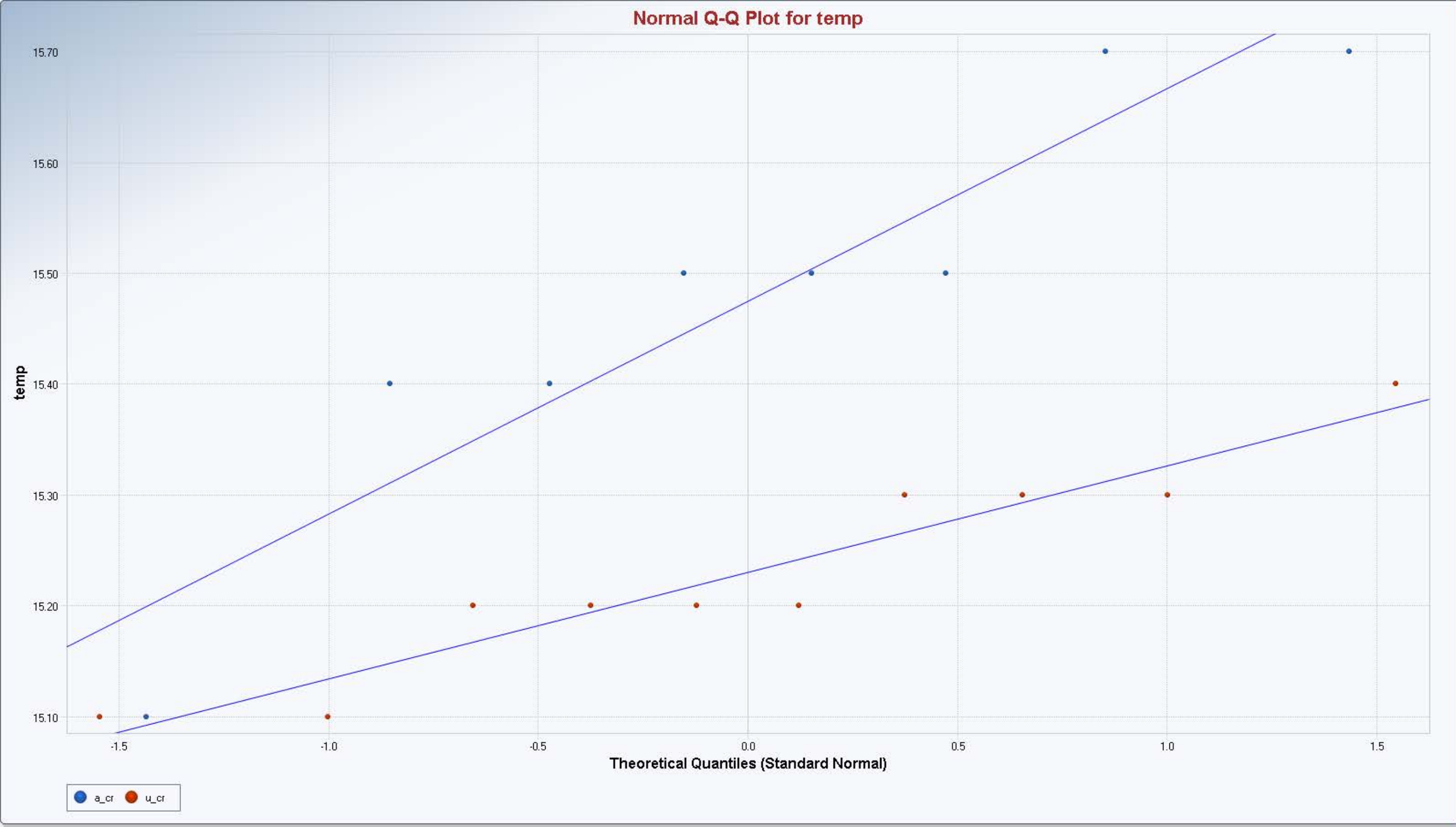


a_cr

n = 8
Mean = 50.76
Sd = 1.716
Slope = 1.772
Intercept = 50.76
Correlation, R = 0.961
Shapiro-Wilk Test
Exact Test Value = 0.942
Critical Val(0.05) = 0.818
Data Appear Normal
Approx. Test Value = 0.925
p-Value = 0.48

u_cr

n = 10
Mean = 49.26
Sd = 2.838
Slope = 2.795
Intercept = 49.26
Correlation, R = 0.926
Shapiro-Wilk Test
Exact Test Value = 0.883
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.865
p-Value = 0.083
Best Fit Line



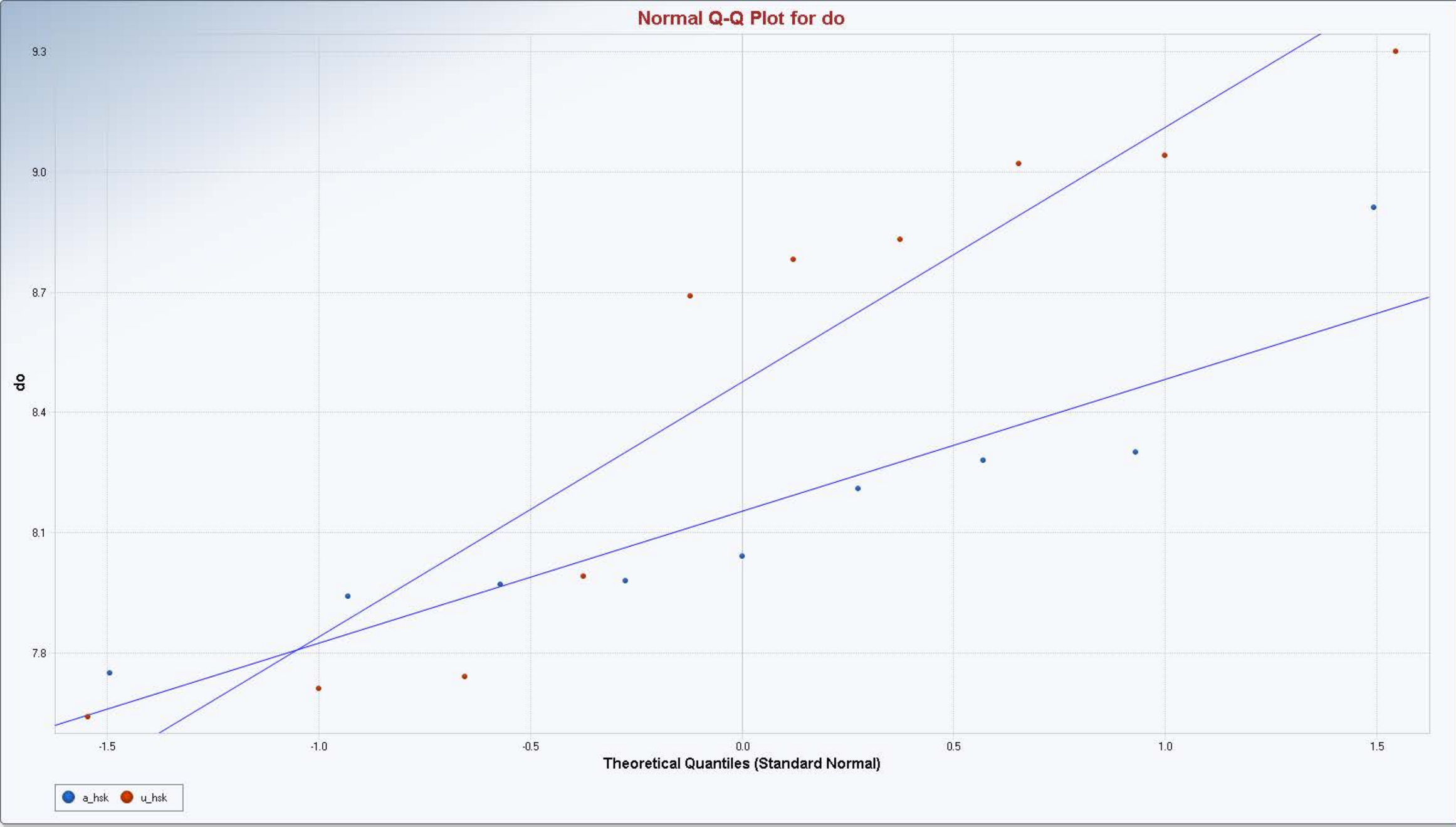
a_cr

- n = 8
- Mean = 15.48
- Sd = 0.191
- Slope = 0.192
- Intercept = 15.48
- Correlation, R = 0.936
- Shapiro-Wilk Test
- Exact Test Value = 0.887
- Critical Val(0.05) = 0.818
- Data Appear Normal
- Approx. Test Value = 0.878
- p-Value = 0.182

u_cr

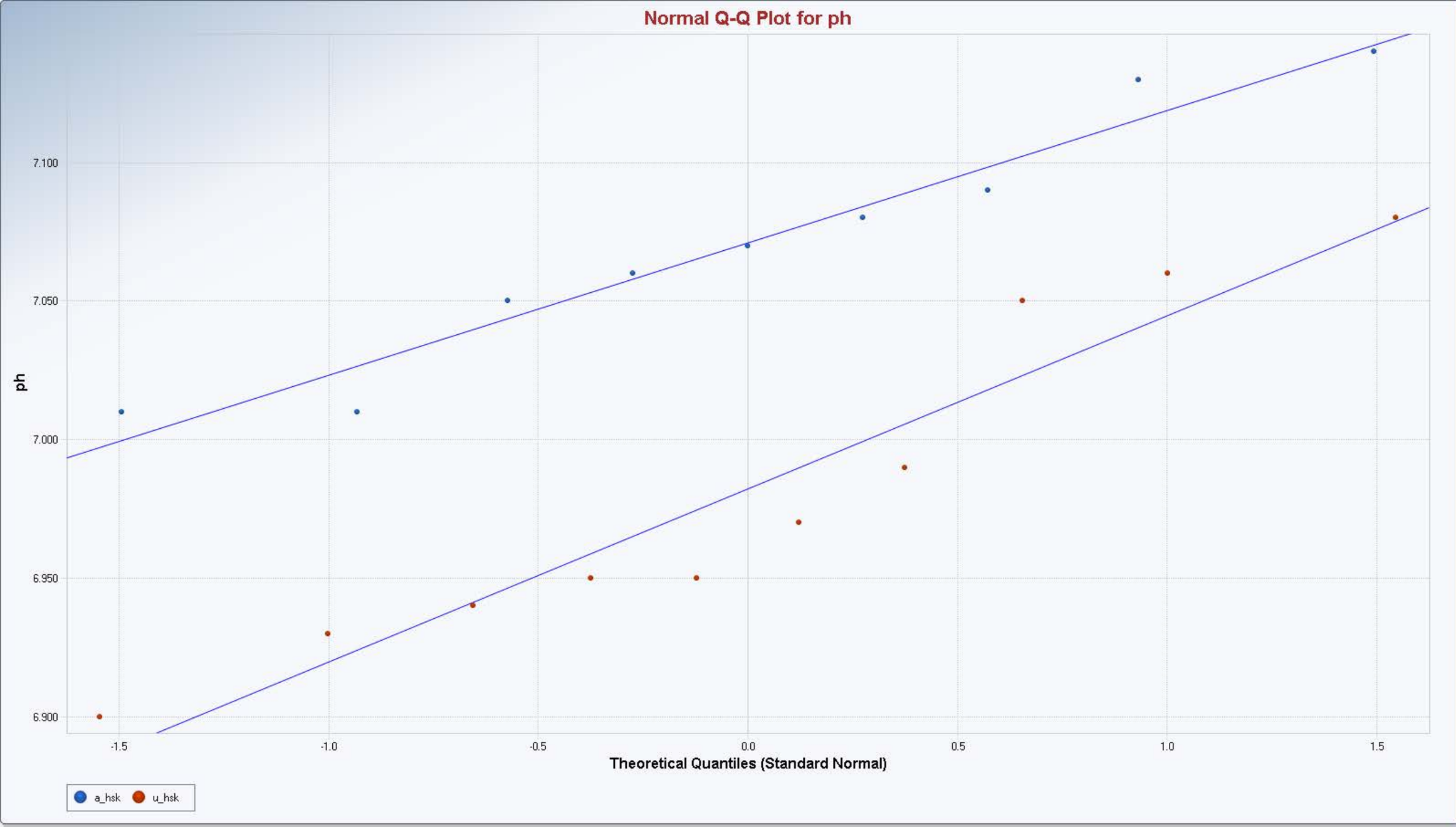
- n = 10
- Mean = 15.23
- Sd = 0.0949
- Slope = 0.0964
- Intercept = 15.23
- Correlation, R = 0.956
- Shapiro-Wilk Test
- Exact Test Value = 0.911
- Critical Val(0.05) = 0.842
- Data Appear Normal
- Approx. Test Value = 0.913
- p-Value = 0.29

