Annual Groundwater Monitoring and Corrective Action Report

Tennessee Valley Authority
John Sevier Fossil Plant Bottom Ash Pond CCR Unit

Prepared for:
Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

Prepared by:
Stantec Consulting Services Inc.

July 31, 2020

July 31, 2020

Reference: **Annual Groundwater Monitoring and Corrective Action Report**
TVA John Sevier Fossil Plant Bottom Ash Pond CCR Unit

This report documents groundwater monitoring activities during 2019 through July 31, 2020, as required under the federal coal combustion residuals (CCR) rule (the CCR Rule) pursuant to 40 CFR § 257.90(e) at the Tennessee Valley Authority (TVA) John Sevier Fossil Plant (JSF) Bottom Ash Pond CCR Unit. This CCR Unit is an inactive CCR surface impoundment (i.e., vacatur unit) under the CCR Rule and is subject to the deadlines set forth in 40 CFR § 257.100. In accordance with 40 CFR § 257.100(e)(5)(ii), TVA prepared the initial Annual Groundwater Monitoring and Corrective Action Report on August 1, 2019 and must prepare reports annually thereafter

An overview of the status of the groundwater monitoring and corrective action program for the Bottom Ash Pond CCR Unit is provided below.

- At the start of the current 2019-2020 annual reporting period,[1] the Bottom Ash Pond CCR Unit was operating under a detection monitoring program in accordance with 40 CFR § 257.94. The detection monitoring program for the Bottom Ash Pond CCR Unit was initiated on April 17, 2019 during the initial 2018-2019 reporting period.

- Results from the initial 2019 detection monitoring sampling event identified statistically significant increases (SSIs) of Appendix III constituents above background at the downgradient overburden and bedrock monitoring wells in the CCR Rule certified groundwater monitoring system. As a result, an alternate source demonstration (ASD) was initiated for the Bottom Ash Pond CCR Unit on July 16, 2019 and was completed on October 15, 2019. The Appendix III ASD was unable to establish that the SSIs were the result of another source or the result of an error.

- An assessment monitoring program was established on January 13, 2020[2], in accordance with 40 CFR § 257.94(e)(2) and 40 CFR § 257.95(a). Groundwater protection standards (GWPS) were established on April 14, 2020, in accordance with 40 CFR § 257.95(d)(2), and a statistical evaluation of whether there were statistically significant levels (SSLs) of Appendix IV constituents above GWPS was completed on July 14, 2020.

- No SSLs were recorded during assessment monitoring in the certified groundwater monitoring system for the JSF Bottom Ash Pond. At the end of this 2019-2020 annual reporting period, the Bottom Ash Pond CCR Unit is being evaluated under an assessment monitoring program in accordance with 40 CFR § 257.95.

- Because no SSLs were recorded, the Bottom Ash Pond CCR Unit remains in assessment monitoring and an Assessment of Corrective Measures is not needed.

- Remedial activities have not been initiated for the Bottom Ash Pond CCR Unit pursuant to 40 CFR § 257.98 during the current 2019-2020 annual reporting period discussed herein.

[1] The current 2019-2020 reporting period began on August 2, 2019 and concludes on July 31, 2020.

[2] TVA initiated the first assessment monitoring groundwater sampling event on January 7-9, 2020 and performed a retest assessment monitoring groundwater sampling event on February 4-6, 2020.

TVA has established a groundwater monitoring system and program at the JSF Bottom Ash Pond CCR Unit in accordance with 40 CFR § 257.91. TVA conducted a statistical analysis of the first 2019 detection monitoring groundwater sampling data in accordance with 40 CFR § 257.93(h), which concluded that there were statistically significant increases (SSIs) over background levels for certain Appendix III constituents. The results were included in Table 1 of the 2019 Initial Annual Groundwater Monitoring and Corrective Action Report, which was placed on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/john-sevier). Additional detection monitoring groundwater sampling results are included in Table 1 of this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.94(b). During 2019-2020, TVA performed the following groundwater monitoring activities:

- Performed an alternate source demonstration for the SSIs over background levels of Appendix III constituents in accordance with 40 CFR § 257.94(e)(2).
- Performed error checking and investigated whether the SSIs over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality as specified in 40 CFR § 257.94(e)(2).
- Established an assessment monitoring program in accordance with 40 CFR § 257.94(e)(2) because the Appendix III alternate source demonstration was unable to establish that the SSIs were the result of another source or the result of an error.
- Placed notification of the establishment of the assessment monitoring program in the facility operating record in accordance with 40 CFR § 257.94(e)(3) and 257.105(h)(5); provided notification to the State of Tennessee in accordance with 40 CFR § 257.106(h)(4); and placed notification on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/john-sevier) in accordance with 40 CFR § 257.107(h)(4).
- Sampled and analyzed groundwater in the certified monitoring well network for Appendix IV constituents in accordance with 40 CFR § 257.95(b).
- Sampled wells in the certified groundwater monitoring system and analyzed samples for CCR constituents (Appendix III and Appendix IV constituents) in accordance with 40 CFR § 257.95(d)(1).
- Placed reported results in the operating record as required by 40 CFR § 257.95(d)(1) and 257.105(h)(6). Additionally, these results are included in Tables 2A and 2B of this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.95(d)(3).
- Established groundwater protection standards in accordance with 40 CFR § 257.95(d)(2) and included the standards in this 2019-2020 Annual Groundwater Monitoring and Corrective Action Report in accordance with 40 CFR § 257.95(d)(3).
- Completed an evaluation of whether one or more Appendix IV constituents are detected at SSLs above the established groundwater protection standards in accordance with 40 CFR § 257.95(g). No SSLs were recorded during Assessment Monitoring in the certified monitoring system for the JSF Bottom Ash Pond.
- Performed field and desktop site characterization investigations to improve the JSF Conceptual Site Model (CSM).
- Continued TVA's third-party Quality Assurance Program to evaluate and improve groundwater analytical data using best practices concerning field methods and validation techniques, as well as the application of the most appropriate statistical methods.
- Reviewed new data as it became available to maintain compliance with 40 CFR § 257.90 through 257.98.
- Complied with recordkeeping requirements as specified in 40 CFR § 257.105(h), notification requirements specified in 40 CFR § 257.106(h), and internet requirements specified in 40 CFR § 257.107(h).

The projected key activities for the next reporting period are:

- Continue semiannual assessment monitoring at the certified groundwater monitoring system consistent with 40 CFR § 257.95.
- Perform further field and desktop site characterization investigations to improve the JSF CSM.
- Continue TVA's third-party Quality Assurance Program to evaluate groundwater analytical data using best practices concerning field methods and validation techniques, as well as the application of the most appropriate statistical methods.
- Review new data as it becomes available and implement changes to the groundwater monitoring program as necessary to maintain compliance with 40 CFR § 257.90 through 257.98.
- Comply with recordkeeping requirements as specified in 40 CFR § 257.105(h), notification requirements specified in 40 CFR § 257.106(h), and internet requirements specified in 40 CFR § 257.107(h).

GROUNDWATER MONITORING SYSTEM

The certified groundwater monitoring system for the JSF Bottom Ash Pond CCR Unit consists of three background wells (JSF-104, JSF-200, and JSF-205) and eight downgradient wells (10-36, JSF-103, JSF-105, W-32, JSF-201, JSF-202, JSF-203, and JSF-204).[3] Figure 1 is an aerial photograph that shows the groundwater monitoring well locations. The monitoring well network was designed for a single CCR Unit (Bottom Ash Pond).

No monitoring wells in the CCR system were installed or decommissioned during the 2019-2020 reporting period. The certification of the groundwater monitoring system required under 40 CFR § 257.91(f) is included in the facility operating record and on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/john-sevier).

GROUNDWATER SAMPLING AND LABORATORY ANALYTICAL TESTING

A groundwater sampling and analysis program was developed and includes procedures and techniques for: sample collection; sample preservation and shipment; analytical procedures; chain-of-custody control; and quality assurance and quality control (QA/QC) required by 40 CFR § 257.93(a). The groundwater monitoring program includes sampling and analysis procedures designed to provide monitoring results that are an accurate representation of groundwater quality at background and downgradient wells.

The second round of detection monitoring and a retest round were completed in compliance with 40 CFR § 257.94. Detection monitoring groundwater sampling results are summarized in Tables 1A and 1B for the overburden and bedrock monitoring wells, respectively. The first round of assessment monitoring and a retest round were completed in compliance with 40 CFR § 257.95. Assessment monitoring groundwater sampling results are summarized in Tables 2A and 2B for the overburden and bedrock monitoring wells, respectively. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates, and monitoring program status is provided in Table 3.

[3] Monitoring wells in the certified network that are screened in overburden deposits include 10-36, JSF-103, JSF-104, JSF-105 and W-32. Monitoring wells with -200 in the well designation (i.e., JSF-200, JSF-201, JSF-202, JSF-203, JSF-204 and JSF-205) are screened in the Sevier Shale bedrock aquifer.

Groundwater elevations were measured in each monitoring well immediately prior to purging as required by 40 CFR § 257.93(c). Groundwater elevations and Holston River surface water elevations are summarized in Table 4. Groundwater flow directions were determined for each sampling event, and a generalized depiction of groundwater flow direction is illustrated on Figures 2A and 2B for the overburden and bedrock monitoring wells, respectively. In general, groundwater flow at the JSF Bottom Ash Pond CCR Unit is influenced by the Holston River to the north and west of the unit. The primary groundwater flow direction from the CCR Unit in the overburden is generally to the north towards the Holston River. The primary groundwater flow direction from the CCR unit in the bedrock is generally to the north towards the Holston River.

Testing for hydraulic conductivity in the overburden and bedrock aquifers at the background and downgradient monitoring wells, as summarized in Table 5, was conducted during a recent hydrogeological evaluation (Terracon, 2019). Testing data indicates the saturated zone in the overburden has a geometric mean hydraulic conductivity of 3.49×10^{-4} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the overburden aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing;
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0110 to 0.0138 feet per foot (ft/ft); and,
- an effective porosity of 10%[4] (Domenico and Schwarz, 1990).

The average linear flow velocity in the overburden aquifer ranges from approximately 40 to 50 feet per year. The rate and direction of groundwater flow in the overburden for each groundwater sampling event is summarized in Table 6A in accordance with 40 CFR § 257.93(c).

Hydraulic conductivity testing was performed in the bedrock aquifer (Sevier Shale), and the results are summarized in Table 5 (Stantec, 2019). Testing data indicates the bedrock aquifer has a geometric mean hydraulic conductivity of 1.07×10^{-3} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the bedrock aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing;
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0116 to 0.0135 feet per foot (ft/ft); and,
- an effective porosity of 1%[4] (Domenico and Schwarz, 1990).

The average linear flow velocity in the bedrock aquifer ranges from approximately 1,284 to 1,488 feet per year. The rate and direction of groundwater flow in the bedrock for each groundwater sampling event is summarized in Table 6B in accordance with 40 CFR § 257.93(c).

[4] Effective porosity range of 1 to 20% (Domenico and Schwarz, 1990). Estimated value of 10% was used in linear velocity calculations in the overburden aquifer. Conservative value of 1% was used in linear velocity calculations in the bedrock aquifer.

STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the assessment monitoring events were evaluated using statistical procedures as required by 40 CFR § 257.93(f) through 257.93(h). The statistical method certification is included in the facility operating record and the TVA CCR Rule Compliance Data and Information website. Groundwater protection standards were established in accordance with 40 CFR § 257.95(h), as the larger of published regulatory limits or screening criteria (e.g., maximum contaminant levels [MCLs]) and upper tolerance limits (UTLs) derived from background). Maximum contaminant levels may or may not be considered the appropriate groundwater protection standard depending on background well concentrations for each Appendix IV[5] constituent[6]. The 2019-2020 Statistical Analysis Reports are included in Appendices A and B for the overburden and bedrock saturated zones, respectively, for the Bottom Ash Pond CCR Unit at JSF.

The sampling results used to identify potential groundwater protection standards exceedances were obtained[7]. Comparisons were made against a fixed groundwater protection standard via a confidence interval or confidence interval band. None of the individual compliance point measurements were directly compared against the groundwater protection standard. The Appendix IV monitoring data collected both in 2019 and 2020 were used to construct the confidence interval bands. Cross-sections of each confidence interval band were then compared to the groundwater protection standard for the most recent assessment monitoring event for the purpose of identifying SSLs. A well-constituent pair is considered out of compliance only if its average constituent levels, as estimated via the confidence interval cross-section, currently exceed the groundwater protection standard. No SSLs above groundwater protection standards were recorded during Assessment Monitoring in the certified groundwater monitoring system for the JSF Bottom Ash Pond CCR Unit.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

In July 2019, TVA evaluated the groundwater monitoring data for SSIs over background levels for the constituents listed in Appendix III[8] as required by 40 CFR § 257.93(h). The groundwater analytical results from the initial round of detection monitoring indicated SSIs of Appendix III CCR constituents at the downgradient monitoring wells. TVA performed error checking and investigated whether the SSI over background resulted from error in sampling, analysis, statistical evaluation, or natural variation in

---

[5] Appendix IV CCR Constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228 combined

[6] USEPA has published MCLs or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the groundwater protection standard is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate groundwater protection standard must be derived from on-site background levels. On July 30, 2018, EPA provided alternate regulatory limits (i.e., that could be used as potential groundwater protection standards) for four of the Appendix IV chemical Constituents of Interest (COIs) for which the agency has not assigned MCLs to date. If site-specific background levels are lower, these may be used in place of background levels under 40 CFR § 257.95(h)(2). Specifically, those alternate COIs include threshold values at the following health-based levels: 1.) Cobalt - 6 µg/L; 2.) Lithium - 40 µg/L; 3.) Molybdenum – 100 µg/L; and, 4.) Lead - 15 µg/L.