Best Fit Line



a_hsk
n = 9
Mean = 8.153
Sd = 0.335
Slope = 0.33
Intercept = 8.153
Correlation, R = 0.921
Shapiro-Wilk Test
Exact Test Value = 0.868
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.852
p-Value = 0.0775

u_hsk
n = 10
Mean = 8.474
Sd = 0.634
Slope = 0.636
Intercept = 8.474
Correlation, R = 0.943
Shapiro-Wilk Test
Exact Test Value = 0.866
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.884
p-Value = 0.139
Best Fit Line



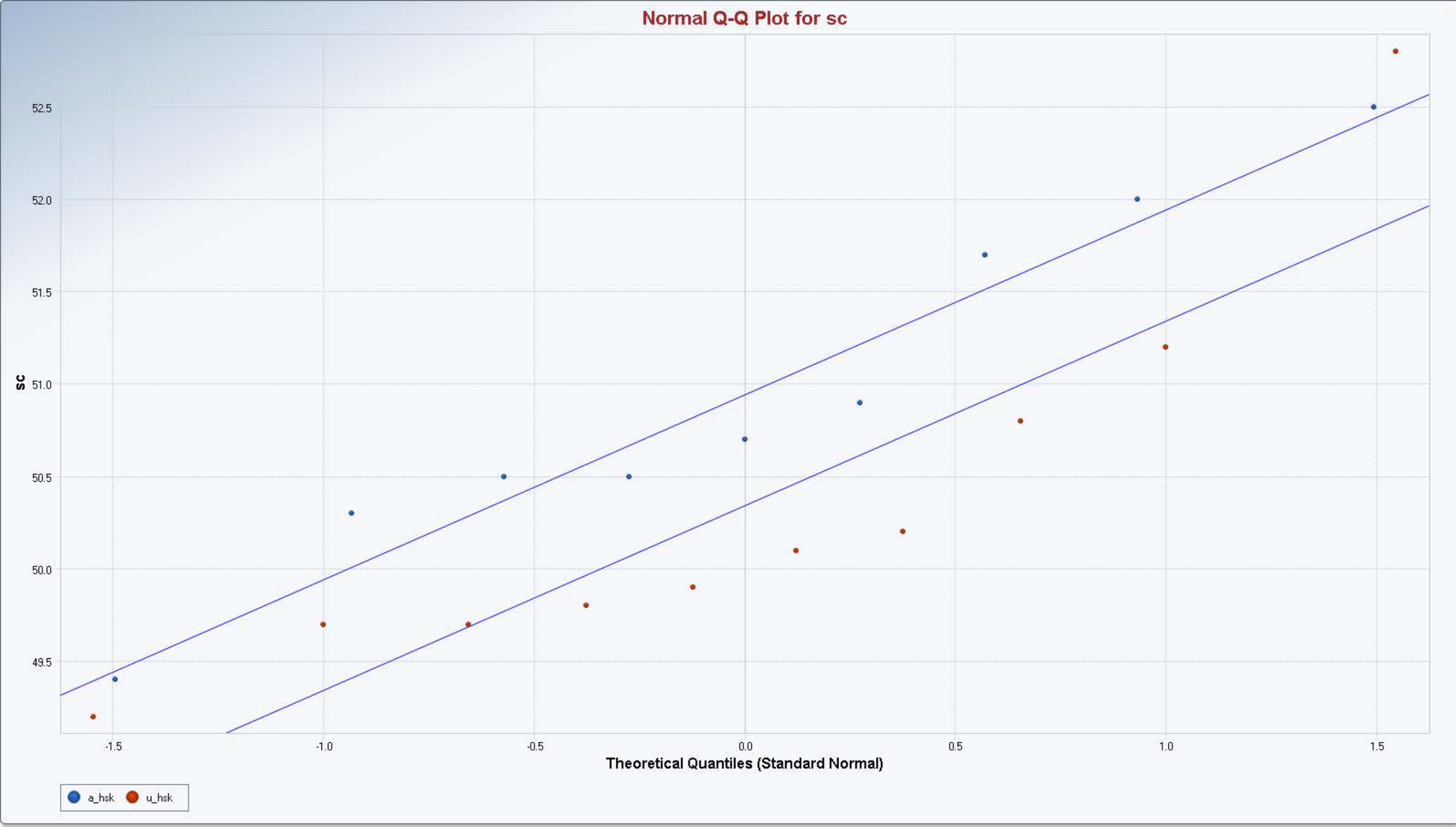
a_hsk

- n = 9
- Mean = 7.071
- Sd = 0.0457
- Slope = 0.0477
- Intercept = 7.071
- Correlation, R = 0.978
- Shapiro-Wilk Test
- Exact Test Value = 0.940
- Critical Val(0.05) = 0.829
- Data Appear Normal
- Approx. Test Value = 0.954
- p-Value = 0.725

u_hsk

- n = 10
- Mean = 6.982
- Sd = 0.0612
- Slope = 0.0626
- Intercept = 6.982
- Correlation, R = 0.961
- Shapiro-Wilk Test
- Exact Test Value = 0.911
- Critical Val(0.05) = 0.842
- Data Appear Normal
- Approx. Test Value = 0.920
- p-Value = 0.347

Best Fit Line

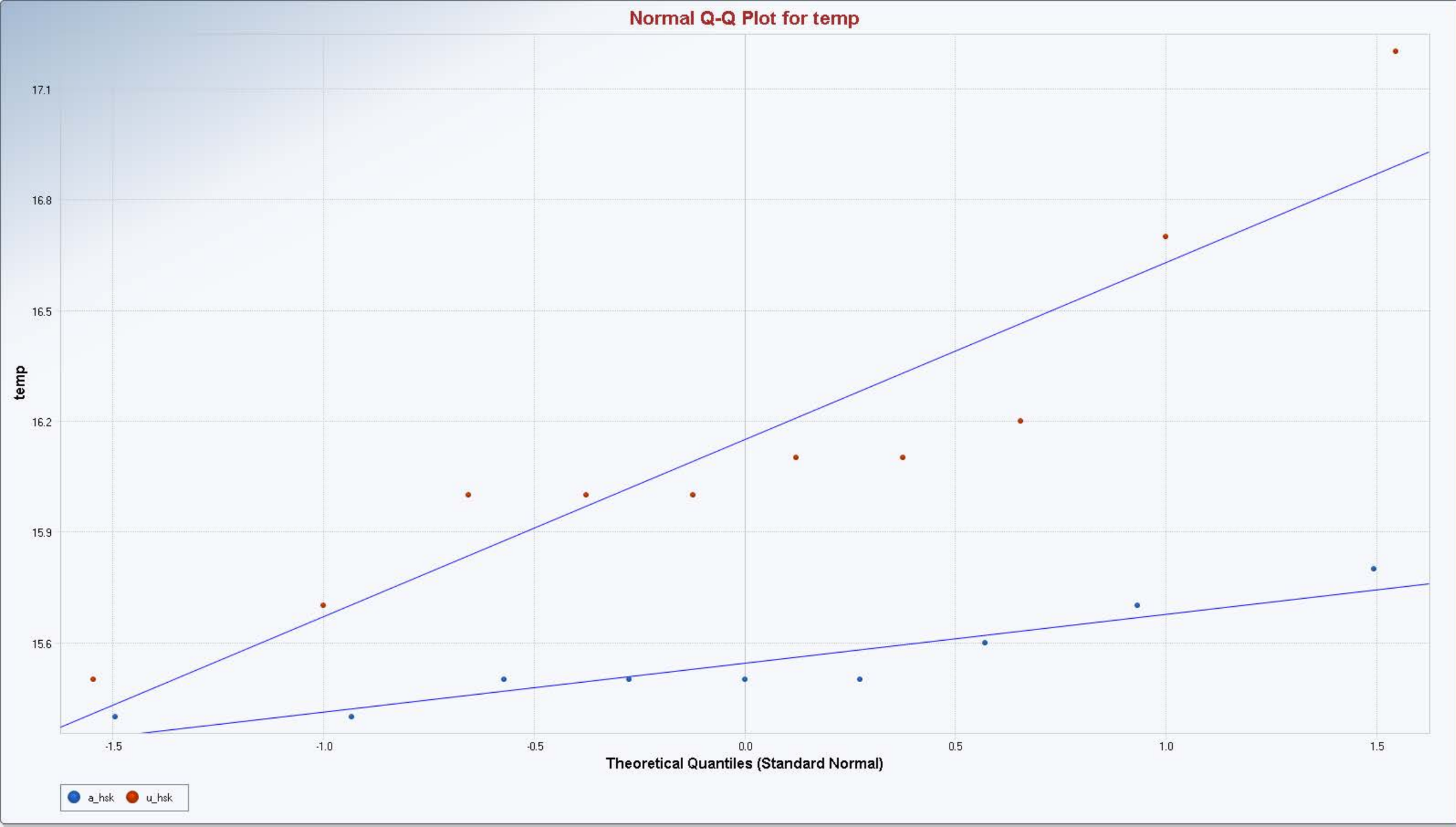


a_hsk

n = 9
Mean = 50.94
Sd = 0.959
Slope = 1.001
Intercept = 50.94
Correlation, R = 0.976
Shapiro-Wilk Test
Exact Test Value = 0.955
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.954
p-Value = 0.729

u_hsk

n = 10
Mean = 50.34
Sd = 1.037
Slope = 1.001
Intercept = 50.34
Correlation, R = 0.907
Shapiro-Wilk Test
Exact Test Value = 0.840
Critical Val(0.05) = 0.842
Data Not Normal
Approx. Test Value = 0.828
p-Value = 0.0313
Best Fit Line



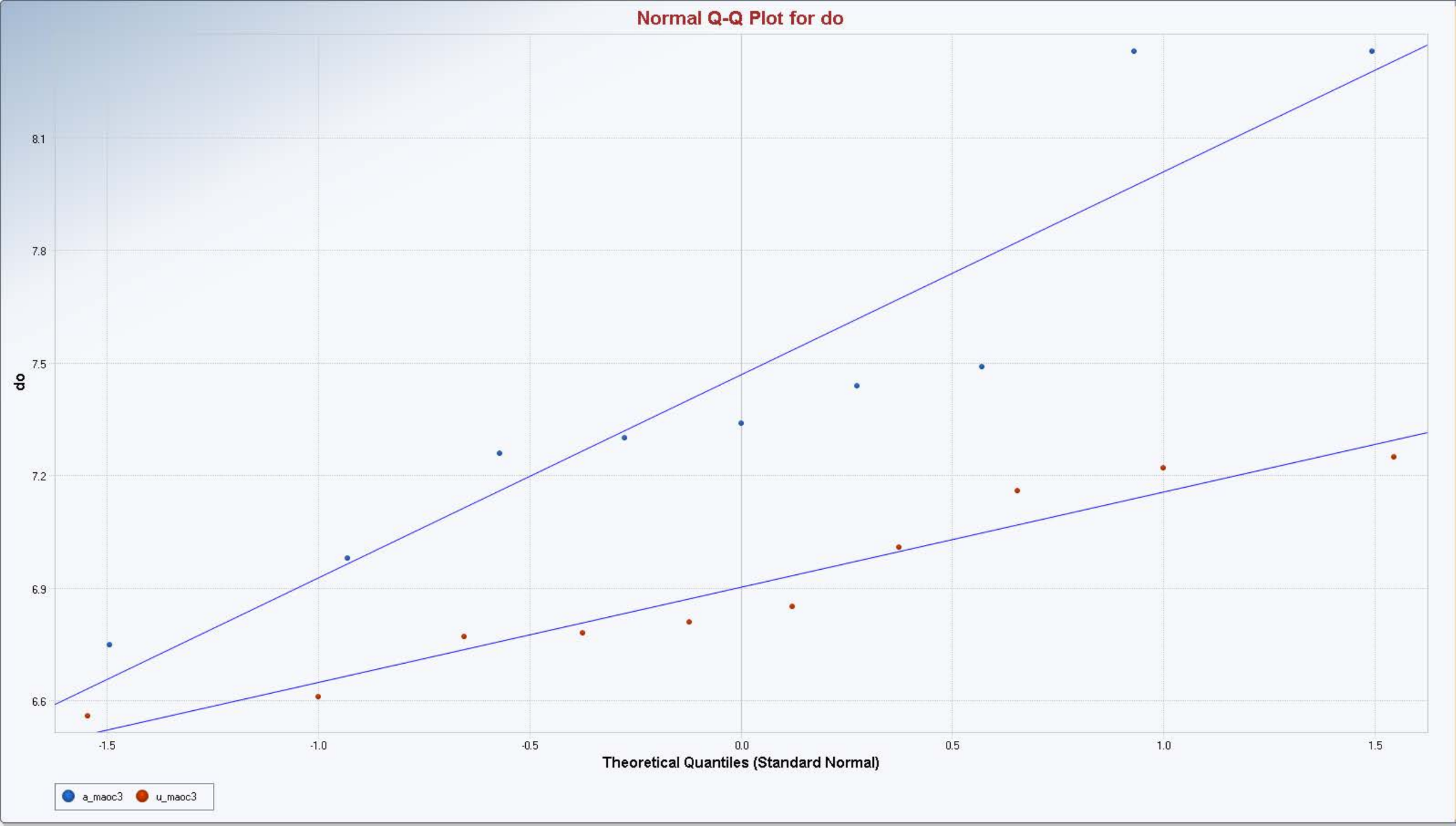
a_hsk

n = 9
Mean = 15.54
Sd = 0.133
Slope = 0.133
Intercept = 15.54
Correlation, R = 0.936
Shapiro-Wilk Test
Exact Test Value = 0.874
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.876
p-Value = 0.141

u_hsk

n = 10
Mean = 16.15
Sd = 0.484
Slope = 0.479
Intercept = 16.15
Correlation, R = 0.931
Shapiro-Wilk Test
Exact Test Value = 0.884
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.872
p-Value = 0.1

Best Fit Line

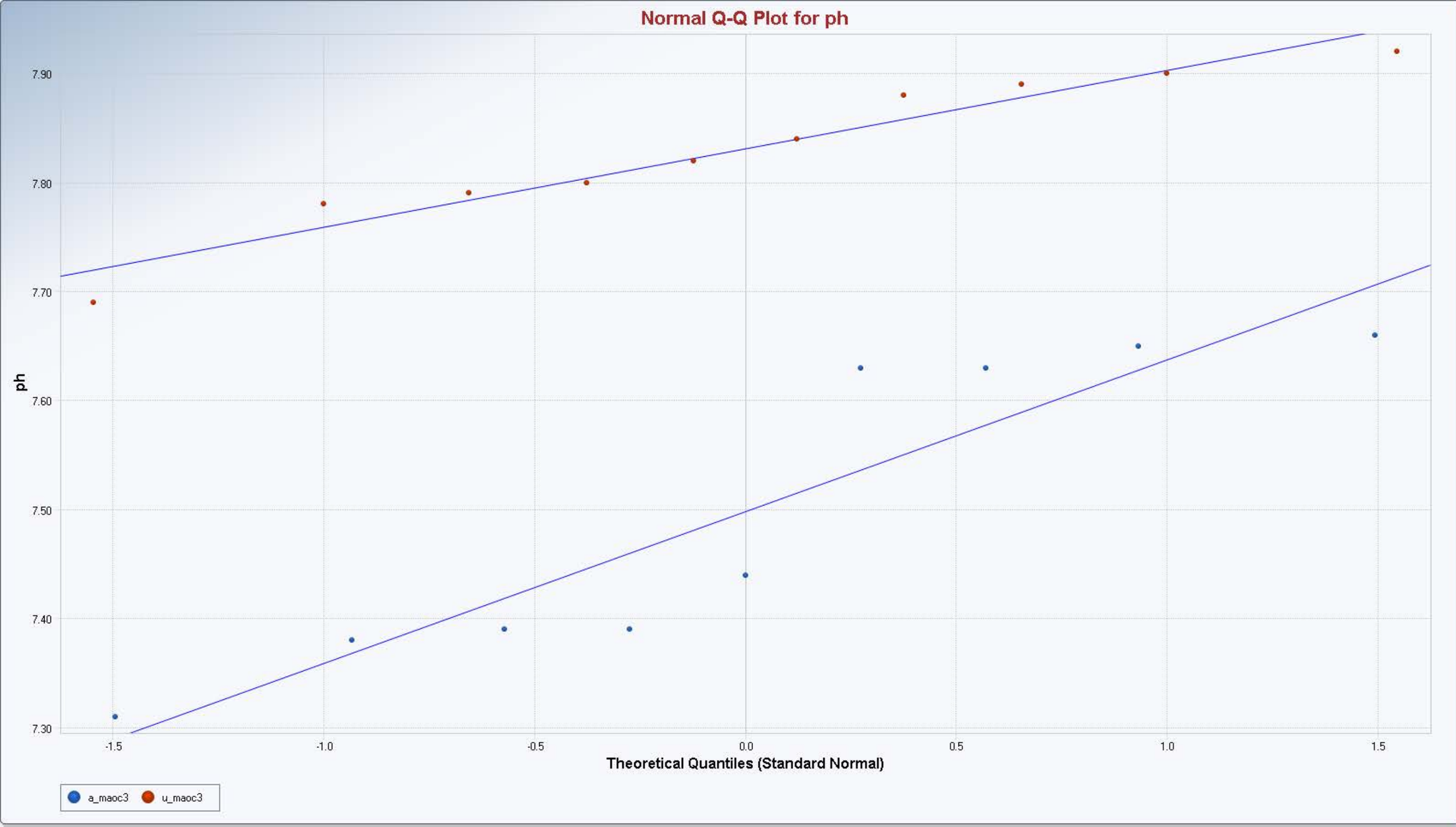


a_maoc3

n = 9
Mean = 7.469
Sd = 0.54
Slope = 0.541
Intercept = 7.469
Correlation, R = 0.938
Shapiro-Wilk Test
Exact Test Value = 0.874
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.879
p-Value = 0.151

u_maoc3

n = 10
Mean = 6.902
Sd = 0.246
Slope = 0.254
Intercept = 6.902
Correlation, R = 0.971
Shapiro-Wilk Test
Exact Test Value = 0.923
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.938
p-Value = 0.516
Best Fit Line

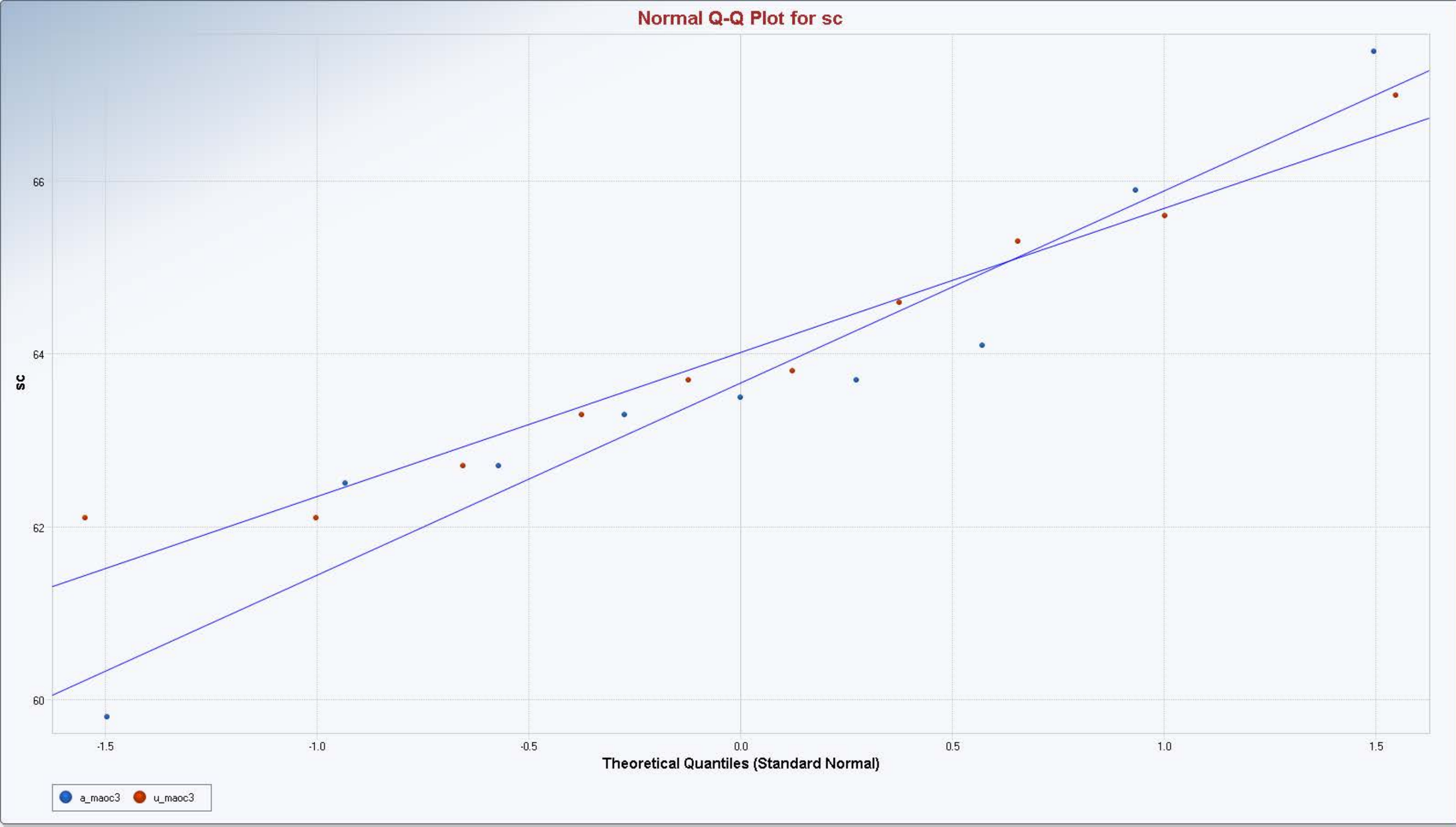


a_maoc3

n = 9
Mean = 7.498
Sd = 0.141
Slope = 0.14
Intercept = 7.498
Correlation, R = 0.923
Shapiro-Wilk Test
Exact Test Value = 0.826
Critical Val(0.05) = 0.829
Data Not Normal
Approx. Test Value = 0.847
p-Value = 0.0692

u_maoc3

n = 10
Mean = 7.831
Sd = 0.0698
Slope = 0.0721
Intercept = 7.831
Correlation, R = 0.971
Shapiro-Wilk Test
Exact Test Value = 0.943
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.944
p-Value = 0.579
Best Fit Line