[7] Baseline data from designated background wells collected through February 2020 were grouped and checked for possible outliers. The grouped baseline data (excluding confirmed outliers) were analyzed to evaluate whether they could be fit to a known statistical model in order to compute or construct an UTL for both the overburden and bedrock zones. These UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS. The CCR Rule requires a minimum of two semiannual sampling events per well once the required background data has been obtained. In 2019-2020, the second detection monitoring event and the initial assessment monitoring event were each followed by retesting groundwater sampling events.

[8] Appendix III CCR Constituents: boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids (TDS).

groundwater quality as specified in 40 CFR § 257.94(e)(2). TVA also performed investigations to evaluate whether a source other than the CCR materials contained within the JSF Bottom Ash Pond was the cause of the SSIs. The alternate source demonstration study did not demonstrate the SSIs were a result of error or another source. An Assessment Monitoring Program was established and implemented as specified in 40 CFR § 257.95. Notification of the assessment monitoring program was provided to the State of Tennessee and placed on the TVA CCR Rule Compliance Data and Information website (https://www.tva.com/environment/environmental-stewardship/coal-combustion-residuals/john-sevier) in accordance with 40 CFR § 257.106(h)(4) and 40 CFR § 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, TVA collected groundwater samples from wells in the certified groundwater monitoring system and analyzed the samples for Appendix IV constituents in accordance with 40 CFR § 257.95(b) within 90 days of triggering assessment monitoring. Subsequent sampling and analysis of wells in the certified groundwater monitoring system for Appendix III and IV constituents occurred in accordance with 40 CFR § 257.95(d)(1). Appendix III and IV constituent concentrations were placed in the facility operating record in accordance with 40 CFR § 257.105(h)(6) and are summarized in Tables 2A and 2B. Groundwater protection standards were established in accordance with 40 CFR § 257.95(d)(2) and are summarized in Tables 7A and 7B for the overburden and bedrock, respectively. In July 2020, an evaluation of whether there are SSLs over established groundwater protection standards for one or more Appendix IV constituents was completed in accordance with 40 CFR § 257.95(g). No SSLs were recorded during Assessment Monitoring in the certified groundwater monitoring system for the JSF Bottom Ash Pond. Therefore, this CCR Unit will remain in Assessment Monitoring in accordance with 40 CFR § 257.95(f). TVA will continue to review new data as it becomes available and implement changes to the groundwater monitoring program as necessary to maintain compliance with 40 CFR § 257.90 through 257.98.

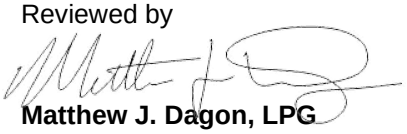
LIMITATIONS

This document entitled Initial Annual Groundwater Monitoring and Corrective Action Report was prepared by Stantec Consulting Services Inc. ("Stantec") for the Tennessee Valley Authority (the "Client"). The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec relied upon data and information supplied to it by the client.

Prepared by

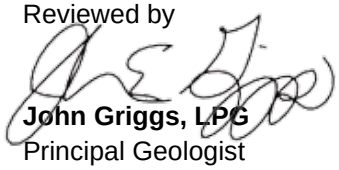
Benjamin D. Schutt
Environmental Engineer

Reviewed by



Matthew J. Dagon, LPG
Principal Geologist

Reviewed by



John Griggs, LPG
Principal Geologist

References:

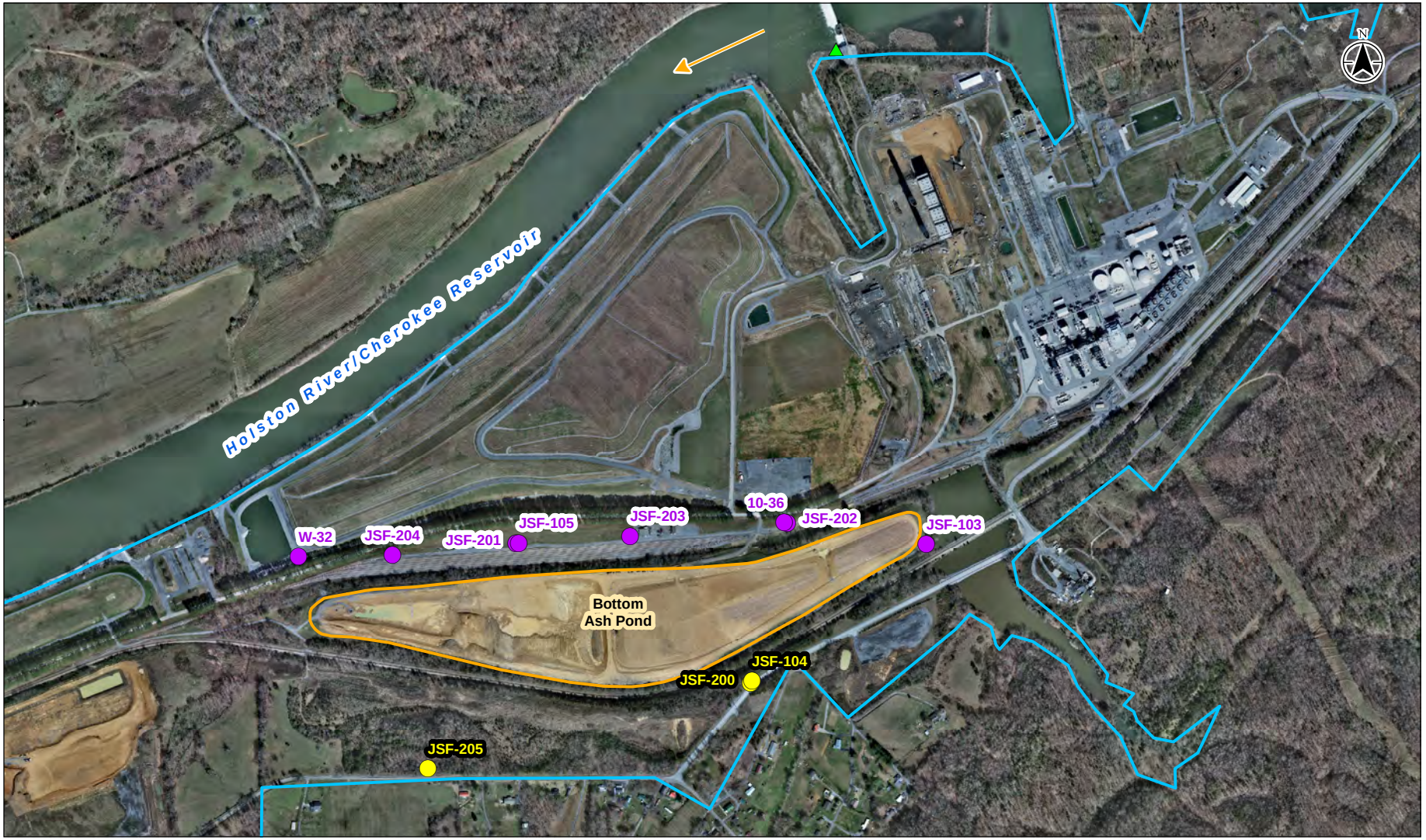
Domenico, P.A. and Schwartz, F.W., 1990. Physical and Chemical Hydrogeology. University of Michigan. Wiley, 1990. 824 pp.

Terracon Consultants, Inc. (Terracon). 2019. “Aquifer Testing Results, TVA CCR Rule, John Sevier Fossil Plant.” July 2019.

Attachments:

Figure 1	Map with CCR Unit Background and Downgradient Wells
Figure 2A	Generalized Groundwater Flow Direction Map – Overburden
Figure 2B	Generalized Groundwater Flow Direction Map - Bedrock
Table 1A	Detection Monitoring Groundwater Sampling Results - Overburden
Table 1B	Detection Monitoring Groundwater Sampling Results - Bedrock
Table 2A	Assessment Monitoring Groundwater Sampling Results - Overburden
Table 2B	Assessment Monitoring Groundwater Sampling Results - Bedrock
Table 3	Groundwater Sampling Summary
Table 4	Groundwater and Surface Water Elevation Summary
Table 5	Hydraulic Conductivity Data Summary
Table 6A	Rate and Direction of Groundwater Flow Summary – Overburden
Table 6B	Rate and Direction of Groundwater Flow Summary – Bedrock
Table 7A	Groundwater Protection Standards – Overburden
Table 7B	Groundwater Protection Standards – Bedrock
Appendix A	Statistical Analysis Report for John Sevier Fossil Plant, 2020 CCR Program, Residuum - Vacatur Unit
Appendix B	Statistical Analysis Report for John Sevier Fossil Plant, 2020 CCR Program, Bedrock - Vacatur Unit

FIGURES



Downgradient Well

Background Well

Staff Gauge

Surface Water Flow Direction

TVA Property Boundary

CCR Unit Area (Approximate)

0 500 1,000 Feet

1:12,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-08) and Imagery

Monitoring Wells in the certified network screened in overburden deposits include: 10-36, JSF-103, JSF-104, JSF-105, and W-32. Monitoring Wells with -200 in the well designation (i.e., JSF-200, JSF-201, JSF-202, JSF-203, JSF-204, and JSF-205) are screened in the Sevier shale bedrock saturated zone.

Project Location
Rogersville, Tennessee

182603522
Prepared by LMB on 2020-06-05
Technical Review by BS on 2020-06-05
Independent Review by TR on 2020-06-05

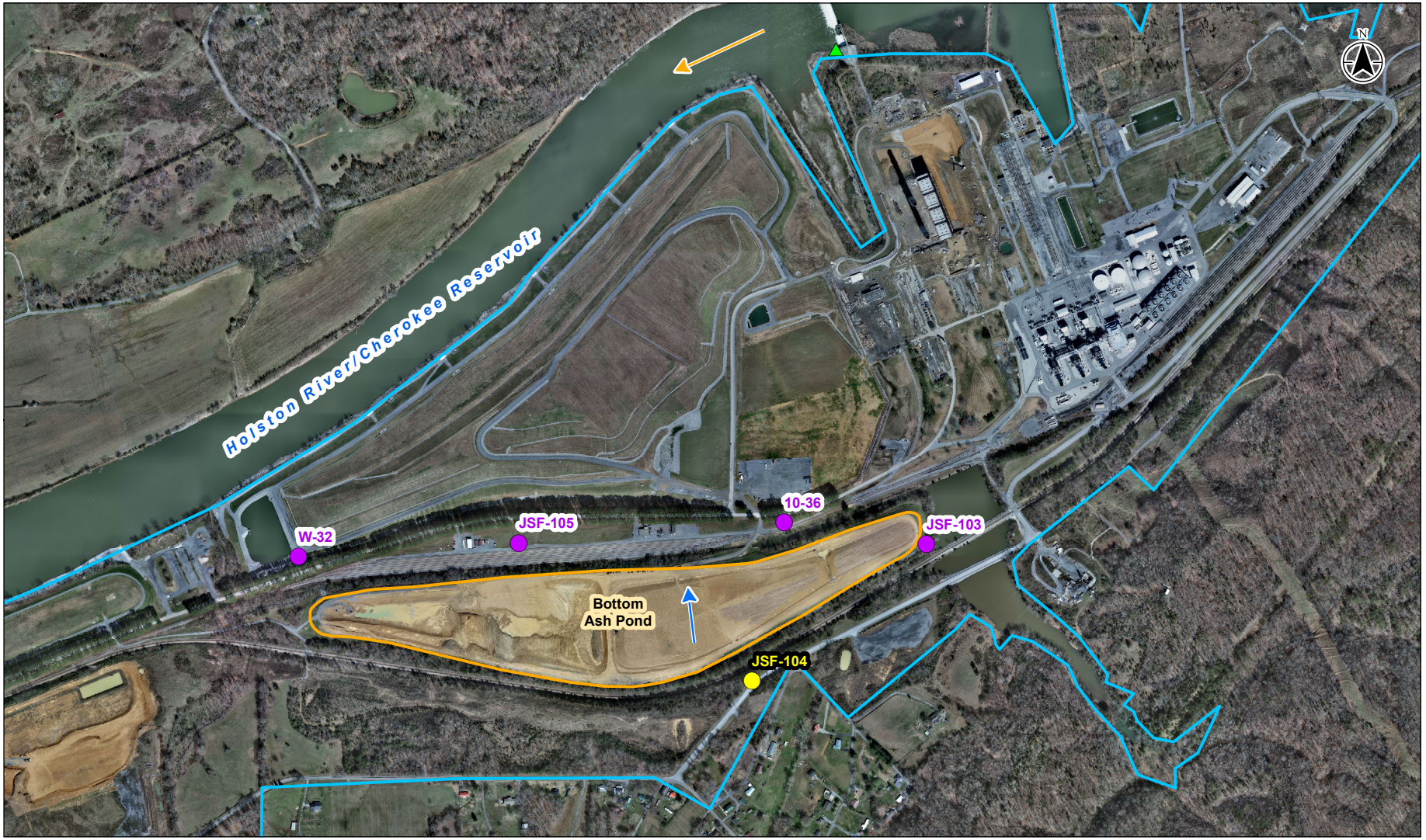
Client/Project
Tennessee Valley Authority
John Sevier Fossil Plant

Figure No.
1

Title
Map with CCR Unit Background and Downgradient Wells

U:\182603174\gis\mxds\JSF\2020\JSF_Fig1_Bottom_Ash_BG_DG_Wells.mxd Revised: 2020-06-05 By: tblackman

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.