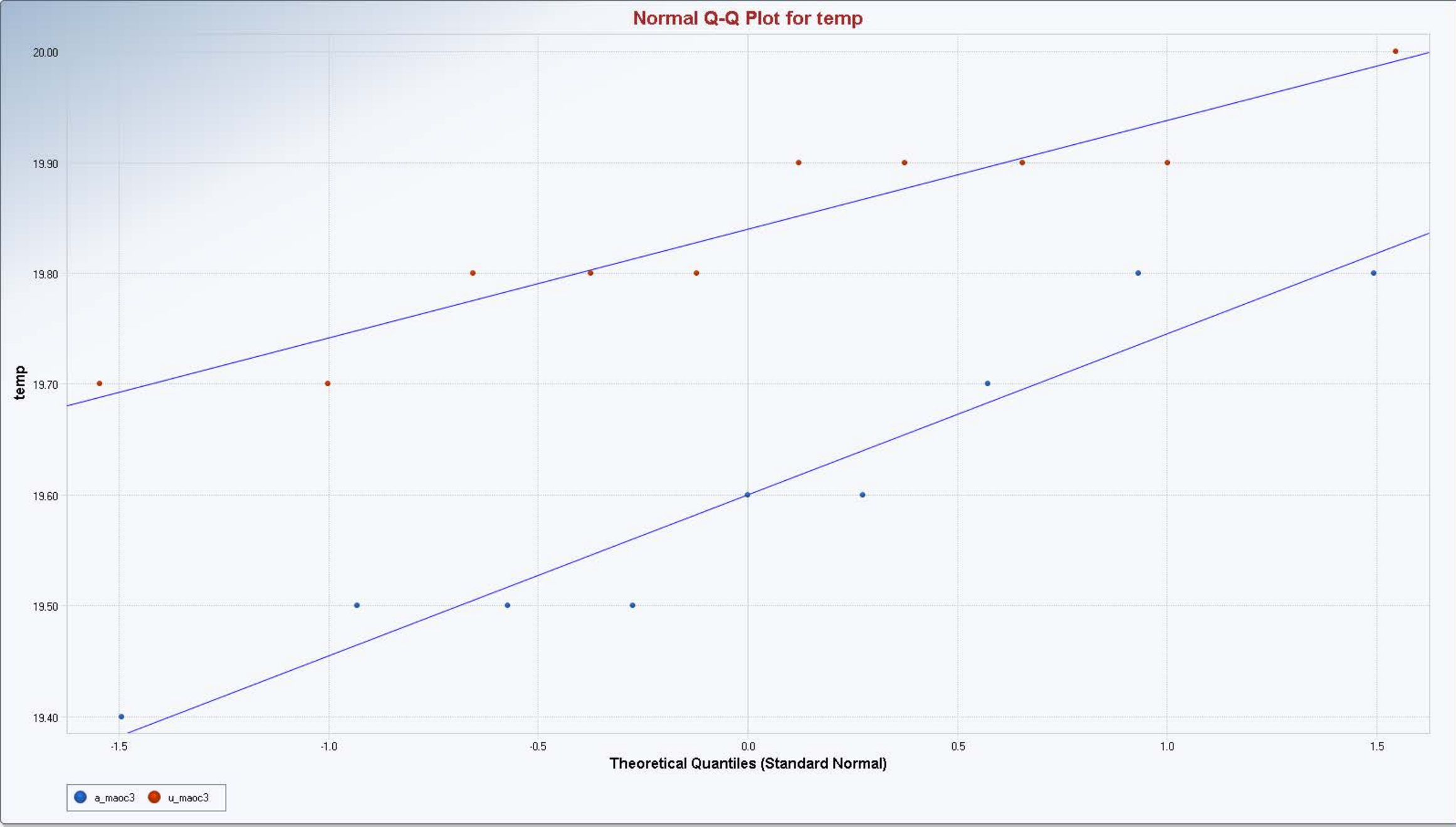


a_maoc3

n = 9
Mean = 63.67
Sd = 2.159
Slope = 2.224
Intercept = 63.67
Correlation, R = 0.964
Shapiro-Wilk Test
Exact Test Value = 0.950
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.934
p-Value = 0.516

u_maoc3

n = 10
Mean = 64.02
Sd = 1.603
Slope = 1.67
Intercept = 64.02
Correlation, R = 0.979
Shapiro-Wilk Test
Exact Test Value = 0.948
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.956
p-Value = 0.731
Best Fit Line



a_maoc3

n = 9
Mean = 19.6
Sd = 0.141
Slope = 0.145
Intercept = 19.6
Correlation, R = 0.962
Shapiro-Wilk Test
Exact Test Value = 0.911
Critical Val(0.05) = 0.829
Data Appear Normal
Approx. Test Value = 0.924
p-Value = 0.42

u_maoc3

n = 10
Mean = 19.84
Sd = 0.0966
Slope = 0.098
Intercept = 19.84
Correlation, R = 0.953
Shapiro-Wilk Test
Exact Test Value = 0.904
Critical Val(0.05) = 0.842
Data Appear Normal
Approx. Test Value = 0.908
p-Value = 0.258

Best Fit Line

APPENDIX C.2

EXPOSURE POINT CONCENTRATIONS

TABLE C.2-1 - CCR Material Data Summary and Exposure Point Concentrations for COPCs
Kingston Fossil Plant

	Data Summary									Exposure Point Concentration		
COPC	Number of Samples	Number of Detections	Detection Frequency	Minimum Reporting Limit for Non-Detects [a]	Maximum Reporting Limit for Non-Detects [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration for Detected Results	Median Concentration for Detects and Non-Detects	95% UCL [b]	ProUCL Method	EPC [c]
			%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		mg/kg
Interim Ash Staging Area												
Arsenic	33	33	100	n/a	n/a	18.1	119	49.1	43.6	56.2	95% Student's-t	5.62E+01
Cobalt	33	33	100	n/a	n/a	3.88	35.6	9.02	7.48	10.7	95% Adjusted Gamma	1.07E+01
Thallium	33	33	100	n/a	n/a	0.395	7.31	1.21	1.03	1.48	95% Adjusted Gamma	1.48E+00
Vanadium	33	33	100	n/a	n/a	15.5	76.7	42.2	38.0	47.3	95% Student's-t	4.73E+01
Sluice Trench and Area East of Sluice Trench												
Arsenic	17	17	100	n/a	n/a	15.9	115	38.8	33.5	49.0	95% Student's-t	4.90E+01
Cobalt	17	17	100	n/a	n/a	3.15	22.1	10.9	8.76	13.5	95% Student's-t	1.35E+01
Thallium	17	17	100	n/a	n/a	0.353	1.75	1.03	1.05	1.18	95% Student's-t	1.18E+00
Vanadium	17	17	100	n/a	n/a	11.1	121	54.3	38.3	70.6	95% Student's-t	7.06E+01
Stilling Pond												
Arsenic	3	3	100	n/a	n/a	32.6	80.8	60.5	68.1	NC	n/a	8.08E+01
Cobalt	3	3	100	n/a	n/a	4.42	7.97	6.10	5.90	n/a [d]	n/a	n/a
Thallium	3	3	100	n/a	n/a	1.05	1.51	1.24	1.16	NC	n/a	1.51E+00
Vanadium	3	3	100	n/a	n/a	25.1	46.1	37.1	40.0	n/a [d]	n/a	n/a

Notes:

%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
USEPA	United States Environmental Protection Agency
EPC	exposure point concentration
mg/kg	milligrams per kilogram
n/a	not applicable
NC	not calculated
UCL	upper confidence limit of the mean concentration

[a] Minimum and maximum reporting limit for non-detects are only provided when detection frequency for a COPC is less than 100%.
[b] Calculated using USEPA's ProUCL version 5.2 (USEPA 2022) for COPCs with a minimum of five detected results.
[c] The EPC for a COPC with five or more detected results is equal to the lower of the UCL of the mean concentration as recommended by ProUCL (USEPA 2022) or the maximum detected concentration. For a COPC at a location where the UCL of the mean concentration could not be calculated, the EPC is equal to the maximum detected concentration if there are less than 10 samples or the lower of the maximum detected concentration or median concentration if there are 10 or more samples.
[d] 95% UCLs and human health risks were not estimated for this constituent because the maximum detected concentration in samples collected from this exposure unit does not exceed the respective screening level presented in Table 4-1.

APPENDIX C.3

ProUCL OUTPUTS

APPENDIX C.3-1

ProUCL OUTPUTS

HUMAN HEALTH RISK ASSESSMENT

CCR MATERIAL

UCL Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.2 7/26/2023 4:58:21 PM
From File	20210312_CCRMC_ProUCL(20210217)_byCCRunit_e.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic (kif_iasa)

General Statistics

Total Number of Observations	33	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	18.1	Mean	49.12
Maximum	119	Median	43.6
SD	24.09	Std. Error of Mean	4.193
Coefficient of Variation	0.49	Skewness	1.025

Normal GOF Test

Shapiro Wilk Test Statistic	0.924	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.906	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.108	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.177	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	56.22	95% Adjusted-CLT UCL (Chen-1995)	56.82
		95% Modified-t UCL (Johnson-1978)	56.35

Gamma GOF Test

A-D Test Statistic	0.191	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.75	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0857	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.154	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.618	k star (bias corrected MLE)	4.218
Theta hat (MLE)	10.64	Theta star (bias corrected MLE)	11.64
nu hat (MLE)	304.8	nu star (bias corrected)	278.4
MLE Mean (bias corrected)	49.12	MLE Sd (bias corrected)	23.92
		Approximate Chi Square Value (0.05)	240.7
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	238.9

Assuming Gamma Distribution

95% Approximate Gamma UCL	56.8	95% Adjusted Gamma UCL	57.23

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.981	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.942	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.0754	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.139	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.896	Mean of logged Data	3.782
Maximum of Logged Data	4.779	SD of logged Data	0.484

Assuming Lognormal Distribution

95% H-UCL	58.17	90% Chebyshev (MVUE) UCL	62.1
95% Chebyshev (MVUE) UCL	67.96	97.5% Chebyshev (MVUE) UCL	76.1
99% Chebyshev (MVUE) UCL	92.08		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	56.02	95% BCA Bootstrap UCL	57.04
95% Standard Bootstrap UCL	55.77	95% Bootstrap-t UCL	56.67
95% Hall's Bootstrap UCL	56.67	95% Percentile Bootstrap UCL	56.29
90% Chebyshev(Mean, Sd) UCL	61.7	95% Chebyshev(Mean, Sd) UCL	67.4
97.5% Chebyshev(Mean, Sd) UCL	75.31	99% Chebyshev(Mean, Sd) UCL	90.84

Suggested UCL to Use

95% Student's-t UCL	56.22

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Arsenic (kif_sluice)

General Statistics

Total Number of Observations	17	Number of Distinct Observations	17
		Number of Missing Observations	0
Minimum	15.9	Mean	38.82
Maximum	115	Median	33.5
SD	24.01	Std. Error of Mean	5.823
Coefficient of Variation	0.618	Skewness	2.205

Normal GOF Test

Shapiro Wilk Test Statistic	0.784	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.851	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.187	**Lilliefors GOF Test**

1% Lilliefors Critical Value	0.241	Data appear Normal at 1% Significance Level

Data appear Approximate Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	48.98	95% Adjusted-CLT UCL (Chen-1995)	51.72
		95% Modified-t UCL (Johnson-1978)	49.5

Gamma GOF Test

A-D Test Statistic	0.379	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.116	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.21	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.871	k star (bias corrected MLE)	3.227
Theta hat (MLE)	10.03	Theta star (bias corrected MLE)	12.03
nu hat (MLE)	131.6	nu star (bias corrected)	109.7
MLE Mean (bias corrected)	38.82	MLE Sd (bias corrected)	21.61
		Approximate Chi Square Value (0.05)	86.55
Adjusted Level of Significance	0.0346	Adjusted Chi Square Value	84.4

Assuming Gamma Distribution

95% Approximate Gamma UCL	49.21	95% Adjusted Gamma UCL	50.47

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.91	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.0796	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.19	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.766	Mean of logged Data	3.524
Maximum of Logged Data	4.745	SD of logged Data	0.51

Assuming Lognormal Distribution

95% H-UCL	50.16	90% Chebyshev (MVUE) UCL	53.03
95% Chebyshev (MVUE) UCL	59.7	97.5% Chebyshev (MVUE) UCL	68.95
99% Chebyshev (MVUE) UCL	87.12		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	48.4	95% BCA Bootstrap UCL	51.04
95% Standard Bootstrap UCL	47.9	95% Bootstrap-t UCL	56.16
95% Hall's Bootstrap UCL	95.83	95% Percentile Bootstrap UCL	48.41

90% Chebyshev(Mean, Sd) UCL	56.29	95% Chebyshev(Mean, Sd) UCL	64.2
97.5% Chebyshev(Mean, Sd) UCL	75.18	99% Chebyshev(Mean, Sd) UCL	96.75

Suggested UCL to Use

95% Student's-t UCL 48.98

When a data set follows an approximate distribution passing only one of the GOF tests,
it is suggested to use a UCL based upon a distribution passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cobalt (kif_iasa)

General Statistics

Total Number of Observations	33	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	3.88	Mean	9.018
Maximum	35.6	Median	7.48
SD	5.819	Std. Error of Mean	1.013
Coefficient of Variation	0.645	Skewness	3.134

Normal GOF Test

Shapiro Wilk Test Statistic	0.707	**Shapiro Wilk GOF Test**	
1% Shapiro Wilk Critical Value	0.906	Data Not Normal at 1% Significance Level	
Lilliefors Test Statistic	0.189	**Lilliefors GOF Test**	
1% Lilliefors Critical Value	0.177	Data Not Normal at 1% Significance Level	

Data Not Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	10.73	95% Adjusted-CLT UCL (Chen-1995)	11.27
		95% Modified-t UCL (Johnson-1978)	10.83

Gamma GOF Test

A-D Test Statistic	0.601	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.752	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.0991	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.154	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.923	k star (bias corrected MLE)	3.586
Theta hat (MLE)	2.299	Theta star (bias corrected MLE)	2.515
nu hat (MLE)	258.9	nu star (bias corrected)	236.7
MLE Mean (bias corrected)	9.018	MLE Sd (bias corrected)	4.762
		Approximate Chi Square Value (0.05)	202.1

Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	200.4

Assuming Gamma Distribution

95% Approximate Gamma UCL	10.56	95% Adjusted Gamma UCL	10.65

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.942	Data appear Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.0783	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.139	Data appear Lognormal at 10% Significance Level	

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.356	Mean of logged Data	2.066
Maximum of Logged Data	3.572	SD of logged Data	0.492

Assuming Lognormal Distribution

95% H-UCL	10.54	90% Chebyshev (MVUE) UCL	11.26
95% Chebyshev (MVUE) UCL	12.34	97.5% Chebyshev (MVUE) UCL	13.84
99% Chebyshev (MVUE) UCL	16.78		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	10.68	95% BCA Bootstrap UCL	11.57
95% Standard Bootstrap UCL	10.63	95% Bootstrap-t UCL	11.75
95% Hall's Bootstrap UCL	18.45	95% Percentile Bootstrap UCL	10.72
90% Chebyshev(Mean, Sd) UCL	12.06	95% Chebyshev(Mean, Sd) UCL	13.43
97.5% Chebyshev(Mean, Sd) UCL	15.34	99% Chebyshev(Mean, Sd) UCL	19.1

Suggested UCL to Use

95% Adjusted Gamma UCL	10.65

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Cobalt (kif_sluice)

General Statistics

Total Number of Observations	17	Number of Distinct Observations	17
		Number of Missing Observations	0
Minimum	3.15	Mean	10.88
Maximum	22.1	Median	8.76
SD	6.257	Std. Error of Mean	1.517
Coefficient of Variation	0.575	Skewness	0.828

Normal GOF Test

Shapiro Wilk Test Statistic	0.863	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.851	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.184	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.241	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	13.53	95% Adjusted-CLT UCL (Chen-1995)	13.7
		95% Modified-t UCL (Johnson-1978)	13.58

Gamma GOF Test

A-D Test Statistic	0.467	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.744	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.161	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.21	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.391	k star (bias corrected MLE)	2.832
Theta hat (MLE)	3.208	Theta star (bias corrected MLE)	3.842
nu hat (MLE)	115.3	nu star (bias corrected)	96.28
MLE Mean (bias corrected)	10.88	MLE Sd (bias corrected)	6.465
		Approximate Chi Square Value (0.05)	74.65
Adjusted Level of Significance	0.0346	Adjusted Chi Square Value	72.65

Assuming Gamma Distribution

95% Approximate Gamma UCL	14.03	95% Adjusted Gamma UCL	14.42

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.91	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.145	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.19	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.147	Mean of logged Data	2.232
Maximum of Logged Data	3.096	SD of logged Data	0.579

Assuming Lognormal Distribution

95% H-UCL	14.97	90% Chebyshev (MVUE) UCL	15.68
95% Chebyshev (MVUE) UCL	17.85	97.5% Chebyshev (MVUE) UCL	20.86
99% Chebyshev (MVUE) UCL	26.77		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	13.37	95% BCA Bootstrap UCL	13.69
95% Standard Bootstrap UCL	13.37	95% Bootstrap-t UCL	14.06
95% Hall's Bootstrap UCL	13.49	95% Percentile Bootstrap UCL	13.5
90% Chebyshev(Mean, Sd) UCL	15.43	95% Chebyshev(Mean, Sd) UCL	17.49
97.5% Chebyshev(Mean, Sd) UCL	20.36	99% Chebyshev(Mean, Sd) UCL	25.98

Suggested UCL to Use

95% Student's-t UCL 13.53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Thallium (kif_iasa)

General Statistics

Total Number of Observations	33	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	0.395	Mean	1.208
Maximum	7.31	Median	1.03
SD	1.172	Std. Error of Mean	0.204
Coefficient of Variation	0.971	Skewness	4.639

Normal GOF Test

Shapiro Wilk Test Statistic	0.499	**Shapiro Wilk GOF Test**	
1% Shapiro Wilk Critical Value	0.906	Data Not Normal at 1% Significance Level	
Lilliefors Test Statistic	0.26	**Lilliefors GOF Test**	
1% Lilliefors Critical Value	0.177	Data Not Normal at 1% Significance Level	

Data Not Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.553	95% Adjusted-CLT UCL (Chen-1995)	1.719
		95% Modified-t UCL (Johnson-1978)	1.581

Gamma GOF Test

A-D Test Statistic	1.284	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.755	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.155	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.667	k star (bias corrected MLE)	2.445
Theta hat (MLE)	0.453	Theta star (bias corrected MLE)	0.494
nu hat (MLE)	176	nu star (bias corrected)	161.4
MLE Mean (bias corrected)	1.208	MLE Sd (bias corrected)	0.772

		Approximate Chi Square Value (0.05)	133
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	131.7

Assuming Gamma Distribution

95% Approximate Gamma UCL	1.465	95% Adjusted Gamma UCL	1.48

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.918	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.942	Data Not Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.0954	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.139	Data appear Lognormal at 10% Significance Level	

Data appear Approximate Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.929	Mean of logged Data	-0.0104
Maximum of Logged Data	1.989	SD of logged Data	0.562

Assuming Lognormal Distribution

95% H-UCL	1.412	90% Chebyshev (MVUE) UCL	1.511
95% Chebyshev (MVUE) UCL	1.673	97.5% Chebyshev (MVUE) UCL	1.898
99% Chebyshev (MVUE) UCL	2.34		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	1.543	95% BCA Bootstrap UCL	1.77
95% Standard Bootstrap UCL	1.527	95% Bootstrap-t UCL	2.008
95% Hall's Bootstrap UCL	2.892	95% Percentile Bootstrap UCL	1.558
90% Chebyshev(Mean, Sd) UCL	1.82	95% Chebyshev(Mean, Sd) UCL	2.097
97.5% Chebyshev(Mean, Sd) UCL	2.482	99% Chebyshev(Mean, Sd) UCL	3.238

Suggested UCL to Use

95% Adjusted Gamma UCL	1.48

When a data set follows an approximate distribution passing only one of the GOF tests,
it is suggested to use a UCL based upon a distribution passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Thallium (kif_sluice)

General Statistics

Total Number of Observations	17	Number of Distinct Observations	17
		Number of Missing Observations	0
Minimum	0.353	Mean	1.027

Maximum	1.75	Median	1.05
SD	0.368	Std. Error of Mean	0.0892
Coefficient of Variation	0.358	Skewness	0.185

Normal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.851	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.12	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.241	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.183	95% Adjusted-CLT UCL (Chen-1995)	1.178
		95% Modified-t UCL (Johnson-1978)	1.184

Gamma GOF Test

A-D Test Statistic	0.359	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.14	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.209	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.242	k star (bias corrected MLE)	6.003
Theta hat (MLE)	0.142	Theta star (bias corrected MLE)	0.171
nu hat (MLE)	246.2	nu star (bias corrected)	204.1
MLE Mean (bias corrected)	1.027	MLE Sd (bias corrected)	0.419
		Approximate Chi Square Value (0.05)	172
Adjusted Level of Significance	0.0346	Adjusted Chi Square Value	169

Assuming Gamma Distribution

95% Approximate Gamma UCL	1.219	95% Adjusted Gamma UCL	1.241

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.927	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.91	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.159	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.19	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.041	Mean of logged Data	-0.0435
Maximum of Logged Data	0.56	SD of logged Data	0.41

Assuming Lognormal Distribution

95% H-UCL	1.272	90% Chebyshev (MVUE) UCL	1.352
95% Chebyshev (MVUE) UCL	1.495	97.5% Chebyshev (MVUE) UCL	1.694
99% Chebyshev (MVUE) UCL	2.085		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	1.174	95% BCA Bootstrap UCL	1.172
95% Standard Bootstrap UCL	1.168	95% Bootstrap-t UCL	1.19
95% Hall's Bootstrap UCL	1.193	95% Percentile Bootstrap UCL	1.164
90% Chebyshev(Mean, Sd) UCL	1.295	95% Chebyshev(Mean, Sd) UCL	1.416
97.5% Chebyshev(Mean, Sd) UCL	1.584	99% Chebyshev(Mean, Sd) UCL	1.915

Suggested UCL to Use

95% Student's-t UCL 1.183

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vanadium (kif_iasa)

General Statistics

Total Number of Observations	33	Number of Distinct Observations	32
		Number of Missing Observations	0
Minimum	15.5	Mean	42.23
Maximum	76.7	Median	38
SD	17.28	Std. Error of Mean	3.008
Coefficient of Variation	0.409	Skewness	0.391