Downgradient Well

Background Well

Staff Gauge

Groundwater Flow Direction

Surface Water Flow Direction

TVA Property Boundary

CCR Unit Area (Approximate)

0 500 1,000 Feet

1:12,000 (At original document size of 8.5x11)

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-08) and Imagery

Groundwater flow directions are based on Holston River elevations and groundwater elevations from CCR and Non-CCR monitoring wells.

Project Location
Rogersville, Tennessee

182603522
Prepared by LMB on 2020-06-25
Technical Review by BS on 2020-06-25
Independent Review by TR on 2020-06-25

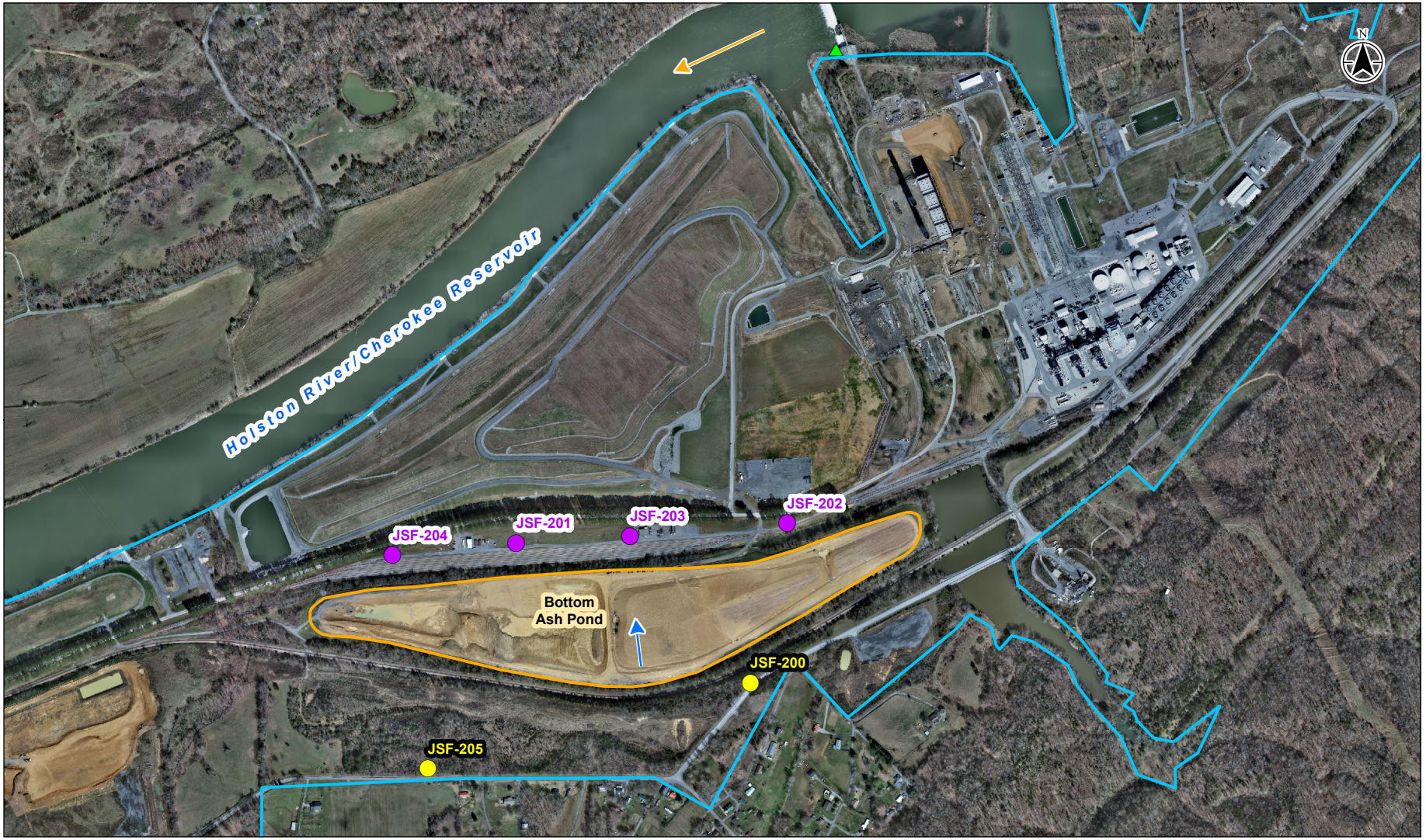
Client/Project
Tennessee Valley Authority
John Sevier Fossil Plant

Figure No.
2A

Title
Generalized Groundwater Flow Direction Map - Overburden

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

U:\182603174\gis\mxds\JSF\2020\JSF_Fig2A_GroundwaterFlowDirectionMap.mxd Revised: 2020-06-25 By: lblackman



Downgradient Well

Background Well

Staff Gauge

Groundwater Flow Direction

Surface Water Flow Direction

TVA Property Boundary

CCR Unit Area (Approximate)

0 500 1,000 Feet

1:12,000 (At original document size of 8.5x11)

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-08) and Imagery

Groundwater flow directions are based on Holston River elevations and groundwater elevations from CCR and Non-CCR monitoring wells.

Project Location
Rogersville, Tennessee

182603522
Prepared by LMB on 2020-06-25
Technical Review by BS on 2020-06-25
Independent Review by TR on 2020-06-25

Client/Project
Tennessee Valley Authority
John Sevier Fossil Plant

Figure No.
2B

Title
Generalized Groundwater Flow Direction Map - Bedrock

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

U:\182603174\gis\mxds\JSF\2020\JSF_Fig2B_GroundwaterFlowDirectionMap.mxd Revised: 2020-06-25 By: tblackman

TABLES

Table 1A - Detection Monitoring Groundwater Sampling Results Overburden

Monitoring Well		10-36			
Sample Date		11-Sep-19		19-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	214		168	
Calcium	µg/L	129000		120000	
Anions					
Chloride	mg/L	6.56		10.2	
Fluoride	mg/L	0.137		0.117	
Sulfate	mg/L	144		142	
General Chemistry					
Total Dissolved Solids	mg/L	539		464	
Field Parameters					
Temperature, Water	DEG_C	20.5		17.6	
Turbidity (field)	NTU	2.30		0.63	
ORP	mV	18.8		42.1	
Specific Conductivity (field)	mS/cm	0.84		0.83	
Dissolved Oxygen	mg/L	0.25		0.47	
pH (field)	SU	7.29		7.08	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1A - Detection Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-103			
Sample Date		10-Sep-19		19-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	247		273	
Calcium	µg/L	161000		196000	
Anions					
Chloride	mg/L	4.42		6.56	
Fluoride	mg/L	0.0785	J	0.0548	J
Sulfate	mg/L	332		495	
General Chemistry					
Total Dissolved Solids	mg/L	629		776	
Field Parameters					
Temperature, Water	DEG_C	19.9		17.0	
Turbidity (field)	NTU	1.43		1.14	
ORP	mV	38.8		85.1	
Specific Conductivity (field)	mS/cm	0.87		1.13	
Dissolved Oxygen	mg/L	0.27		1.89	
pH (field)	SU	6.80		6.01	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1A - Detection Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-104			
Sample Date		10-Sep-19		21-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 38.6	U	< 38.6	U
Calcium	µg/L	22200		27200	
Anions					
Chloride	mg/L	6.11		6.84	
Fluoride	mg/L	0.0338	J	0.0356	J
Sulfate	mg/L	5.42		5.89	
General Chemistry					
Total Dissolved Solids	mg/L	103		130	
Field Parameters					
Temperature, Water	DEG_C	19.4		15.9	
Turbidity (field)	NTU	2.01		0.45	
ORP	mV	138.2		160.7	
Specific Conductivity (field)	mS/cm	0.141		0.204	
Dissolved Oxygen	mg/L	3.18		3.80	
pH (field)	SU	6.16		6.10	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1A - Detection Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-105			
Sample Date		11-Sep-19		20-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	44.8	J	< 38.6	U
Calcium	µg/L	99200		93000	
Anions					
Chloride	mg/L	3.24		4.57	
Fluoride	mg/L	0.0526	J	< 0.0538	U*
Sulfate	mg/L	71.1		67.6	
General Chemistry					
Total Dissolved Solids	mg/L	296		244	
Field Parameters					
Temperature, Water	DEG_C	20.8		17.3	
Turbidity (field)	NTU	4.35		1.16	
ORP	mV	-23.9		61.6	
Specific Conductivity (field)	mS/cm	0.49		0.501	
Dissolved Oxygen	mg/L	0.23		0.49	
pH (field)	SU	7.31		7.01	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1A - Detection Monitoring Groundwater Sampling Results Overburden

Monitoring Well		W-32			
Sample Date		11-Sep-19		21-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	112		59.5	J
Calcium	µg/L	127000		137000	
Anions					
Chloride	mg/L	8.57		11.1	
Fluoride	mg/L	0.0442	J	0.0464	J
Sulfate	mg/L	54.8		49.4	
General Chemistry					
Total Dissolved Solids	mg/L	366		334	
Field Parameters					
Temperature, Water	DEG_C	18.0		17.4	
Turbidity (field)	NTU	4.63		3.81	
ORP	mV	196.9		85.2	
Specific Conductivity (field)	mS/cm	0.61		0.716	
Dissolved Oxygen	mg/L	1.44		1.40	
pH (field)	SU	6.50		6.99	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-200			
Sample Date		10-Sep-19		21-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 38.6	U	41.4	J
Calcium	µg/L	101000		102000	
Anions					
Chloride	mg/L	7.40		9.33	
Fluoride	mg/L	0.0472	J	0.0494	J
Sulfate	mg/L	18.1		19.5	
General Chemistry					
Total Dissolved Solids	mg/L	317		282	
Field Parameters					
Temperature, Water	DEG_C	18.7		16.1	
Turbidity (field)	NTU	0.84		0.66	
ORP	mV	7.0		67.2	
Specific Conductivity (field)	mS/cm	0.53		0.573	
Dissolved Oxygen	mg/L	0.79		0.47	
pH (field)	SU	7.84		7.18	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-201			
Sample Date		11-Sep-19		20-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 38.6	U	< 38.6	U
Calcium	µg/L	86000		82000	
Anions					
Chloride	mg/L	3.53		5.59	
Fluoride	mg/L	0.0576	J	< 0.0543	U*
Sulfate	mg/L	51.2		48.4	
General Chemistry					
Total Dissolved Solids	mg/L	257		237	
Field Parameters					
Temperature, Water	DEG_C	19.9		17.0	
Turbidity (field)	NTU	0.46		0.33	
ORP	mV	8.8		100.7	
Specific Conductivity (field)	mS/cm	0.45		0.457	
Dissolved Oxygen	mg/L	0.28		1.39	
pH (field)	SU	7.47		7.42	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-202			
Sample Date		11-Sep-19		21-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	158		168	
Calcium	µg/L	136000		126000	
Anions					
Chloride	mg/L	7.96		10.4	
Fluoride	mg/L	0.119		0.134	
Sulfate	mg/L	239		212	
General Chemistry					
Total Dissolved Solids	mg/L	600		533	
Field Parameters					
Temperature, Water	DEG_C	19.5		17.6	
Turbidity (field)	NTU	2.15		0.88	
ORP	mV	-85.1		21.1	
Specific Conductivity (field)	mS/cm	0.89		0.86	
Dissolved Oxygen	mg/L	0.19		0.59	
pH (field)	SU	7.90		6.09	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-203			
Sample Date		11-Sep-19		20-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	1740		1630	
Calcium	µg/L	101000		101000	
Anions					
Chloride	mg/L	12.0		15.7	
Fluoride	mg/L	0.0683	J	< 0.0664	U*
Sulfate	mg/L	67.0		72.1	
General Chemistry					
Total Dissolved Solids	mg/L	349		336	
Field Parameters					
Temperature, Water	DEG_C	19.1		17.4	
Turbidity (field)	NTU	1.88		0.52	
ORP	mV	-28.7		38.3	
Specific Conductivity (field)	mS/cm	0.60		0.619	
Dissolved Oxygen	mg/L	0.22		0.72	
pH (field)	SU	7.49		7.23	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-204			
Sample Date		11-Sep-19		20-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	108		94.0	
Calcium	µg/L	95300		94400	
Anions					
Chloride	mg/L	8.37		9.54	
Fluoride	mg/L	0.0522	J	< 0.0443	U*
Sulfate	mg/L	54.5		45.6	
General Chemistry					
Total Dissolved Solids	mg/L	321		287	
Field Parameters					
Temperature, Water	DEG_C	18.6		17.4	
Turbidity (field)	NTU	3.66		1.66	
ORP	mV	-8.7		7.5	
Specific Conductivity (field)	mS/cm	0.54		0.552	
Dissolved Oxygen	mg/L	0.15		1.60	
pH (field)	SU	7.11		7.13	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 1B - Detection Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-205			
Sample Date		10-Sep-19		19-Nov-19	
Sample Round		2		2 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Boron	µg/L	< 38.6	U	< 38.6	U
Calcium	µg/L	79000		74800	
Anions					
Chloride	mg/L	5.91		7.62	
Fluoride	mg/L	0.0648	J	0.0662	J
Sulfate	mg/L	21.2		21.5	
General Chemistry					
Total Dissolved Solids	mg/L	250		141	
Field Parameters					
Temperature, Water	DEG_C	17.5		15.1	
Turbidity (field)	NTU	0.73		0.22	
ORP	mV	-82.8		-139.4	
Specific Conductivity (field)	mS/cm	0.42		0.466	
Dissolved Oxygen	mg/L	0.78		1.32	
pH (field)	SU	7.49		7.35	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