Normal GOF Test

Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.906	Data appear Normal at 1% Significance Level
Lilliefors Test Statistic	0.122	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.177	Data appear Normal at 1% Significance Level

Data appear Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	47.32	95% Adjusted-CLT UCL (Chen-1995)	47.39
		95% Modified-t UCL (Johnson-1978)	47.36

Gamma GOF Test

A-D Test Statistic	0.361	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.748	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.103	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.153	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	5.948	k star (bias corrected MLE)	5.428
Theta hat (MLE)	7.099	Theta star (bias corrected MLE)	7.78
nu hat (MLE)	392.6	nu star (bias corrected)	358.2
MLE Mean (bias corrected)	42.23	MLE Sd (bias corrected)	18.13
		Approximate Chi Square Value (0.05)	315.4
Adjusted Level of Significance	0.0419	Adjusted Chi Square Value	313.3

Assuming Gamma Distribution

95% Approximate Gamma UCL	47.97	95% Adjusted Gamma UCL	48.28

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**	
10% Shapiro Wilk Critical Value	0.942	Data appear Lognormal at 10% Significance Level	
Lilliefors Test Statistic	0.11	**Lilliefors Lognormal GOF Test**	
10% Lilliefors Critical Value	0.139	Data appear Lognormal at 10% Significance Level	

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.741	Mean of logged Data	3.657
Maximum of Logged Data	4.34	SD of logged Data	0.432

Assuming Lognormal Distribution

95% H-UCL	49.1	90% Chebyshev (MVUE) UCL	52.29
95% Chebyshev (MVUE) UCL	56.77	97.5% Chebyshev (MVUE) UCL	62.99
99% Chebyshev (MVUE) UCL	75.21		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	47.17	95% BCA Bootstrap UCL	47.28
95% Standard Bootstrap UCL	47.01	95% Bootstrap-t UCL	47.33
95% Hall's Bootstrap UCL	47.19	95% Percentile Bootstrap UCL	47.07
90% Chebyshev(Mean, Sd) UCL	51.25	95% Chebyshev(Mean, Sd) UCL	55.34
97.5% Chebyshev(Mean, Sd) UCL	61.01	99% Chebyshev(Mean, Sd) UCL	72.16

Suggested UCL to Use

95% Student's-t UCL	47.32

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vanadium (kif_sluice)

General Statistics

Total Number of Observations	17	Number of Distinct Observations	17
		Number of Missing Observations	0

Minimum	11.1	Mean	54.25
Maximum	121	Median	38.3
SD	38.58	Std. Error of Mean	9.356
Coefficient of Variation	0.711	Skewness	0.939

Normal GOF Test

Shapiro Wilk Test Statistic	0.824	**Shapiro Wilk GOF Test**
1% Shapiro Wilk Critical Value	0.851	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.224	**Lilliefors GOF Test**
1% Lilliefors Critical Value	0.241	Data appear Normal at 1% Significance Level

Data appear Approximate Normal at 1% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	70.59	95% Adjusted-CLT UCL (Chen-1995)	71.92
		95% Modified-t UCL (Johnson-1978)	70.94

Gamma GOF Test

A-D Test Statistic	0.531	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.749	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.163	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.211	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.226	k star (bias corrected MLE)	1.872
Theta hat (MLE)	24.37	Theta star (bias corrected MLE)	28.97
nu hat (MLE)	75.69	nu star (bias corrected)	63.66
MLE Mean (bias corrected)	54.25	MLE Sd (bias corrected)	39.65
		Approximate Chi Square Value (0.05)	46.31
Adjusted Level of Significance	0.0346	Adjusted Chi Square Value	44.76

Assuming Gamma Distribution

95% Approximate Gamma UCL	74.59	95% Adjusted Gamma UCL	77.17

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.946	**Shapiro Wilk Lognormal GOF Test**
10% Shapiro Wilk Critical Value	0.91	Data appear Lognormal at 10% Significance Level
Lilliefors Test Statistic	0.144	**Lilliefors Lognormal GOF Test**
10% Lilliefors Critical Value	0.19	Data appear Lognormal at 10% Significance Level

Data appear Lognormal at 10% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.407	Mean of logged Data	3.753
Maximum of Logged Data	4.796	SD of logged Data	0.731

Assuming Lognormal Distribution

95% H-UCL	84.6	90% Chebyshev (MVUE) UCL	85.53
95% Chebyshev (MVUE) UCL	99.54	97.5% Chebyshev (MVUE) UCL	119

99% Chebyshev (MVUE) UCL	157.1

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution

Nonparametric Distribution Free UCLs

95% CLT UCL	69.64	95% BCA Bootstrap UCL	71.64
95% Standard Bootstrap UCL	69.56	95% Bootstrap-t UCL	75.11
95% Hall's Bootstrap UCL	69.77	95% Percentile Bootstrap UCL	70.58
90% Chebyshev(Mean, Sd) UCL	82.32	95% Chebyshev(Mean, Sd) UCL	95.04
97.5% Chebyshev(Mean, Sd) UCL	112.7	99% Chebyshev(Mean, Sd) UCL	147.3

Suggested UCL to Use

95% Student's-t UCL	70.59

When a data set follows an approximate distribution passing only one of the GOF tests,
it is suggested to use a UCL based upon a distribution passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness using results from simulation studies.
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

APPENDIX D – HUMAN HEALTH RISK ASSESSMENT CALCULATIONS

APPENDIX D.1

EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Appendix D.1 – Example Human Health Risk Calculations

Human Health and Ecological Risk Assessment
Kingston Fossil Plant
Harriman, Tennessee

September 19, 2025

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

Stantec Consulting Services Inc.
Lexington, Kentucky

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APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Exposure Dose Equations
September 19, 2025

This appendix provides equations used to estimate exposure doses for all receptors with potentially complete pathways and example calculations for deriving the human health exposure, carcinogenic risk, and noncancer hazard estimates presented in the Kingston Fossil Plant Human Health Risk Assessment (HHRA). Example calculations for chemical constituents of potential concern (COPCs) are provided for onsite workers exposed to arsenic in coal combustion residuals (CCR) material.

Exposure Dose Equations
September 19, 2025

1.0 EXPOSURE DOSE EQUATIONS

1.1 CCR MATERIAL

1.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion Dose for Carcinogenic Risk Estimates (milligrams [mg] per kilogram [kg] per day [mg/kg-day]) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

IR_{CCR} = Ingestion rate of CCR material (mg/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_C = Averaging time (cancer) (days)

Incidental Ingestion Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

IR_{CCR} = Ingestion rate of CCR material (mg/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

RBA = Relative bioavailability factor (unitless)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_{NCw} = Averaging time (noncancer) (days)

1.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

AF_w = Adherence factor of CCR material to skin (mg/square centimeter [cm^2])

ABS = Dermal absorption factor (unitless)

SA_w = Skin surface area available for contact (cm^2)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_c = Averaging time (cancer) (days)

Dermal Absorption Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

AF_w = Adherence factor of CCR material to skin (mg/cm^2)

ABS = Dermal absorption factor (unitless)

SA_w = Skin surface area available for contact (cm^2)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

CF = Conversion factor (kg/mg)

BW_w = Body weight (kg)

AT_{NCw} = Averaging time (noncancer) (days)

1.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates Concentration for Carcinogenic Risk Estimates (micrograms [µg] per cubic meters [m^3] [$\mu g/m^3$]) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_c \times CF}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

PEF = Particulate emission factor (m^3/kg)

ET_w = Exposure time (hours/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

AT_c = Averaging time (cancer) (days)

CF = Conversion factor (mg/µg)

Inhalation of Particulates Concentration for Noncancer Hazard Estimates (mg/m^3) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_{NCw}}$$

Where:

C_{CCR} = Chemical concentration in CCR material (mg/kg)

PEF = Particulate emission factor (m^3/kg)

ET_w = Exposure time (hours/day)

EF_w = Exposure frequency (days/year)

ED_w = Exposure duration (years)

AT_{NCw} = Averaging time (noncancer) (days)

2.0 EXAMPLE CALCULATIONS

2.1 CALCULATED INGESTION AND DERMAL EXPOSURE DOSES AND INHALATION CONCENTRATIONS FOR CHEMICAL COPCS

Examples of the methods used to calculate ingestion and dermal exposure doses and inhalation concentrations of arsenic in CCR material are provided below. These calculations serve as examples for other COPCs. Exposure point concentrations and exposure assumptions used in these calculations are summarized in Sections 5.1.2 and 5.1.3 of the human health and ecological risk assessment (HHERA) report. The tables referenced in this appendix are presented in the HHERA report.

2.1.1 Arsenic in CCR Material

2.1.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion Dose for Carcinogenic Risk Estimates (milligrams [mg]/kilogram [kg]-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
IR_{CCR}	= Ingestion rate of CCR material (mg/day)	= 330 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
RBA	= Arsenic relative bioavailability factor (unitless)	= 0.6 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_C	= Averaging time (cancer) (days)	= 25,550 (Table 5-2)

Result:

Incidental ingestion dose (cancer) (mg/kg-day)	= $1.09x10^{-7}$ (Appendix D.2)

APPENDIX D.1 – EXAMPLE HUMAN HEALTH RISK CALCULATIONS

Example Calculations
September 19, 2025

Incidental Ingestion Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times IR_{CCR} \times EF_w \times ED_w \times RBA \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
IR_{CCR}	= Ingestion rate of CCR material (mg/day)	= 330 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
RBA	= Arsenic relative bioavailability factor (unitless)	= 0.6 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_{NCw}	= Averaging time (noncancer) (days)	= 28 (Table 5-2)

Result:

Incidental ingestion dose (noncancer) (mg/kg-day)	= $9.94x10^{-5}$ (Appendix D.2)

2.1.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption Dose for Carcinogenic Risk Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_c}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
AF_w	= Adherence factor of CCR material to skin (mg/square centimeter [cm^2])	= 0.3 (Table 5-2)
ABS	= Arsenic dermal absorption factor (unitless)	= 0.03 (RAGS Part E)
SA_w	= Skin surface area available for contact (cm^2)	= 3,527 (Table 5-2)

EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_c	= Averaging time (cancer)	= 25,550 (Table 5-2)

Result:

Dermal absorption dose (cancer) (mg/kg-day) = $1.75x10^{-8}$ (Appendix D.2)

Dermal Absorption Dose for Noncancer Hazard Estimates (mg/kg-day) =

$$\frac{C_{CCR} \times AF_w \times ABS \times SA_w \times EF_w \times ED_w \times CF}{BW_w \times AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
AF_w	= Adherence factor of CCR material to skin (mg/cm^2)	= 0.3 (Table 5-2)
ABS	= Arsenic dermal absorption factor (unitless)	= 0.03 (RAGS Part E)
SA_w	= Skin surface area available for contact (cm^2)	= 3,527 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
CF	= Conversion factor (kg/mg)	= $1x10^{-6}$ (Table 5-2)
BW_w	= Body weight (kg)	= 80 (Table 5-2)
AT_{NCw}	= Averaging time (noncancer)	= 28 (Table 5-2)

Result:

Dermal absorption dose (noncancer) (mg/kg-day) = $1.59x10^{-5}$ (Appendix D.2)

2.1.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates Concentration for Carcinogenic Risk Estimates (micrograms [µg] per cubic meters [m^3] [$\mu g/m^3$]) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_c \times CF}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
PEF	= Particulate emission factor (m^3/kg)	= $1.36x10^{+9}$ (Table 5-2)
ET_w	= Exposure time (hours/day)	= 8 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)
ED_w	= Exposure duration (years)	= 1 (Table 5-2)
AT_C	= Averaging time (cancer) (days)	= 25,550 (Table 5-2)
CF	= Conversion factor (mg/µg)	= $1x10^{-3}$ (Table 5-2)

Result:

Inhalation of particulates concentration (cancer) ($\mu g/m^3$) = $1.08x10^{-8}$ (Appendix D.2)

Inhalation of Particulates Concentration for Noncancer Hazard Estimates (mg/m^3) =

$$\frac{C_{CCR} \times \left(\frac{1}{PEF}\right) \times ET_w \times \left(\frac{1\ day}{24\ Hours}\right) \times EF_w \times ED_w}{AT_{NCw}}$$

Where:

C_{CCR}	= Arsenic concentration in the Interim Ash Staging Area (mg/kg)	= 56.2 (Table C.2-1)
PEF	= Particulate emission factor (m^3/kg)	= $1.36x10^{+9}$ (Table 5-2)
ET_w	= Exposure time (hours/day)	= 8 (Table 5-2)
EF_w	= Exposure frequency (days/year)	= 20 (Table 5-2)

ED_w = Exposure duration (years) = 1 (Table 5-2)

AT_{NCw} = Averaging time (noncancer) (days) = 28 (Table 5-2)

Result:

Inhalation of particulates concentration (noncancer) (mg/m^3) = $9.84x10^{-9}$ (Appendix D.2)

2.2 CALCULATED CANCER RISK AND NONCANCER HAZARD FOR CHEMICAL COPCS

Examples of the methods used to calculate incremental lifetime cancer risks (ILCRs) and noncancer hazard quotients (HQs) for arsenic in CCR material are provided below. These calculations serve as examples for other COPCs and exposure media. Toxicity values used in these calculations are summarized in Section 5.2 of the HHERA report.

2.2.1 Quantification of Arsenic ILCR

2.2.1.1 Onsite Worker Incidental Ingestion of CCR Material

Incidental Ingestion ILCR (unitless) = Incidental ingestion dose (cancer) x CSF_o

Where:

Incidental ingestion dose (cancer) (mg/kg-day) = $1.09x10^{-7}$ (Appendix D.2)

CSF_o = Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$ = 1.5 (Table 5-3)

Result:

Incidental ingestion ILCR (unitless) = $1.6x10^{-7}$ (Appendix D.2)

2.2.1.2 Onsite Worker Dermal Contact with CCR Material

Dermal Absorption ILCR (unitless) = Dermal absorption dose (cancer) x CSF_d

Where:

Dermal absorption dose (cancer) (mg/kg-day) = $1.75x10^{-8}$ (Appendix D.2)

CSF_d = Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$ = 1.5 (Table 5-3)

Result:

Dermal Absorption ILCR (unitless) = $2.6x10^{-8}$ (Appendix D.2)

2.2.1.3 Onsite Worker Inhalation of Particulates

Inhalation of Particulates ILCR (unitless) = Inhalation of particulates concentration (cancer) x IUR_i

Where:

Inhalation of particulates dose (cancer) ($\mu g/m^3$) = 1.08×10^{-8} (Appendix D.2)

IUR_i = Inhalation unit risk $(\mu g/m^3)^{-1}$ = 0.0043 (Table 5-3)

Result:

Inhalation of particulates ILCR (unitless) = 4.6×10^{-11} (Appendix D.2)

2.2.1.4 Onsite Worker Exposed to CCR Material COPC-Specific ILCR

Arsenic COPC-Specific ILCR (unitless) =

Incidental ingestion ILCR + Dermal absorption ILCR + Inhalation of particulates ILCR

Where:

Incidental ingestion ILCR = 1.6×10^{-7} (Appendix D.2)

Dermal absorption ILCR = 2.6×10^{-8} (Appendix D.2)

Inhalation of particulates ILCR = 4.6×10^{-11} (Appendix D.2)

Result:

Arsenic COPC-Specific ILCR (unitless) = 1.9×10^{-7} (Appendix D.2)

2.2.2 Quantification of Arsenic Noncancer Hazard

2.2.2.1 Onsite Worker Incidental Ingestion of CCR Material

$$\text{Incidental Ingestion HQ (unitless)} = \frac{\text{Incidental ingestion dose (noncancer)}}{RfD_o}$$

Where:

Incidental ingestion dose (noncancer) (mg/kg-day) = 9.94×10^{-5} (Appendix D.2)

RfD_o = Oral reference dose (mg/kg-day) = 0.00030 (Table 5-3)

Result:

Incidental ingestion HQ (unitless) = 0.33 (Appendix D.2)

2.2.2.2 Onsite Worker Dermal Contact with CCR Material

$$\text{Dermal Absorption HQ (unitless)} = \frac{\text{Dermal absorption dose (noncancer)}}{RfD_d}$$

Where:

Dermal absorption dose (noncancer) (mg/kg-day) = 1.59×10^{-5} (Appendix D.2)

RfD_d = Dermal reference dose (mg/kg-day) = 0.00030 (Table 5-3)

Result:

Dermal absorption HQ (unitless) = 0.053 (Appendix D.2)

2.2.2.3 Onsite Worker Inhalation of Particulates

$$\text{Inhalation of particulates HQ (unitless)} = \frac{\text{Inhalation of particulates concentration (noncancer)}}{RfC_i}$$

Where:

Inhalation of particulates concentration (noncancer) (mg/m^3) = 9.84×10^{-9} (Appendix D.2)

RfC_i = Inhalation reference concentration (mg/m^3) = 1.5×10^{-5} (Table 5-3)

Result:

Inhalation of particulates HQ (unitless) = 0.00066 (Appendix D.2)

2.2.2.4 Onsite Worker Exposed to CCR Material Noncancer HQ

Arsenic HQ (unitless) =

Incidental ingestion HQ + Dermal absorption HQ + Inhalation of particulates HQ

Where:

Incidental ingestion HQ = 0.33 (Appendix D.2)

Dermal absorption HQ = 0.053 (Appendix D.2)

Inhalation of particulates HQ = 0.00066 (Appendix D.2)

Result:

Arsenic COPC-Specific HQ (unitless) = 0.39 (Appendix D.2)

APPENDIX D.2

HUMAN HEALTH RISK CALCULATIONS FOR CHEMICALS

TABLE D.2-1 - Cancer Risk Calculations for an Onsite Worker Exposed to Chemical COPCs in CCR Material
Kingston Fossil Plant

CCR Unit/COPC	EPC [a] CCR Material	Exposure Dose/Concentration Ingestion	Exposure Dose/Concentration Dermal	Exposure Dose/Concentration Inhalation	Cancer Slope Factor Oral	Cancer Slope Factor Dermal	Unit Risk Inhalation	ILCR [b] Pathway-Specific Soil Ingestion	ILCR [b] Pathway-Specific Dermal Contact	ILCR [b] Pathway-Specific Inhalation	ILCR [b] COPC-Specific
	mg/kg	mg/kg-d	mg/kg-d	µg/m^3	(mg/kg-d)$^{-1}$	(mg/kg-d)$^{-1}$	(µg/m^3)$^{-1}$	unitless	unitless	unitless	unitless
Interim Ash Staging Area											
Arsenic	5.62E+01	1.09E-07	1.75E-08	1.08E-08	1.5E+00	1.5E+00	4.3E-03	1.6E-07	2.6E-08	4.6E-11	1.9E-07
Cobalt	1.07E+01	3.44E-08	n/a	2.04E-09	-	-	9.0E-03	n/a	n/a	1.8E-11	1.8E-11
										Cumulative ILCR:	2E-07
Sluice Trench and Area East of Sluice Trench											
Arsenic	4.90E+01	9.49E-08	1.52E-08	9.40E-09	1.5E+00	1.5E+00	4.3E-03	1.4E-07	2.3E-08	4.0E-11	1.7E-07
Cobalt	1.35E+01	4.37E-08	n/a	2.60E-09	-	-	9.0E-03	n/a	n/a	2.3E-11	2.3E-11
										Cumulative ILCR:	2E-07
Stilling Pond											
Arsenic	8.08E+01	1.57E-07	2.51E-08	1.55E-08	1.5E+00	1.5E+00	4.3E-03	2.3E-07	3.8E-08	6.7E-11	2.7E-07
										Cumulative ILCR:	3E-07

Notes:

-	not available
%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
ILCR	incremental lifetime cancer risk
µg/m^3	micrograms per cubic meter
mg/kg	milligrams per kilogram
mg/kg-d	milligrams per kilogram per day
n/a	not applicable
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the State of Tennessee acceptable cancer risk.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] Risks shown only for carcinogenic COPCs with available doses and toxicity values.

TABLE D.2-2 - Noncancer Hazard Calculations for an Onsite Worker Exposed to Chemical COPCs in CCR Material
Kingston Fossil Plant

CCR Unit/COPC	EPC [a] CCR Material	Exposure Dose/Concentration			Subchronic Reference Dose		Subchronic Reference Concentration	Hazard Quotient [b] Pathway-Specific			COPC-Specific
		Ingestion	Dermal	Inhalation	Oral	Dermal	Inhalation	Soil Ingestion	Dermal Contact	Inhalation	
	mg/kg	mg/kg-d	mg/kg-d	mg/m^3	mg/kg-d	mg/kg-d	mg/m^3	unitless	unitless	unitless	unitless
Interim Ash Staging Area											
Arsenic	5.62E+01	9.94E-05	1.59E-05	9.84E-09	3.0E-04	3.0E-04	1.5E-05	3.3E-01	5.3E-02	6.6E-04	0.39
Cobalt	1.07E+01	3.14E-05	n/a	1.86E-09	3.0E-03	3.0E-03	2.0E-05	1.0E-02	n/a	9.3E-05	0.011
Thallium	1.48E+00	4.36E-06	n/a	2.59E-10	4.0E-05	4.0E-05	-	1.1E-01	n/a	n/a	0.11
Vanadium	4.73E+01	1.39E-04	n/a	8.28E-09	1.0E-02	2.6E-04	1.0E-04	1.4E-02	n/a	8.3E-05	0.014
										HI:	0.5
Sluice Trench and Area East of Sluice Trench											
Arsenic	4.90E+01	8.66E-05	1.39E-05	8.57E-09	3.0E-04	3.0E-04	1.5E-05	2.9E-01	4.6E-02	5.7E-04	0.34
Cobalt	1.35E+01	3.99E-05	n/a	2.37E-09	3.0E-03	3.0E-03	2.0E-05	1.3E-02	n/a	1.2E-04	0.013
Thallium	1.18E+00	3.49E-06	n/a	2.07E-10	4.0E-05	4.0E-05	-	8.7E-02	n/a	n/a	0.087
Vanadium	7.06E+01	2.08E-04	n/a	1.24E-08	1.0E-02	2.6E-04	1.0E-04	2.1E-02	n/a	1.2E-04	0.021
										HI:	0.5
Stilling Pond											
Arsenic	8.08E+01	1.43E-04	2.29E-05	1.41E-08	3.0E-04	3.0E-04	1.5E-05	4.8E-01	7.6E-02	9.4E-04	0.55
Thallium	1.51E+00	4.45E-06	n/a	2.64E-10	4.0E-05	4.0E-05	-	1.1E-01	n/a	n/a	0.11
										HI:	0.7

Notes:

-	not available
%	percent
CCR	coal combustion residuals
COPC	constituent of potential concern
EPC	exposure point concentration
HI	hazard index
mg/kg	milligrams per kilogram
mg/kg-d	milligrams per kilogram per day
mg/m^3	milligrams per cubic meter
n/a	not available/applicable
UCL	upper confidence limit

Bold, where applicable, indicates the risk estimate is above the noncancer threshold.

[a] Summary statistics, derived 95% UCLs (where applicable), and EPCs are provided in Appendix C.2.