DETECTION MONITORING

Table 2A - Assessment Monitoring Groundwater Sampling Results Overburden

Monitoring Well		10-36			
Sample Date		08-Jan-20		05-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	45.3		43.0	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	139		146	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	127000		134000	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	0.247	J	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	25.0		18.5	
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.487	U	0.822	J
Anions					
Chloride	mg/L	9.13		9.14	
Fluoride	mg/L	0.168		0.149	
Sulfate	mg/L	234		204	
General Chemistry					
Total Dissolved Solids	mg/L	627		621	
Field Parameters					
Temperature, Water	DEG_C	15.8		15.0	
Turbidity (field)	NTU	0.59		0.39	
ORP	mV	90.9		158.5	
Specific Conductivity (field)	mS/cm	0.90		0.90	
Dissolved Oxygen	mg/L	1.29		1.69	
pH (field)	SU	7.12		6.96	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2A - Assessment Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-103			
Sample Date		08-Jan-20		05-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	32.8		29.1	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	33.0		27.2	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	18400		12700	
Chromium	µg/L	2.74		2.51	
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	< 1.65	U	< 1.65	U
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.565	U	< 0.304	UJ
Anions					
Chloride	mg/L	3.74		3.24	
Fluoride	mg/L	< 0.0240	U	< 0.0240	U
Sulfate	mg/L	55.9		38.2	
General Chemistry					
Total Dissolved Solids	mg/L	114		81.0	J
Field Parameters					
Temperature, Water	DEG_C	15.3		15.5	
Turbidity (field)	NTU	0.41		0.71	
ORP	mV	260.5		306.8	
Specific Conductivity (field)	mS/cm	0.171		0.125	
Dissolved Oxygen	mg/L	2.73		2.42	
pH (field)	SU	5.28		4.79	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2A - Assessment Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-104			
Sample Date		07-Jan-20		04-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	41.7		41.0	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	< 16.0	U	< 16.0	U
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	20400		15700	
Chromium	µg/L	1.78	J	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	6.06	J	4.05	J
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.412	U	< 0.175	UJ
Anions					
Chloride	mg/L	7.94		7.55	
Fluoride	mg/L	0.0291	J	< 0.0240	U
Sulfate	mg/L	7.26		9.78	
General Chemistry					
Total Dissolved Solids	mg/L	93.0		83.0	
Field Parameters					
Temperature, Water	DEG_C	16.7		16.1	
Turbidity (field)	NTU	0.25		0.17	
ORP	mV	207.2		261.8	
Specific Conductivity (field)	mS/cm	0.143		0.119	
Dissolved Oxygen	mg/L	3.73		4.05	
pH (field)	SU	5.86		5.31	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2A - Assessment Monitoring Groundwater Sampling Results Overburden

Monitoring Well		JSF-105			
Sample Date		09-Jan-20		06-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	55.7		52.3	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	24.1		18.6	J
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	46100		46600	
Chromium	µg/L	2.50		< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	< 1.65	U	< 1.65	U
Mercury	µg/L	< 0.130	U	< 0.130	U
Molybdenum	µg/L	< 1.08	U	1.36	J
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	0.348	J
Radium 226 + Radium 228	pCi/L	< 0.409	U	0.671	J
Anions					
Chloride	mg/L	1.55		1.43	
Fluoride	mg/L	0.0384	J	0.0295	J
Sulfate	mg/L	95.1		92.2	
General Chemistry					
Total Dissolved Solids	mg/L	191		222	
Field Parameters					
Temperature, Water	DEG_C	16.2		14.7	
Turbidity (field)	NTU	0.61		0.32	
ORP	mV	141.0		220.0	
Specific Conductivity (field)	mS/cm	0.302		0.303	
Dissolved Oxygen	mg/L	1.46		1.77	
pH (field)	SU	5.64		5.55	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2A - Assessment Monitoring Groundwater Sampling Results Overburden

Monitoring Well		W-32			
Sample Date		08-Jan-20		05-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	50.6		56.2	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	46.0		56.2	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	128000		135000	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	2.51	J	< 1.65	U
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.772	U	< 0.812	UJ
Anions					
Chloride	mg/L	11.1		11.0	
Fluoride	mg/L	< 0.0406	U*	0.0404	J
Sulfate	mg/L	54.7		55.5	
General Chemistry					
Total Dissolved Solids	mg/L	368		356	
Field Parameters					
Temperature, Water	DEG_C	16.2		15.8	
Turbidity (field)	NTU	2.27		1.14	
ORP	mV	197.3		282.9	
Specific Conductivity (field)	mS/cm	0.69		0.69	
Dissolved Oxygen	mg/L	1.13		1.05	
pH (field)	SU	6.91		6.77	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentration

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well		JSF-200			
Sample Date		07-Jan-20		04-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	182		195	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	17.7	J	18.4	J
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	95400		100000	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	11.4		10.9	
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.521	U	< 0.210	UJ
Anions					
Chloride	mg/L	9.77		9.38	
Fluoride	mg/L	0.0413	J	0.0414	J
Sulfate	mg/L	18.3		17.2	
General Chemistry					
Total Dissolved Solids	mg/L	311		314	
Field Parameters					
Temperature, Water	DEG_C	16.4		16.2	
Turbidity (field)	NTU	0.67		0.37	
ORP	mV	103.5		122.8	
Specific Conductivity (field)	mS/cm	0.522		0.527	
Dissolved Oxygen	mg/L	6.44		0.74	
pH (field)	SU	7.01		6.89	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well		JSF-201			
Sample Date		09-Jan-20		06-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	106		117	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	16.3	J	18.9	J
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	86800		90800	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	2.80	J	2.91	J
Mercury	µg/L	< 0.130	U	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.297	U	1.30	J
Anions					
Chloride	mg/L	3.94		3.43	
Fluoride	mg/L	0.0462	J	0.0430	J
Sulfate	mg/L	50.7		51.9	
General Chemistry					
Total Dissolved Solids	mg/L	294		279	
Field Parameters					
Temperature, Water	DEG_C	16.6		15.2	
Turbidity (field)	NTU	0.15		0.27	
ORP	mV	90.7		177.1	
Specific Conductivity (field)	mS/cm	0.461		0.476	
Dissolved Oxygen	mg/L	0.78		1.10	
pH (field)	SU	7.35		7.22	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well		JSF-202			
Sample Date		09-Jan-20		05-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	54.8		55.5	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	161		171	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	176000		181000	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	37.1		34.9	
Mercury	µg/L	< 0.130	U	< 0.130	U
Molybdenum	µg/L	1.73	J	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.495	U	< 0.418	UJ
Anions					
Chloride	mg/L	8.49		8.71	
Fluoride	mg/L	0.131		0.126	
Sulfate	mg/L	419		416	
General Chemistry					
Total Dissolved Solids	mg/L	900		864	
Field Parameters					
Temperature, Water	DEG_C	15.6		16.1	
Turbidity (field)	NTU	2.03		3.38	
ORP	mV	9.0		111.6	
Specific Conductivity (field)	mS/cm	1.13		1.15	
Dissolved Oxygen	mg/L	0.60		0.48	
pH (field)	SU	7.10		7.07	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-203			
Sample Date		09-Jan-20		06-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	1.00	J
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	84.2		87.6	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	1560		1820	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	98600		99900	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	11.1		11.7	
Mercury	µg/L	< 0.130	U	< 0.130	U
Molybdenum	µg/L	26.9		31.6	
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	1.07	
Radium 226 + Radium 228	pCi/L	1.80		< 0.430	UJ
Anions					
Chloride	mg/L	15.4		15.7	
Fluoride	mg/L	0.0714		0.0682	
Sulfate	mg/L	74.1		75.4	
General Chemistry					
Total Dissolved Solids	mg/L	374		394	
Field Parameters					
Temperature, Water	DEG_C	16.3		16.4	
Turbidity (field)	NTU	2.32		3.71	
ORP	mV	55.2		85.5	
Specific Conductivity (field)	mS/cm	0.592		0.597	
Dissolved Oxygen	mg/L	1.10		0.88	
pH (field)	SU	7.30		7.05	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

Monitoring Well		JSF-204			
Sample Date		09-Jan-20		06-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	0.922	J	1.80	J
Barium	µg/L	50.2		57.0	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	80.7		103	
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	85200		93200	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	0.275	J	0.316	J
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	5.07	J	5.74	J
Mercury	µg/L	< 0.130	U	< 0.130	U
Molybdenum	µg/L	< 1.08	U	< 1.08	U
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.345	U	< 0.659	UJ
Anions					
Chloride	mg/L	9.17		9.07	
Fluoride	mg/L	0.0455	J	0.0431	J
Sulfate	mg/L	50.5		50.9	
General Chemistry					
Total Dissolved Solids	mg/L	337		328	
Field Parameters					
Temperature, Water	DEG_C	17.7		17.2	
Turbidity (field)	NTU	2.59		4.86	
ORP	mV	7.5		18.5	
Specific Conductivity (field)	mS/cm	0.531		0.536	
Dissolved Oxygen	mg/L	3.01		0.97	
pH (field)	SU	7.17		7.06	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 2B - Assessment Monitoring Groundwater Sampling Results Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well		JSF-205			
Sample Date		08-Jan-20		04-Feb-20	
Sample Round		1		1 - Retest	
Monitoring Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	µg/L	< 0.570	U	< 0.570	U
Arsenic	µg/L	< 0.750	U	< 0.750	U
Barium	µg/L	73.7		75.7	
Beryllium	µg/L	< 0.305	U	< 0.305	U
Boron	µg/L	< 16.0	U	< 16.0	U
Cadmium	µg/L	< 0.197	U	< 0.197	U
Calcium	µg/L	69700		71900	
Chromium	µg/L	< 0.980	U	< 0.980	U
Cobalt	µg/L	< 0.190	U	< 0.190	U
Lead	µg/L	< 0.450	U	< 0.450	U
Lithium	µg/L	3.55	J	2.94	J
Mercury	µg/L	< 0.130	UJ	< 0.130	U
Molybdenum	µg/L	1.79	J	1.68	J
Selenium	µg/L	< 0.890	U	< 0.890	U
Thallium	µg/L	< 0.200	U	< 0.200	U
Radium 226 + Radium 228	pCi/L	< 0.157	U	< 0.257	UJ
Anions					
Chloride	mg/L	7.52		7.48	
Fluoride	mg/L	< 0.0784	U*	0.0710	
Sulfate	mg/L	25.1		24.6	
General Chemistry					
Total Dissolved Solids	mg/L	247		249	
Field Parameters					
Temperature, Water	DEG_C	13.1		13.9	
Turbidity (field)	NTU	0.75		0.65	
ORP	mV	103.0		178.0	
Specific Conductivity (field)	mS/cm	0.405		0.409	
Dissolved Oxygen	mg/L	0.91		3.86	
pH (field)	SU	7.37		7.35	

Notes:

NA - Not Available

Q - Data Qualifier

U* - Result should be considered not detected. Detected in an associated field or laboratory blank at a similar concentratio

UJ - Analyte not detected, but the reporting limit may or may not be higher due to a bias identified during data validation

J - Quantitation is approximate due to limitations identified during data validation

U - Concentration not detected

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

ASSESSMENT MONITORING

Table 3
Groundwater Sampling Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well ID	Monitoring Well Designation	Number of Samples Collected	September 10-11, 2019	November 19-21, 2019	January 7-9, 2020	February 4-6, 2020	Monitoring Program
Overburden Monitoring Wells							
10-36	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-103	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-104	Background	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-105	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
W-32	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Table 3
Groundwater Sampling Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well ID	Monitoring Well Designation	Number of Samples Collected	September 10-11, 2019	November 19-21, 2019	January 7-9, 2020	February 4-6, 2020	Monitoring Program
Bedrock Monitoring Wells							
JSF-200	Background	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-201	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-202	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-203	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-204	Downgradient	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
JSF-205	Background	2	X	X			Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
		2			X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Notes:

Appendix III Constituents - boron, calcium, chloride, fluoride, pH, sulfate, total dissolved solids (TDS)

Appendix IV Constituents - antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228

Table 4
Groundwater and Surface Water Elevation Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Groundwater Elevation Collection Date		09-Sep-19	18-Nov-19	06-Jan-20	03-Feb-20
Monitoring Well	Units	**Overburden**			
10-36	ft-MSL	1108.67	1109.38	1112.75	1112.64
JSF-103	ft-MSL	1112.95	1114.33	1116.60	1116.13
JSF-104	ft-MSL	1122.54	1122.44	1123.75	1123.73
JSF-105	ft-MSL	1107.18	1107.78	1110.95	1110.63
W-32	ft-MSL	1086.58	1086.53	1087.47	1087.28
Monitoring Well	Units	**Bedrock**			
JSF-200	ft-MSL	1122.25	1122.17	1123.31	1123.25
JSF-201	ft-MSL	1106.67	1107.35	1109.92	1109.74
JSF-202	ft-MSL	1108.43	1109.18	1112.47	1112.36
JSF-203	ft-MSL	1108.03	1108.54	1110.65	1110.47
JSF-204	ft-MSL	1097.81	1098.00	1099.31	1099.45
JSF-205	ft-MSL	1123.34	1122.60	1128.31	1128.11
Surface Water					
Holston River	ft-MSL	NA	1061.64	1065.72	1063.50

Notes:

ft-MSL - feet above mean sea level

NA - Not available; iSite system surface water elevation data not available between 9/4/19 and 9/11/19

Table 5
Hydraulic Conductivity Data Summary

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Monitoring Well ID	Monitoring Well Designation	Slug Test Hydraulic Conductivity (cm/sec)
10-36	Downgradient	1.46E-04
JSF-103	Downgradient	7.52E-04
JSF-104	Background	3.12E-04
JSF-105	Downgradient	2.25E-04
W-32	Downgradient	6.70E-04
Geometric Mean of Hydraulic Conductivity Overburden (cm/sec)		**3.49E-04**
JSF-200	Background	1.96E-03
JSF-201	Downgradient	3.06E-04
JSF-202	Downgradient	9.00E-04
JSF-203	Downgradient	9.26E-04
JSF-204	Downgradient	4.24E-03
JSF-205	Background	6.92E-04
Geometric Mean of Hydraulic Conductivity Bedrock (cm/sec)		**1.07E-03**

Notes:

cm/sec - centimeters per second

NA - Not available

Table 6A
Rate and Direction of Groundwater Flow Summary - Overburden

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Groundwater Elevation Collection Date	9-Sep-19	18-Nov-19	6-Jan-20	3-Feb-20
Horizontal Gradient	0.0138	0.0133	0.0111	0.0110
Hydraulic Conductivity (cm/sec)	3.49E-04	3.49E-04	3.49E-04	3.49E-04
Effective Porosity	10%	10%	10%	10%
Flow Direction (cardinal)	North	North	North	North
Linear Velocity (ft/yr)	49.7	48.2	40.1	39.8

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

Table 6B
Rate and Direction of Groundwater Flow Summary - Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Groundwater Elevation Collection Date	9-Sep-19	18-Nov-19	6-Jan-20	3-Feb-20
Horizontal Gradient	0.0135	0.0127	0.0116	0.0118
Hydraulic Conductivity (cm/sec)	1.07E-03	1.07E-03	1.07E-03	1.07E-03
Effective Porosity	1%	1%	1%	1%
Flow Direction (cardinal)	North	North	North	North
Linear Velocity (ft/yr)	1487.7	1402.4	1284.0	1296.8

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

Table 7A
Groundwater Protection Standards - Overburden

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Constituent Name	Unit	GWPS
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	2
Beryllium	mg/L	0.004
Boron	mg/L	0.08*
Cadmium	mg/L	0.005
Calcium	mg/L	16.1*
Chloride	mg/L	9.7*
Chromium	mg/L	0.1
Cobalt	mg/L	0.006
Fluoride	mg/L	4
Lead	mg/L	0.015
Lithium	mg/L	0.04
Mercury	mg/L	0.002
Molybdenum	mg/L	0.1
pH (field)	SU	5.05 - 5.94*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	9.4*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	111.6*

Notes:

GWPS - groundwater protection standard

* - BTV - Background Threshold Value for Appendix III Constituents (2019)

mg/L - milligrams per liter

SU - standard units

pCi/L - picocuries per liter

Table 7B
Groundwater Protection Standards - Bedrock

CCR Annual Groundwater Monitoring and Corrective Action Report - TVA John Sevier Fossil Plant

Constituent Name	Unit	GWPS
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	2
Beryllium	mg/L	0.004
Boron	mg/L	0.08*
Cadmium	mg/L	0.005
Calcium	mg/L	103*
Chloride	mg/L	11*
Chromium	mg/L	0.1
Cobalt	mg/L	0.006
Fluoride	mg/L	4
Lead	mg/L	0.015
Lithium	mg/L	0.04
Mercury	mg/L	0.002
Molybdenum	mg/L	0.1
pH (field)	SU	6.53 - 7.76*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	18.3*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	340.7*

Notes:

GWPS - groundwater protection standard

* - BTV - Background Threshold Value for Appendix III Constituents (2019)

mg/L - milligrams per liter

SU - standard units

pCi/L - picocuries per liter

N/A - not applicable

APPENDIX A - STATISTICAL ANALYSIS REPORT FOR JOHN SEVIER FOSSIL PLANT, 2020 CCR PROGRAM, RESIDUUM - VACATUR UNIT

Statistical Analysis Report for John Sevier Fossil Plant

2020 CCR Program, Residuum Vacatur Unit

Kirk Cameron, Ph.D., MacStat Consulting, Ltd.

2020-04-10

Contents

1 Introduction **2**

2 Statistical Analysis **3**
2.1 Developing Groundwater Protection Standards (GWPS) 4
2.2 Computing Trend Lines and Confidence Interval Bands 7
2.3 Comparing Confidence Interval Bands Against G WPS 9

3 Summary of Statistical Analysis **10**

4 References **11**

1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during 2020 under the Coal Combustion Residuals (CCR) Rule's Ground Water Quality Monitoring (GWQM) Program for the Residuum Vacatur Unit at the Tennessee Valley Authority (TVA) John Sevier Fossil Plant (JSF). When this unit was established in 2019, CCR sampling and monitoring for the required Appendix III and Appendix IV constituents (COI) were conducted to develop baseline conditions at this site and to identify any statistically significant exceedances of background levels.

The United States Environmental Protection Agency (USEPA) requires all Owners and/or Operators of fossil plants to establish baseline groundwater quality conditions using a minimum of eight sampling events, collected roughly over a period of one year. As a follow-up to the establishment of baseline groundwater quality conditions, USEPA also requires subsequent performance of at least a single sampling event, under a monitoring phase known as Detection Monitoring, to collect samples for chemical-laboratory analysis of Appendix III constituents. Although most Appendix III constituents are naturally occurring chemicals in groundwater, USEPA requires analysis of these constituents to determine if the CCR unit shows signs of contributing contamination to a 'usable aquifer.'

During the first year of Detection Monitoring for the Vacatur Unit, monitoring and statistical evaluation of the Appendix III constituents listed in the left-hand column of **Table 1** identified selected values with statistically significant increases (SSI) over background levels. Subsequently, the site moved into Assessment Monitoring, requiring chemical-laboratory analysis of Appendix IV constituents and comparison of those levels against Groundwater Protection Standards (GWPS).

Table 1: CCR Rule Constituents

Appendix III	Appendix IV
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
Sulfate	Cadmium
pH	Chromium
TDS	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Rad226+228
	Selenium
	Thallium

For this year's efforts, the baseline datasets of the CCR-Rule GWQM Program were augmented with routine monitoring samples in order to update the background data set. The background data were then utilized to develop statistically-derived GWPS in those cases where site-specific background levels naturally exceed published regulatory limits. Finally, data from the compliance wells were statistically compared to the GWPS to determine whether any standards were exceeded.

As discussed in USEPA's Unified Guidance document on the statistical analysis of groundwater monitoring data (USEPA 2009), confidence-interval (CI) bands are a recommended technique for performing statistical comparisons against GWPS. In particular, trends at downgradient wells in analytical concentrations of Constituents of Interest (COI) can be plotted and used to estimate CI bands, which in turn can be compared against their respective GWPS. A statistically significant increase (SSI) is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

As required by the USEPA's Coal Combustion Residuals (CCR) Rule section describing the Assessment Monitoring Program (§257.95), test results for the 2020 Assessment Monitoring events were compared to the GWPS for determination of any exceedances. Additional description of how the GWPS for each COI and each CCR Unit were established is provided in subsequent sections of this report.

At the JSF CCR Residuum Vacatur Unit, the sampling results used to identify SSIs above the GWPS were obtained from distinct monitoring events collected between January of 2019 and February of 2020 by the firm of Terracon, with Laboratory Analysis performed by Test America Laboratories (located at Pittsburgh, PA, and GEL Laboratories, Charleston, S.C.), and Quality Assurance Controls by Environmental Standards, Inc., all under direct contract to TVA.

At TVA's request, 'Traffic Light' matrices were constructed to facilitate an at-a-glance identification of any exceedances of GWPS and to promote intra-company follow-up assessments to explain the outcomes (e.g., other identifiable chemicals used on site or in the vicinity of the plant) and to plan for mitigation actions, whenever warranted. Sample analytical results of CCR-Rule Appendix III and IV constituents obtained from each of the monitoring wells and events were used to perform the statistical analysis and generate the graphs shown in this report. The current CCR Rule groundwater monitoring network for the Residuum Vacatur unit, as Certified by a Professional Engineer, are presented in **Table 2**.

The 'R' Statistical Analysis package (www.r-project.org) in conjunction with R-Studio (www.rstudio.com) (both popular public domain software products) and other analytical tools were used in the production of the statistical estimates and graphs. ProUCL data dumps from TVA's EQuIS Professional and Enterprise Database were used to populate the R-based statistical analyses.

Table 2: Residuum CCR Monitoring Network

Background	Downgradient
JSF-104	JSF-103
	JSF-105
	W-32
	10-36

2 Statistical Analysis

At the JSF Residuum Vacatur network (see **Table 2**), the sampling results used to compute the background statistics were obtained only from designated background wells using historical data that were first screened for possible trends or shifts in concentration levels over time. Any early data exhibiting a substantially different pattern or average concentration level than more recent data were excluded from the calculations. The cutoff date used for selecting background data was determined

on a constituent by constituent basis, but was designed to include as much data as possible reflecting current groundwater conditions.

Groundwater samples were analyzed for 21 distinct constituents as required for the CCR monitoring program (see **Table 1**). Fluoride is monitored under both Appendices. Only non-filtered sample results were utilized for the statistical analysis. As high turbidity measurements during the purging of wells (e.g., values above 5 NTUs) have the propensity to increase the concentrations of Appendix III and IV constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-identified SSIs.

The basic steps in the Assessment Monitoring analysis included the following:

1. Developing groundwater protection standards (GWPS) for each Appendix IV constituent, using published MCLs and/or water quality limits, along with baseline data from upgradient and background well locations at each CCR site;
2. Computing trends and associated confidence interval (CI) bands for each well location and Appendix IV constituent (i.e., for each well-constituent pair); and
3. Comparing each CI band against its respective GWPS to assess whether or not a statistically significant exceedance occurred.

To accomplish these steps, the data were first summarized and modeled. The background data were initially examined and summarized with descriptive statistics, as shown in **Table 3**. To handle any non-detects in these calculations, non-detect values were treated as statistically 'left-censored,' with the censoring limit equal to the reporting limit (RL). Then the Kaplan-Meier adjustment method (USEPA 2009) was employed to derive estimated summary statistics that account for the presence of non-detects.

2.1 Developing Groundwater Protection Standards (GWPS)

USEPA has published maximum contaminant limits (MCL) or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the Groundwater Protection Standard (GWPS) is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate GWPS must be derived from on-site background levels.

According to the promulgated CCR Rule (80 Federal Register 21302, 21405, April 17, 2015):

> "For each appendix IV constituent that is detected, a groundwater protection standard must be set. The groundwater protection standards must be the MCL or the background concentration level for the detected constituent, whichever is higher. If there is no MCL promulgated for a detected constituent, then the groundwater protection standard must be set at background."

The CCR Rule is also consistent with EPA's Unified Guidance for the statistical analysis of groundwater monitoring data, which states:

> "But a number of situations arise where a GWPS must be based on a background limit. The Part 264 regulations presume such a standard as one of the options under §264.94(a);

Table 3: Background Data Summary Statistics

COI	Units	N	No. NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	12	12	0.002	0.002	0.001	0.002
Arsenic	mg/L	12	10	0.000333	0.005	0.0004	0.000333
Barium	mg/L	12	0	0.0365	0.0484	0.0432	0.044
Beryllium	mg/L	12	12	0.001	0.001	0.0005	0.001
Cadmium	mg/L	12	12	0.001	0.001	0.0005	0.001
Chromium	mg/L	12	8	0.0016	0.00538	0.0017	0.00172
Cobalt	mg/L	12	11	0.0005	0.001	0.0005	0.0005
Fluoride	mg/L	12	9	0.0267	0.1	0.0282	0.0288
Lead	mg/L	12	9	0.000114	0.001	0.0002	0.000155
Lithium	mg/L	12	2	0.00405	0.00919	0.0061	0.00621
Mercury	mg/L	12	12	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	12	12	0.005	0.005	0.0025	0.005
Rad226+228	pCi/L	11	0	0.0178	0.412	0.193	0.219
Selenium	mg/L	12	12	0.005	0.005	0.0025	0.005
Thallium	mg/L	12	12	0.001	0.001	0.0005	0.001

> an ACL may also be determined from background under §264.94(b). More recent Part 258 rules specify a background GWPS where a promulgated or risk-based standard is not available or if the historical background is greater than an MCL [§258.55(h)(2) & (3)]." ((USEPA 2009), p. 7-20)

Based on these rules and guidance, TVA has established GWPS across its CCR program using the following decision logic:

- For each Appendix IV parameter where a GWPS must be established, a comparison is made between the promulgated regulatory limit and a site-specific limit computed from background data.
- If the background-based limit is larger than the promulgated limit, the GWPS is set to the background limit. But if the promulgated limit is larger, the GWPS is set to the published value.