[b] Hazards shown only for noncarcinogenic COPCs with available doses and toxicity values.

APPENDIX E – UPDATED ARSENIC TOXICITY FACTORS

DRAFT

Stantec

Memo

To:	Brandon Boyd; Roy Quinn TVA	From:	Stantec Consulting Services Inc. Lexington, Kentucky
Project/File:	TDEC Order Fossil Plants	Date:	September 19, 2025

Reference: USEPA's Updated Arsenic Toxicity Factors – Implications for TVA Risk Assessments

As requested by Tennessee Valley Authority (TVA), Stantec Consulting Services Inc. (Stantec) reviewed the United States Environmental Protection Agency's (USEPA's) updated toxicity values for inorganic arsenic and assessed their implications for the Human Health and Ecological Risk Assessments (HHERAs) previously completed under the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order). The HHERAs were prepared by Stantec on behalf of TVA for the Bull Run Fossil Plant, Cumberland Fossil Plant, Johnsonville Fossil Plant, John Sevier Fossil Plant, Kingston Fossil Plant, and Watts Bar Fossil Plant. While the updated toxicity values (a 5-fold decrease in the noncancer reference dose and a 21-fold increase in the cancer slope factor) result in higher calculated risk estimates, the overall conclusions of the HHERAs remain unchanged.

1 Updated Arsenic Toxicity Factors

At the request of USEPA national programs, USEPA's Integrated Risk Information System (IRIS) Program initiated review of the health effects database for inorganic arsenic in 2019 following a well-defined multi-step peer-review process (USEPA 2024a). IRIS published their updated *Toxicological Review of Inorganic Arsenic* on January 13, 2025 (USEPA 2025). The 2025 report summarizes and evaluates new information on health effects and dose-response relationships for human populations exposed to inorganic arsenic published since the previous Toxicological Review in 1995. USEPA derived updated cancer slope factors (CSF) and noncancer reference doses (RfD) for human exposures to inorganic arsenic from (predominately) dietary sources. USEPA determined that the weight of evidence did not support revising the 1995 inhalation toxicity factors.

USEPA's basis for the updated inorganic arsenic toxicity factors is briefly summarized below.

1.1 Cancer Toxicity Assessment

Decades of epidemiological studies have established that inorganic arsenic is a human carcinogen under some circumstances of exposure. Skin, lung, and bladder cancer are well documented outcomes in populations living in geological areas with naturally occurring "high arsenic" levels in drinking water and dietary sources. The focus of the IRIS assessment was to update quantitative estimates of cancer risk using dose-response models developed since 1995. The modeling focused on estimated increases in mean lifetime extra risks for bladder and lung cancer in populations exposed to inorganic arsenic in the "low dose" range in drinking water.

USEPA (2024a) defines the CSF as “an estimate of the increased cancer risk from oral exposure to a dose of 1 milligram per kilogram per day (mg/kg-day) for a lifetime”. The updated 2025 CSF is 32 per mg/kg-d, which is 21 times higher than the previous 1995 CSF of 1.5 per mg/kg-day. The higher the CSF, the greater the chances of developing cancer for each incremental increase in daily dose of a carcinogen. In other words, USEPA’s (2025) assessment concluded that inorganic arsenic is a stronger carcinogen than indicated previously in 1995.

Cancer risk (expressed as an incremental lifetime cancer risk [ILCR]) is calculated by multiplying the receptor’s estimated daily dose of inorganic arsenic averaged over a 70-year lifetime (lifetime average daily dose [LADD]) by the CSF: ILCR = LADD (mg/kg-day) x CSF (32 per mg arsenic/kg-day). The doses cancel resulting in a unitless estimate of the receptor’s chances of getting cancer during their lifetime resulting from the dose used in the model. Risk is typically expressed as X chance in 1 million up to X chance in ten thousand (XE-06 up to XE-04). USEPA (1991) policy clarifying the role of the baseline risk assessment in Superfund remedy selection defines a cancer risk management range of 1E-06 to 1E-04. Estimated cancer risks less than 1E-06 typically do not require further action or evaluation; while estimated risks of 1E-04 or greater require considering actions to mitigate the source of risk. In practice, USEPA programs such as RCRA and many states’ regulatory programs, including TDEC (2024), use an estimated risk of 1E-05 (the midpoint of the OSWER risk management range) as the regulatory target for considering further action. Applying the updated inorganic arsenic CSF will result in higher estimates of cancer risk than would have been derived using the previous CSF, and likely more frequent instances of risk estimates requiring additional evaluation.

1.2 Noncancer Toxicity Assessment

The IRIS program reviewed studies of noncancer health effects associated with inorganic arsenic in human populations and selected increased incidence of diabetes and ischemic heart disease (IHD) as the basis for developing an overall RfD. USEPA (2024a) 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 risk of deleterious effects during a lifetime.” USEPA states that confidence in the RfD is medium-high, based on high confidence in the diabetes specific RfD and medium-high confidence in the IHD organ/system-specific RfD. According to USEPA (2025) the final RfD is expected to be protective against all noncancer adverse health effects associated with inorganic arsenic for all members of the population. The RfD is expressed as the daily intake of inorganic arsenic per kg body weight of the receptor (mg/kg-day).

The updated 2025 RfD is 0.00006 mg/kg-day (or 6E-05 mg/kg-day). This is five times lower than the previous 1991 RfD of 0.0003 mg/kg-day (or 3E-04 mg/kg-day). USEPA (2025) concluded that “*On the basis of a robust epidemiological evidence base, the currently available evidence demonstrates that iAs causes diseases of the circulatory system (DCS) and diabetes in humans given sufficient exposure conditions*”. The previous RfD published on IRIS in 1991 was based on hyperpigmentation, keratosis, and possible vascular complications in human populations exposed to inorganic arsenic in drinking water.

Noncancer hazard is expressed as the Hazard Quotient (HQ) for a single constituent. The HQ is calculated by dividing the receptor average daily dose (ADD) by the RfD: HQ = ADD (mg/kg-d) / RfD (mg/kg-d). If the

resulting HQ is less than 1, then the receptor's exposure is less than the RfD and generally no further evaluation is warranted. If the resulting quotient is greater than 1, then further evaluation or action is generally warranted.

2 Implications of the Updated Arsenic Toxicity Factors for TVA TDEC Order Risk Assessments and Management Decisions in the CARA

IRIS assessments are an important source of toxicity information for the USEPA, state and local health agencies, other federal agencies, and international health organizations. The USEPA stated that the mission of the IRIS program is to develop impartial toxicity information, independent of its regulatory use in setting national standards and cleaning up hazardous sites. While IRIS toxicity factors are not regulatory standards, they often influence regulatory programs and risk management decisions (USEPA 2024a). The updated 2025 inorganic arsenic toxicity factors have implications for the interpretation of risk assessments, especially those concerning coal combustion residuals (CCR), given that USEPA's justification for the 2015 CCR Rule centered on cancer risks from inorganic arsenic in groundwater used as drinking water.

2.1 CARA Plan - Groundwater Protection Standards (GWPS)

As of June 2025, there are no indications that USEPA (2025b) is planning to revise the current federal drinking water maximum contaminant level (MCL) for inorganic arsenic, which is set at 10 micrograms per Liter (µg/L) (USEPA 2018). MCLs are enforceable standards for public drinking water supplies developed by the USEPA Office of Drinking Water and promulgated through the Chemical Contaminant Rules (USEPA 2024b). The Groundwater Protection Standard (GWPS) for inorganic arsenic under the federal CCR Rule and Tennessee (TN) Rules (TDEC 2024) is the MCL. The GWPS for inorganic arsenic and related management decisions in the Corrective Action/Risk Assessment (CARA) Plan, prepared for each of the six TVA fossil plants listed earlier, are not expected to change in the near future as a result of the updated toxicity factors.

2.2 Evaluation of Human Receptors in the TDEC Order Risk Assessments

Because the IRIS toxicity factors apply to human health, the following sections provide an overview of the implications for the Onsite Worker, the Offsite Resident, and the Recreational Swimmer, Beachcomber, and Consumer of Locally Caught Fish. Since these toxicity values do not apply to ecological receptors, the methods for evaluating ecological risk and the conclusions of the TVA's TDEC Order ecological risk assessments will not change.

2.2.1 Onsite Short-Term Worker Exposure to CCR Material in Closed Units

Application of the 2025 RfD for inorganic arsenic in evaluating short-term worker exposure to CCR material during repair activities in closed CCR units results in increased numerical estimates of noncancer HQ to be greater than 1. However, this increase does not alter the overall conclusions of the risk assessments. As described in the HHERA reports for the Watts Bar Fossil Plant (Stantec 2025a) and John Sevier Fossil Plant (Stantec 2025b), potential exposures and associated risks for short-term workers are effectively

managed through adherence to standard health and safety protocols, and the determination of no unacceptable risk for this receptor remains valid.

2.2.2 Offsite Residential Use of Surface Water and Recreator – Swimmer

Inorganic arsenic concentrations in surface water bodies used for domestic potable supply and recreational water contact were found to be below both the current federal MCL and TN water quality criteria (10 µg/L) for use of surface stream water as a domestic potable source (TDEC 2024). These concentrations were consistent across samples collected upstream, adjacent to, and downstream of TVA's fossil plants. As there have been no changes to the applicable drinking water standards, the evaluation of offsite residential use of surface stream water as a domestic potable source, as well as the assessment of recreational swimmer exposure, remains unchanged in the TVA TDEC Order risk assessments.

2.2.3 Recreational Beachcomber – Contact with Seasonally Exposed Sediment

Using the 2025 CSF and RfD for inorganic arsenic to assess exposure of adult and child recreational beachcombers to CCR constituents in seasonally exposed stream sediment results in higher numerical estimates of cancer risk and noncancer hazard. Nonetheless, these increases do not affect the conclusions of the risk assessments. Inorganic arsenic concentrations in sediment samples collected adjacent to and downstream of TVA fossil plants were comparable to those collected from upstream background reference transects, indicating no incremental increase in risk associated with the CCR units. Further, inorganic arsenic concentrations in surface stream sediment aligned with the site-specific background threshold values (BTVs) derived from samples of unimpacted soils. Residential receptors typically have more frequent contact with soil than recreational beachcombers have with seasonally exposed surface stream sediment. Given that concentrations of inorganic arsenic in surface stream sediments were within the range of site-specific background soil concentrations, and no incremental increases in concentrations were observed at adjacent and downstream sediment locations compared to upstream, the risk characterization for this receptor remains unchanged.

2.2.4 Recreational Receptor - Consuming Locally Caught Fish

Incorporating the updated 2025 CSF for inorganic arsenic into the evaluation of risks from ingestion of locally caught fish increases the quantitative cancer risk estimates but does not alter the conclusions of the risk assessments. According to the 2025 Toxicological Review, the USEPA does not consider fish and shellfish to be significant sources of inorganic arsenic exposure, as arsenic in these organisms is predominantly present in organic forms such as arsenobetaine, arsenosugars, and arsenolipids, which are not toxic to humans. Speciation analyses of fish filet tissue samples from the Emory, Clinch, and Tennessee Rivers during the Kingston Recovery Project confirmed that arsenic was almost exclusively in organic forms (Jacobs 2012). Consequently, inorganic arsenic was not identified as a constituent of potential concern in most samples (Jacobs 2012). For conservatism, the TVA TDEC Order risk assessments assumed that 10% of arsenic (total) detected in fish filet was inorganic, a precedent-based approach intended to overestimate potential exposure (Schoof and Yager 2007). Arsenic (total) concentrations in fish were similar across upstream, adjacent, and downstream sampling locations, and no incremental increase in receptor risk was identified for fish consumption near TVA fossil plants.

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Sincerely,

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