In cases where a background limit must be computed, USEPA's Unified Guidance recommends different strategies for computing a background-based GWPS ((USEPA 2009), Section 7.5). One of these strategies — a 95% confidence, 95% coverage upper tolerance limit (UTL) on background — was selected and used to compute the UTL on site-specific background data for each Appendix IV parameter. Then these UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS.

To compute each tolerance limit (UTL), the following steps were taken:

1. All baseline data from designated upgradient or background wells collected through February 2020 were grouped and checked for possible outliers. Outlier screening was performed visually on time series plots of the data, as well as systematically via a modified version of Tukey's boxplot rule.

In a boxplot, the length of the box is the range of the central 50% of the sorted measurements. Tukey's original outlier rule states that any observation more than 1.5 box lengths above or below

the edges of the boxplot classifies as a possible outlier. For stable, symmetric data distributions, Tukey's rule often works well.

Groundwater data is often skewed instead of symmetric, and may exhibit shorter (i.e., localized) or longer-term (non-linear) trends. Because of this reality, a modified version of Tukey's rule is generally needed to avoid identifying too many possible outliers. The modification consists of three parts: a) a non-linear trend is fit to each time series and residuals of the data are computed from the estimated trend; b) a possible outlier is identified only if flagged *both* as an extreme residual from the trend; and c) as an extreme outlier relative to the overall dataset (i.e., more than 3 box lengths above or below the edges of the boxplot). Together, these modifications better account for data skewness and localized trends in the background observations.

If any possible outliers are flagged, they are visually compared against observations at other well locations. If similar patterns or measurement ranges are common, the suspect values are kept in the data. If not, the suspected outliers are formally assessed using Rosner's outlier test. Any confirmed outliers are excluded from the UTL computations.

At the JSF Residuum Vacatur unit, 0 possible outliers were flagged in the grouped background data. Therefore, no background outliers were found or excluded from the analysis.

2. The grouped baseline data — excluding any confirmed outliers — were analyzed to determine whether they could be fit to a known statistical model. If so, a parametric UTL was computed; if not, a nonparametric UTL was constructed.

To fit potential statistical models, a series of normalizing mathematical transformations was applied to each baseline dataset. These transformations are known as power transformations, since they raise each observation to a mathematical power. The goal is to find, if possible, a transformation that normalizes the data on the transformed scale. Models tested ranged from the tenth root to the tenth power, and included the null transformation (power = 1), which assumes the data are normally distributed without transformation; the logarithm, which models the lognormal distribution; and the cube root, which closely mimics the gamma distribution.

The transformation which most nearly normalized the data was then formally tested using Filliben's probability plot correlation coefficient test. Filliben's test checks for normality of the transformed measurements by computing the correlation between the data and matched quantiles (i.e., z-scores) from a standard normal distribution. The process parallels fitting a line on a normal probability plot of the (transformed) data. The closer to a linear fit, the higher the correlation; the further from a linear fit, the smaller the correlation. Filliben's test formally assesses the strength of the correlation to determine whether it is high enough to declare that the data are consistent with a normal model.

Filliben's test yields a p-value measuring the statistical significance of the result. A p-value no less than 0.01 was judged as sufficient to assume normality of the (transformed) observations, while data with a Filliben's test p-value less than 0.01 were judged significantly non-normal. Datasets passing Filliben's test were assumed to have a parametric model corresponding to the transformation employed, e.g., data tested on the log-scale were assumed consistent with the lognormal distribution; data tested on the square root scale were assumed consistent with the square-root normal distribution, etc.

Datasets which could not be sufficiently normalized, thus failing Filliben's test, were analyzed by nonparametric means. In many instances, this may occur when the data includes a large fraction of non-detects. **Table 4** lists a shorthand for the statistical model utilized for each Constituent of Interest (COI) under the Model column. As examples, NP stands for nonparametric; Log stands for the logarithm, implying a lognormal model; and Normal represents the null transformation, implying a normal model.

3. The final statistical model for each COI was used to compute an upper tolerance limit (UTL) with 95% coverage and 95% confidence.

When a parametric model is appropriate, on the normalized scale, a UTL is computed using the standard normal theory equation:

$$UTL = \bar{x} + \kappa s$$

where $\bar{x}$ and s represent the mean and standard deviation of the (transformed) observations, and κ is a multiplier which depends on the number of baseline measurements, as well as the desired coverage and confidence levels. If the data have been transformed, the final UTL is derived by back-transforming the scaled UTL, e.g, for a log transformation, the result is exponentiated; for a square-root transformation, the result is squared, etc.

Note that the formula for an upper tolerance limit looks identical to the general formula for a parametric upper prediction limit. The important difference is in how the κ multiplier is computed, which in turn depends on type and purpose of the statistical limit. In general, parametric prediction and tolerance limits will not be the same, even when using the same background data.

For nonparametric models, the normal theory equation does not apply. Instead, the UTL is selected as one of the largest of the sample values, often the maximum. Because there is no multiplier (κ) as in the parametric case, the confidence level associated with a nonparametric UTL is computed 'after the fact,' based on the sample size and desired coverage level: the smaller the sample size, the lower the confidence; the bigger the sample size, the higher the confidence level.

Since nonparametric UTLs do not assume a known statistical model, unless the sample size is fairly large, the achieved confidence level can be much lower than the target of 95%. When this happens, the computed UTL may not be very accurate. A more accurate UTL would likely be larger than the one computed from the available sample data. Unfortunately, without a statistical model, and especially with a large percentage of non-detects, little improvement is possible in the UTL estimates unless a larger sample size can be employed.

For the JSF Residuum Vacatur unit, **Table 4** lists the calculated GWPS limits established for this monitoring network.

2.2 Computing Trend Lines and Confidence Interval Bands

USEPA's Unified Guidance recommends comparing some type of confidence interval (CI) against a groundwater protection standard (GWPS) in order to assess whether or not the limit has been exceeded with statistical significance. If the entire interval exceeds the GWPS, a statistically significant increase (SSI) is identified. If none of the interval, or only part, exceeds the GWPS, no SSI is recorded.

The rationale behind this procedure is predicated on the following:

1. A confidence interval is typically designed to 'contain' or 'capture' a specific target or feature of the underlying groundwater population, usually the mean or median measurement value. An interval rather than a point estimate is utilized because that is the only way to ensure the target is captured with a high degree of statistical confidence.
2. When a confidence interval is entirely on one side or the other of a fixed numerical limit, the confidence is high that the desired population target is also to that side of the limit.

Table 4: JSF Residuum GWPS Limits

COI	Model	N	Coverage	Confidence	UTL	RegLimit	GWPS
Antimony	NP	12	0.95	0.46	0.002	0.006	0.006
Arsenic	NP	12	0.95	0.46	0.005	0.01	0.01
Barium	Fourth Power	12	0.95	NA	0.0516	2	2
Beryllium	NP	12	0.95	0.46	0.001	0.004	0.004
Cadmium	NP	12	0.95	0.46	0.001	0.005	0.005
Chromium	Tenth Power	12	0.95	NA	0.00183	0.1	0.1
Cobalt	NP	12	0.95	0.46	0.001	0.006	0.006
Fluoride	NP	12	0.95	0.46	0.1	4	4
Lead	NP	12	0.95	0.46	0.001	0.015	0.015
Lithium	Fourth Power	12	0.95	NA	0.00753	0.04	0.04
Mercury	NP	12	0.95	0.46	0.0002	0.002	0.002
Molybdenum	NP	12	0.95	0.46	0.005	0.1	0.1
Rad226+228	Normal	11	0.95	NA	0.585	5	5
Selenium	NP	12	0.95	0.46	0.005	0.05	0.05
Thallium	NP	12	0.95	0.46	0.001	0.002	0.002

3. Because the target may exist anywhere in the range represented by the confidence interval, an interval that 'straddles' the fixed limit is not guaranteed to be either above or below the GWPS, and certainly not with high or known statistical confidence.

USEPA's logic thus ensures that a correct decision about the occurrence of an SSI can be made with high statistical assurance.

Since groundwater data are collected over time, and not all at once, some or most of the variation in the measurements may be due to a trend. To better account for this possibility, USEPA also recommends a variation on the confidence interval method known as a confidence interval band around a trend line. In this case, a (linear) trend line is first fit to the data, then a confidence band is constructed around the trend line. The confidence interval band can be compared against a GWPS in much the same fashion as a confidence interval, only now a comparison can be made at different points in time by comparing the 'cross-section' of the band for a given sampling date. If the interval represented by the confidence band cross-section fully exceeds the GWPS, an SSI is identified for that sampling event.

At TVA's CCR sites, CI bands were constructed (as described below) for each well-constituent pair using all available sample data. Cross-sections of each band were then compared to the GWPS for the most recent Assessment Monitoring event in each case for the purpose of identifying any SSIs. Note that in cases where the data are obviously trending, the CI band technique provides a much more powerful and accurate means of judging exceedances above GWPS. Ignoring a trend typically makes a standard confidence interval too wide and uncertain to be of much use, due to the extra variation imparted by the trend. For data that are more stable, both methods will tend to give similar results.

2.2.1 Trend Lines Using Linear Regression

Unless there are extreme outliers and/or curvature in the data, linear regression provides a standard and well-tested method for estimating the linear portion of a trend. The slope of the regression line

points to the magnitude and direction of the trend. There is also a standard method for computing a confidence band around a linear regression trend line. For instance, equations [21.24] and [21.25] of Section 21.3 in the *Unified Guidance* can be compactly written as

$$CB_{1-\alpha} = \hat{x}_0 \pm \sqrt{2 s_e^2 F_{1-\alpha,n-2} \left[\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2} \right]}$$

where CB = confidence band, $\hat{x}_0$ is the regression line estimate at time t_0, s_e^2 is the mean squared error of the regression line, F is a quantile from the F-distribution with 2 and $n-2$ degrees of freedom, and $\bar{t}$ and s_t^2 represent the mean and standard deviation of the sampling dates.

For well-constituent pairs with no non-detects, linear regression and the formula above were used to construct each confidence band with 98% overall confidence, corresponding to a lower confidence limit with 99% confidence. When non-detects are present, the same formulas apply but an adjustment must be made for the censored measurements. The strategy adopted for TVA's CCR sites involves the following steps:

1. Each non-detect is assumed to follow a triangle distribution centered at half the (sample-specific) reporting limit, and with limits extending from zero to the reporting limit. Then an imputation for each non-detect is randomly drawn from this distribution;
2. The combined set of detected values and imputed non-detects is used to estimate a linear regression trend line and associated confidence band with 98% statistical confidence;
3. Steps (1) and (2) are repeated 500 times, each time with a different set of random imputations, leading to 500 potentially different trend lines and confidence bands;
4. The 500 sets of trends lines and bands are averaged point-wise (i.e., at each time along a sequence of dates spanning the date range of the data) to compute the final trend and confidence band estimates.

By repeating this sequence of steps a large number of times (500), the uncertainty associated with the non-detects can be reasonably captured within the final CI band estimate.

2.2.2 Outliers

Prior to constructing any of the confidence interval (CI) bands, the data at each well-constituent pair were examined for possible outliers. As with the grouped background data, visual examination was done with time series plots and the modified Tukey's boxplot rule was utilized for initial screening. Any observations that were flagged and confirmed as pairwise outliers were excluded from calculation of the CI bands.

No pairwise outliers were confirmed or excluded from this analysis.

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2020 Assessment Monitoring at TVA's CCR sites, the confidence interval (CI) bands described in **Section 2.2** were compared against the constituent-specific groundwater protection standards (GWPS) described in **Section 2.1**. Of note, an SSI was identified if and only if the CI band fully exceeded the GWPS at the most recent sampling event.

To clarify the importance of this last statement, consider the difference in statistical approach between Detection Monitoring and Assessment Monitoring. When utilizing prediction limits in Detection

Monitoring, at least two sampling events per year must be collected and evaluated to identify any SSIs above background levels. Each prediction limit is derived from the baseline or background data, then each new compliance point value is compared against its respective prediction limit. If the newest compliance value exceeds the limit, a potential SSI is flagged, to be confirmed or disconfirmed via additional resampling and retesting.

The statistical approach in Assessment Monitoring is different. Comparisons are made against a fixed GWPS via a confidence interval or confidence interval band. No retesting is conducted and none of the individual compliance point measurements are directly compared against the GWPS. Instead, multiple compliance observations must be used to construct each confidence interval or CI band, necessarily at least four and preferably 8 to 10 or more. Consequently, all the Assessment Monitoring data collected from 2019 to 2020 were used to construct the CI bands. Furthermore, a well-constituent pair is considered out of compliance only if its constituent levels currently exceed the GWPS. This is best assessed by considering the cross-section of the CI band associated with the most recent sampling event.

3 Summary of Statistical Analysis

To facilitate an 'at-a-glance' summary of the statistical comparison results, **Table 5** is a 'traffic light' matrix, showing a compact representation of each well location matched against each constituent in Appendix IV. This summary is useful in planning for mitigation actions. Green cells indicate that no SSI was observed. Red cells indicate the opposite: an SSI was flagged at the most recent sampling event. Yellow cells are warnings which indicate that a well-constituent pair should be closely watched. These cases have increasing trends and a CI band whose lower limit is at least 65% of the GWPS. Often, in yellow cells, the CI band cross-section straddles the GWPS.

At the JSF Residuum Vacatur unit, a total of 0 SSIs and 0 warnings were identified during the 2020 Assessment Monitoring analysis.

Table 5: Traffic Light Matrix for JSF Residuum CCR Vacatur Unit

	Well Locations				
COI	**JSF-104**	**JSF-103**	**JSF-105**	**W-32**	**10-36**
Antimony	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Arsenic	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Barium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Beryllium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Cadmium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Chromium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Cobalt	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Fluoride	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Lead	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Lithium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Mercury	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Molybdenum	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Rad226+228	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Selenium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**
Thallium	**GRN**	**GRN**	**GRN**	**GRN**	**GRN**

Color-Coding Key:
RED = CI Band above GWPS;
GRN = CI Band below GWPS;
YLW = CI Lower Bound at least 65% of GWPS)

4 References

USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance." USEPA: Office of Resource Conservation & Recovery, EPA 530-R-09-007.

APPENDIX B - STATISTICAL ANALYSIS REPORT FOR JOHN SEVIER FOSSIL PLANT, 2020 CCR PROGRAM, BEDROCK - VACATUR UNIT

Statistical Analysis Report for John Sevier Fossil Plant

2020 CCR Program, Bedrock Vacatur Unit

Kirk Cameron, Ph.D., MacStat Consulting, Ltd.

2020-04-13

Contents

1 Introduction **2**

2 Statistical Analysis **3**
2.1 Developing Groundwater Protection Standards (GWPS) 4
2.2 Computing Trend Lines and Confidence Interval Bands 7
2.3 Comparing Confidence Interval Bands Against G WPS 10

3 Summary of Statistical Analysis **10**

4 References **11**

1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during 2020 under the Coal Combustion Residuals (CCR) Rule's Ground Water Quality Monitoring (GWQM) Program for the Bedrock Vacatur Unit at the Tennessee Valley Authority (TVA) John Sevier Fossil Plant (JSF). When this unit was established in 2019, CCR sampling and monitoring for the required Appendix III and Appendix IV constituents (COI) were conducted to develop baseline conditions at this site and to identify any statistically significant exceedances of background levels.

The United States Environmental Protection Agency (USEPA) requires all Owners and/or Operators of fossil plants to establish baseline groundwater quality conditions using a minimum of eight sampling events, collected roughly over a period of one year. As a follow-up to the establishment of baseline groundwater quality conditions, USEPA also requires subsequent performance of at least a single sampling event, under a monitoring phase known as Detection Monitoring, to collect samples for chemical-laboratory analysis of Appendix III constituents. Although most Appendix III constituents are naturally occurring chemicals in groundwater, USEPA requires analysis of these constituents to determine if the CCR unit shows signs of contributing contamination to a 'usable aquifer.'

During the first year of Detection Monitoring for the Vacatur Unit, monitoring and statistical evaluation of the Appendix III constituents listed in the left-hand column of **Table 1** identified selected values with statistically significant increases (SSI) over background levels. Subsequently, the site moved into Assessment Monitoring, requiring chemical-laboratory analysis of Appendix IV constituents and comparison of those levels against Groundwater Protection Standards (GWPS).

Table 1: CCR Rule Constituents

Appendix III	Appendix IV
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
Sulfate	Cadmium
pH	Chromium
TDS	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Rad226+228
	Selenium
	Thallium

For this year's efforts, the baseline datasets of the CCR-Rule GWQM Program were augmented with routine monitoring samples in order to update the background data set. The background data were then utilized to develop statistically-derived GWPS in those cases where site-specific background levels naturally exceed published regulatory limits. Finally, data from the compliance wells were statistically compared to the GWPS to determine whether any standards were exceeded.

As discussed in USEPA's Unified Guidance document on the statistical analysis of groundwater monitoring data (USEPA 2009), confidence-interval (CI) bands are a recommended technique for performing statistical comparisons against GWPS. In particular, trends at downgradient wells in analytical concentrations of Constituents of Interest (COI) can be plotted and used to estimate CI bands, which in turn can be compared against their respective GWPS. A statistically significant increase (SSI) is found if and only if the lower limit of the CI band exceeds the GWPS for the most recent Assessment Monitoring sampling event.

As required by the USEPA's Coal Combustion Residuals (CCR) Rule section describing the Assessment Monitoring Program (§257.95), test results for the 2020 Assessment Monitoring events were compared to the GWPS for determination of any exceedances. Additional description of how the GWPS for each COI and each CCR Unit were established is provided in subsequent sections of this report.

At the JSF CCR Bedrock Vacatur Unit, the sampling results used to identify SSIs above the GWPS were obtained from distinct monitoring events collected between January of 2019 and February of 2020 by the firm of Terracon, with Laboratory Analysis performed by Test America Laboratories (located at Pittsburgh, PA, and GEL Laboratories, Charleston, S.C.), and Quality Assurance Controls by Environmental Standards, Inc., all under direct contract to TVA.

At TVA's request, 'Traffic Light' matrices were constructed to facilitate an at-a-glance identification of any exceedances of GWPS and to promote intra-company follow-up assessments to explain the outcomes (e.g., other identifiable chemicals used on site or in the vicinity of the plant) and to plan for mitigation actions, whenever warranted. Sample analytical results of CCR-Rule Appendix III and IV constituents obtained from each of the monitoring wells and events were used to perform the statistical analysis and generate the graphs shown in this report. The current CCR Rule groundwater monitoring network for the Bedrock Vacatur unit, as Certified by a Professional Engineer, are presented in **Table 2**.

The 'R' Statistical Analysis package (www.r-project.org) in conjunction with R-Studio (www.rstudio.com) (both popular public domain software products) and other analytical tools were used in the production of the statistical estimates and graphs. ProUCL data dumps from TVA's EQuIS Professional and Enterprise Database were used to populate the R-based statistical analyses.

Table 2: Bedrock CCR Monitoring Network

Background	Downgradient
JSF-200	JSF-201
JSF-205	JSF-202
	JSF-203
	JSF-204

2 Statistical Analysis

At the JSF Bedrock Vacatur network (see **Table 2**), the sampling results used to compute the background statistics were obtained only from designated background wells using historical data that were first screened for possible trends or shifts in concentration levels over time. Any early data exhibiting a substantially different pattern or average concentration level than more recent data were excluded from the calculations. The cutoff date used for selecting background data was determined

on a constituent by constituent basis, but was designed to include as much data as possible reflecting current groundwater conditions.

Groundwater samples were analyzed for 21 distinct constituents as required for the CCR monitoring program (see **Table 1**). Fluoride is monitored under both Appendices. Only non-filtered sample results were utilized for the statistical analysis. As high turbidity measurements during the purging of wells (e.g., values above 5 NTUs) have the propensity to increase the concentrations of Appendix III and IV constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-identified SSIs.

The basic steps in the Assessment Monitoring analysis included the following:

1. Developing groundwater protection standards (GWPS) for each Appendix IV constituent, using published MCLs and/or water quality limits, along with baseline data from upgradient and background well locations at each CCR site;
2. Computing trends and associated confidence interval (CI) bands for each well location and Appendix IV constituent (i.e., for each well-constituent pair); and
3. Comparing each CI band against its respective GWPS to assess whether or not a statistically significant exceedance occurred.

To accomplish these steps, the data were first summarized and modeled. The background data were initially examined and summarized with descriptive statistics, as shown in **Table 3**. To handle any non-detects in these calculations, non-detect values were treated as statistically 'left-censored,' with the censoring limit equal to the reporting limit (RL). Then the Kaplan-Meier adjustment method (USEPA 2009) was employed to derive estimated summary statistics that account for the presence of non-detects.

2.1 Developing Groundwater Protection Standards (GWPS)

USEPA has published maximum contaminant limits (MCL) or alternate regulatory limits for each of the Appendix IV constituents. Consequently, in most cases the Groundwater Protection Standard (GWPS) is equal to the MCL. However, there may be cases where background levels of a constituent exceed the MCL. In these instances, an alternate GWPS must be derived from on-site background levels.

According to the promulgated CCR Rule (80 Federal Register 21302, 21405, April 17, 2015):

> "For each appendix IV constituent that is detected, a groundwater protection standard must be set. The groundwater protection standards must be the MCL or the background concentration level for the detected constituent, whichever is higher. If there is no MCL promulgated for a detected constituent, then the groundwater protection standard must be set at background."

The CCR Rule is also consistent with EPA's Unified Guidance for the statistical analysis of groundwater monitoring data, which states:

> "But a number of situations arise where a GWPS must be based on a background limit. The Part 264 regulations presume such a standard as one of the options under §264.94(a);

Table 3: Background Data Summary Statistics

COI	Units	N	No. NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	24	23	0.000577	0.002	0.0006	0.00129
Arsenic	mg/L	24	13	0.000355	0.005	0.0009	0.000872
Barium	mg/L	24	0	0.056	0.24	0.138	0.13
Beryllium	mg/L	24	24	0.001	0.001	0.0005	0.001
Cadmium	mg/L	24	24	0.001	0.001	0.0005	0.001
Chromium	mg/L	24	23	0.00163	0.00227	0.0016	0.00202
Cobalt	mg/L	24	6	0.00014	0.001	0.0003	0.000225
Fluoride	mg/L	24	5	0.0278	0.1	0.0532	0.0414
Lead	mg/L	24	24	0.001	0.001	0.0005	0.001
Lithium	mg/L	24	4	0.00294	0.0172	0.0085	0.00793
Mercury	mg/L	24	24	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	24	19	0.000587	0.005	0.0011	0.000824
Rad226+228	pCi/L	22	0	0.0306	0.932	0.362	0.275
Selenium	mg/L	24	24	0.005	0.005	0.0025	0.005
Thallium	mg/L	24	24	0.001	0.001	0.0005	0.001

> an ACL may also be determined from background under §264.94(b). More recent Part 258 rules specify a background GWPS where a promulgated or risk-based standard is not available or if the historical background is greater than an MCL [§258.55(h)(2) & (3)]." ((USEPA 2009), p. 7-20)

Based on these rules and guidance, TVA has established GWPS across its CCR program using the following decision logic:

- For each Appendix IV parameter where a GWPS must be established, a comparison is made between the promulgated regulatory limit and a site-specific limit computed from background data.
- If the background-based limit is larger than the promulgated limit, the GWPS is set to the background limit. But if the promulgated limit is larger, the GWPS is set to the published value.

In cases where a background limit must be computed, USEPA's Unified Guidance recommends different strategies for computing a background-based GWPS ((USEPA 2009), Section 7.5). One of these strategies — a 95% confidence, 95% coverage upper tolerance limit (UTL) on background — was selected and used to compute the UTL on site-specific background data for each Appendix IV parameter. Then these UTLs were compared against the promulgated regulatory limits to determine the site-specific GWPS.

To compute each tolerance limit (UTL), the following steps were taken:

1. All baseline data from designated upgradient or background wells collected through February 2020 were grouped and checked for possible outliers. Outlier screening was performed visually on time series plots of the data, as well as systematically via a modified version of Tukey's boxplot rule.

In a boxplot, the length of the box is the range of the central 50% of the sorted measurements. Tukey's original outlier rule states that any observation more than 1.5 box lengths above or below

the edges of the boxplot classifies as a possible outlier. For stable, symmetric data distributions, Tukey's rule often works well.

Groundwater data is often skewed instead of symmetric, and may exhibit shorter (i.e., localized) or longer-term (non-linear) trends. Because of this reality, a modified version of Tukey's rule is generally needed to avoid identifying too many possible outliers. The modification consists of three parts: a) a non-linear trend is fit to each time series and residuals of the data are computed from the estimated trend; b) a possible outlier is identified only if flagged *both* as an extreme residual from the trend; and c) as an extreme outlier relative to the overall dataset (i.e., more than 3 box lengths above or below the edges of the boxplot). Together, these modifications better account for data skewness and localized trends in the background observations.

If any possible outliers are flagged, they are visually compared against observations at other well locations. If similar patterns or measurement ranges are common, the suspect values are kept in the data. If not, the suspected outliers are formally assessed using Rosner's outlier test. Any confirmed outliers are excluded from the UTL computations.

At the JSF Bedrock Vacatur unit, 0 possible outliers were flagged in the grouped background data. Therefore, no background outliers were found or excluded from the analysis.

2. The grouped baseline data — excluding any confirmed outliers — were analyzed to determine whether they could be fit to a known statistical model. If so, a parametric UTL was computed; if not, a nonparametric UTL was constructed.

To fit potential statistical models, a series of normalizing mathematical transformations was applied to each baseline dataset. These transformations are known as power transformations, since they raise each observation to a mathematical power. The goal is to find, if possible, a transformation that normalizes the data on the transformed scale. Models tested ranged from the tenth root to the tenth power, and included the null transformation (power = 1), which assumes the data are normally distributed without transformation; the logarithm, which models the lognormal distribution; and the cube root, which closely mimics the gamma distribution.

The transformation which most nearly normalized the data was then formally tested using Filliben's probability plot correlation coefficient test. Filliben's test checks for normality of the transformed measurements by computing the correlation between the data and matched quantiles (i.e., z-scores) from a standard normal distribution. The process parallels fitting a line on a normal probability plot of the (transformed) data. The closer to a linear fit, the higher the correlation; the further from a linear fit, the smaller the correlation. Filliben's test formally assesses the strength of the correlation to determine whether it is high enough to declare that the data are consistent with a normal model.

Filliben's test yields a p-value measuring the statistical significance of the result. A p-value no less than 0.01 was judged as sufficient to assume normality of the (transformed) observations, while data with a Filliben's test p-value less than 0.01 were judged significantly non-normal. Datasets passing Filliben's test were assumed to have a parametric model corresponding to the transformation employed, e.g., data tested on the log-scale were assumed consistent with the lognormal distribution; data tested on the square root scale were assumed consistent with the square-root normal distribution, etc.

Datasets which could not be sufficiently normalized, thus failing Filliben's test, were analyzed by nonparametric means. In many instances, this may occur when the data includes a large fraction of non-detects. **Table 4** lists a shorthand for the statistical model utilized for each Constituent of Interest (COI) under the Model column. As examples, NP stands for nonparametric; Log stands for the logarithm, implying a lognormal model; and Normal represents the null transformation, implying a normal model.

3. The final statistical model for each COI was used to compute an upper tolerance limit (UTL) with 95% coverage and 95% confidence.

When a parametric model is appropriate, on the normalized scale, a UTL is computed using the standard normal theory equation:

$$UTL = \bar{x} + \kappa s$$

where $\bar{x}$ and s represent the mean and standard deviation of the (transformed) observations, and κ is a multiplier which depends on the number of baseline measurements, as well as the desired coverage and confidence levels. If the data have been transformed, the final UTL is derived by back-transforming the scaled UTL, e.g, for a log transformation, the result is exponentiated; for a square-root transformation, the result is squared, etc.

Note that the formula for an upper tolerance limit looks identical to the general formula for a parametric upper prediction limit. The important difference is in how the κ multiplier is computed, which in turn depends on type and purpose of the statistical limit. In general, parametric prediction and tolerance limits will not be the same, even when using the same background data.

For nonparametric models, the normal theory equation does not apply. Instead, the UTL is selected as one of the largest of the sample values, often the maximum. Because there is no multiplier (κ) as in the parametric case, the confidence level associated with a nonparametric UTL is computed 'after the fact,' based on the sample size and desired coverage level: the smaller the sample size, the lower the confidence; the bigger the sample size, the higher the confidence level.

Since nonparametric UTLs do not assume a known statistical model, unless the sample size is fairly large, the achieved confidence level can be much lower than the target of 95%. When this happens, the computed UTL may not be very accurate. A more accurate UTL would likely be larger than the one computed from the available sample data. Unfortunately, without a statistical model, and especially with a large percentage of non-detects, little improvement is possible in the UTL estimates unless a larger sample size can be employed.

For the JSF Bedrock Vacatur unit, **Table 4** lists the calculated GWPS limits established for this monitoring network.

2.2 Computing Trend Lines and Confidence Interval Bands

USEPA's Unified Guidance recommends comparing some type of confidence interval (CI) against a groundwater protection standard (GWPS) in order to assess whether or not the limit has been exceeded with statistical significance. If the entire interval exceeds the GWPS, a statistically significant increase (SSI) is identified. If none of the interval, or only part, exceeds the GWPS, no SSI is recorded.

The rationale behind this procedure is predicated on the following:

1. A confidence interval is typically designed to 'contain' or 'capture' a specific target or feature of the underlying groundwater population, usually the mean or median measurement value. An interval rather than a point estimate is utilized because that is the only way to ensure the target is captured with a high degree of statistical confidence.
2. When a confidence interval is entirely on one side or the other of a fixed numerical limit, the confidence is high that the desired population target is also to that side of the limit.

Table 4: JSF Bedrock GWPS Limits

COI	Model	N	Coverage	Confidence	UTL	RegLimit	GWPS
Antimony	NP	24	0.95	0.708	0.002	0.006	0.006
Arsenic	NP	24	0.95	0.708	0.005	0.01	0.01
Barium	NP	24	0.95	0.708	0.24	2	2
Beryllium	NP	24	0.95	0.708	0.001	0.004	0.004
Cadmium	NP	24	0.95	0.708	0.001	0.005	0.005
Chromium	NP	24	0.95	0.708	0.00227	0.1	0.1
Cobalt	Log	24	0.95	NA	0.000614	0.006	0.006
Fluoride	Tenth Root	24	0.95	NA	0.108	4	4
Lead	NP	24	0.95	0.708	0.001	0.015	0.015
Lithium	Normal	24	0.95	NA	0.0175	0.04	0.04
Mercury	NP	24	0.95	0.708	0.0002	0.002	0.002
Molybdenum	Log	24	0.95	NA	0.00362	0.1	0.1
Rad226+228	Square Root	22	0.95	NA	1.05	5	5
Selenium	NP	24	0.95	0.708	0.005	0.05	0.05
Thallium	NP	24	0.95	0.708	0.001	0.002	0.002

3. Because the target may exist anywhere in the range represented by the confidence interval, an interval that 'straddles' the fixed limit is not guaranteed to be either above or below the GWPS, and certainly not with high or known statistical confidence.

USEPA's logic thus ensures that a correct decision about the occurrence of an SSI can be made with high statistical assurance.

Since groundwater data are collected over time, and not all at once, some or most of the variation in the measurements may be due to a trend. To better account for this possibility, USEPA also recommends a variation on the confidence interval method known as a confidence interval band around a trend line. In this case, a (linear) trend line is first fit to the data, then a confidence band is constructed around the trend line. The confidence interval band can be compared against a GWPS in much the same fashion as a confidence interval, only now a comparison can be made at different points in time by comparing the 'cross-section' of the band for a given sampling date. If the interval represented by the confidence band cross-section fully exceeds the GWPS, an SSI is identified for that sampling event.

At TVA's CCR sites, CI bands were constructed (as described below) for each well-constituent pair using all available sample data. Cross-sections of each band were then compared to the GWPS for the most recent Assessment Monitoring event in each case for the purpose of identifying any SSIs. Note that in cases where the data are obviously trending, the CI band technique provides a much more powerful and accurate means of judging exceedances above GWPS. Ignoring a trend typically makes a standard confidence interval too wide and uncertain to be of much use, due to the extra variation imparted by the trend. For data that are more stable, both methods will tend to give similar results.

2.2.1 Trend Lines Using Linear Regression

Unless there are extreme outliers and/or curvature in the data, linear regression provides a standard and well-tested method for estimating the linear portion of a trend. The slope of the regression line

points to the magnitude and direction of the trend. There is also a standard method for computing a confidence band around a linear regression trend line. For instance, equations [21.24] and [21.25] of Section 21.3 in the *Unified Guidance* can be compactly written as

$$CB_{1-\alpha} = \hat{x}_0 \pm \sqrt{2 s_e^2 F_{1-\alpha,n-2} \left[\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2} \right]}$$

where CB = confidence band, $\hat{x}_0$ is the regression line estimate at time t_0, s_e^2 is the mean squared error of the regression line, F is a quantile from the F-distribution with 2 and $n-2$ degrees of freedom, and $\bar{t}$ and s_t^2 represent the mean and standard deviation of the sampling dates.

For well-constituent pairs with no non-detects, linear regression and the formula above were used to construct each confidence band with 98% overall confidence, corresponding to a lower confidence limit with 99% confidence. When non-detects are present, the same formulas apply but an adjustment must be made for the censored measurements. The strategy adopted for TVA's CCR sites involves the following steps:

1. Each non-detect is assumed to follow a triangle distribution centered at half the (sample-specific) reporting limit, and with limits extending from zero to the reporting limit. Then an imputation for each non-detect is randomly drawn from this distribution;
2. The combined set of detected values and imputed non-detects is used to estimate a linear regression trend line and associated confidence band with 98% statistical confidence;
3. Steps (1) and (2) are repeated 500 times, each time with a different set of random imputations, leading to 500 potentially different trend lines and confidence bands;
4. The 500 sets of trends lines and bands are averaged point-wise (i.e., at each time along a sequence of dates spanning the date range of the data) to compute the final trend and confidence band estimates.

By repeating this sequence of steps a large number of times (500), the uncertainty associated with the non-detects can be reasonably captured within the final CI band estimate.

2.2.2 Outliers

Prior to constructing any of the confidence interval (CI) bands, the data at each well-constituent pair were examined for possible outliers. As with the grouped background data, visual examination was done with time series plots and the modified Tukey's boxplot rule was utilized for initial screening. Any observations that were flagged and confirmed as pairwise outliers were excluded from calculation of the CI bands.

1 pairwise outliers were confirmed. These outliers are listed in **Table 5** below.

Table 5: Confirmed and Excluded Pairwise Outliers

COI	Well	Date	Result	Outlier
Rad226+228	JSF-203	2020-01-09	1.8	TRUE

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2020 Assessment Monitoring at TVA's CCR sites, the confidence interval (CI) bands described in **Section 2.2** were compared against the constituent-specific groundwater protection standards (GWPS) described in **Section 2.1**. Of note, an SSI was identified if and only if the CI band fully exceeded the GWPS at the most recent sampling event.

To clarify the importance of this last statement, consider the difference in statistical approach between Detection Monitoring and Assessment Monitoring. When utilizing prediction limits in Detection Monitoring, at least two sampling events per year must be collected and evaluated to identify any SSIs above background levels. Each prediction limit is derived from the baseline or background data, then each new compliance point value is compared against its respective prediction limit. If the newest compliance value exceeds the limit, a potential SSI is flagged, to be confirmed or disconfirmed via additional resampling and retesting.

The statistical approach in Assessment Monitoring is different. Comparisons are made against a fixed GWPS via a confidence interval or confidence interval band. No retesting is conducted and none of the individual compliance point measurements are directly compared against the GWPS. Instead, multiple compliance observations must be used to construct each confidence interval or CI band, necessarily at least four and preferably 8 to 10 or more. Consequently, all the Assessment Monitoring data collected from 2019 to 2020 were used to construct the CI bands. Furthermore, a well-constituent pair is considered out of compliance only if its constituent levels currently exceed the GWPS. This is best assessed by considering the cross-section of the CI band associated with the most recent sampling event.

3 Summary of Statistical Analysis

To facilitate an 'at-a-glance' summary of the statistical comparison results, **Table 6** is a 'traffic light' matrix, showing a compact representation of each well location matched against each constituent in Appendix IV. This summary is useful in planning for mitigation actions. Green cells indicate that no SSI was observed. Red cells indicate the opposite: an SSI was flagged at the most recent sampling event. Yellow cells are warnings which indicate that a well-constituent pair should be closely watched. These cases have increasing trends and a CI band whose lower limit is at least 65% of the GWPS. Often, in yellow cells, the CI band cross-section straddles the GWPS.

At the JSF Bedrock Vacatur unit, a total of 0 SSIs and 1 warnings were identified during the 2020 Assessment Monitoring analysis.

Table 6: Traffic Light Matrix for JSF Bedrock CCR Vacatur Unit

	Well Locations					
COI	**JSF-200**	**JSF-205**	**JSF-201**	**JSF-202**	**JSF-203**	**JSF-204**
Antimony	GRN	GRN	GRN	GRN	GRN	GRN
Arsenic	GRN	GRN	GRN	GRN	GRN	GRN
Barium	GRN	GRN	GRN	GRN	GRN	GRN
Beryllium	GRN	GRN	GRN	GRN	GRN	GRN
Cadmium	GRN	GRN	GRN	GRN	GRN	GRN
Chromium	GRN	GRN	GRN	GRN	GRN	GRN
Cobalt	GRN	GRN	GRN	GRN	GRN	GRN
Fluoride	GRN	GRN	GRN	GRN	GRN	GRN
Lead	GRN	GRN	GRN	GRN	GRN	GRN
Lithium	GRN	GRN	GRN	YLW	GRN	GRN
Mercury	GRN	GRN	GRN	GRN	GRN	GRN
Molybdenum	GRN	GRN	GRN	GRN	GRN	GRN
Rad226+228	GRN	GRN	GRN	GRN	GRN	GRN
Selenium	GRN	GRN	GRN	GRN	GRN	GRN
Thallium	GRN	GRN	GRN	GRN	GRN	GRN

Color-Coding Key:
RED = CI Band above GWPS;
GRN = CI Band below GWPS;
YLW = CI Lower Bound at least 65% of GWPS)

4 References

USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance." USEPA: Office of Resource Conservation & Recovery, EPA 530-R-09-007.