

**2019 Annual Groundwater
Monitoring and Corrective
Action Report**



Tennessee Valley Authority
Colbert Fossil Plant Ash Disposal
Area 4 CCR Unit

Prepared for:
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January 31, 2020

Document Certification

I certify under penalty of law that this document and attachments were prepared under the supervision of a professional engineer licensed in the State of Alabama in accordance with the United States Environmental Protection Agency's coal combustion residual rule (40 CFR 257 Subpart D) and ADEM Admin. Code r. 335-13-15. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.



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January 31, 2020



January 31, 2020

Reference: 2019 Annual Groundwater Monitoring and Corrective Action Report
TVA Colbert Fossil Plant Ash Disposal Area 4 CCR Unit

In accordance with 40 CFR § 257.90(e) of the Disposal of Coal Combustion Residuals from Electric Utilities final rule (CCR Rule) and the Alabama Department of Environmental Management CCR Rule (335-13-15-.06 through -.08), this 2019 Annual Groundwater Monitoring and Corrective Action Report (2019 Annual Report) documents 2019 groundwater monitoring activities at the Ash Disposal Area 4 CCR Unit at the Tennessee Valley Authority (TVA) Colbert Fossil Plant (COF). This CCR Unit is also known as Ash Pond 4 in ADEM documents.

The Alabama Department of Environmental Protection (ADEM) has promulgated a state CCR Rule (ADEM Land Division –Solid Waste Program, Division 13 (ADEM Admin. Code r. 335-13-15)). As the ADEM CCR Rule has not been approved by the U.S. EPA to operate in lieu of the U.S. EPA CCR Rule, TVA must comply with both the ADEM and U.S. EPA CCR Rules. This 2019 Annual Groundwater Monitoring and Corrective Action Report is also intended to comply with the requirements of the ADEM CCR Rule¹.

An overview of the current status of the groundwater monitoring and corrective action program for the Ash Disposal Area 4 is provided below.

- At the start and end of the 2019 annual reporting period, Ash Disposal Area 4 was operating under an assessment monitoring program in accordance with 40 CFR § 257.95. The assessment monitoring program for the Ash Disposal Area 4 was initiated on August 15, 2018.
- In the 2018 assessment monitoring sampling, statistically significant levels (SSLs) above the groundwater protection standard were observed at monitoring wells COF-102 and COF-105 for cobalt and arsenic, respectively. As a result, an assessment of corrective measures (ACM) was initiated for Ash Disposal Area 4 on April 15, 2019 and was completed on July 15, 2019.
- For the 2019 assessment monitoring events, no new SSLs were identified, and the SSLs for the same constituents are at the same wells as identified for the 2018 assessment monitoring events.
- As a final groundwater remedy has not been selected for Ash Disposal Area 4 pursuant to 40 CFR § 257.97, a Semiannual Report on the Progress of Remedy Selection was prepared and placed in the operating record on January 15, 2020, in accordance with 40 CFR § 257.97(a) and § 257.105(h)(12), to document the progress made toward selection and design of the remedy.
- Since a remedy has not been selected pursuant to 40 CFR § 257.97, remedial activities have not been initiated for Ash Disposal Area 4 pursuant to 40 CFR § 257.98 during the current 2019 annual reporting period discussed herein.

¹ The ADEM CCR Rule (335-13-15) requires a PE certification of this report; however, this is not a requirement of the federal CCR Rule.

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In 2017, TVA established a groundwater monitoring network and program at the COF Ash Disposal Area 4 CCR Unit in accordance with 40 CFR § 257.90. The groundwater monitoring network was certified by a qualified Professional Engineer as required by 40 CFR § 257.91(f). During 2019, TVA performed the following groundwater monitoring activities:

- Completed the statistical evaluation of the 2018 assessment monitoring data for Appendix IV constituents in accordance with 40 CFR § 257.95(g) in January 2019 and determined that there were statistically significant levels over the groundwater protection standards for cobalt in well COF-102 and arsenic in well COF-105.
- Placed notification of the statistical exceedances of the groundwater protection standards for cobalt in well COF-102 and arsenic in well COF-105 in the facility operating record on February 13, 2019 in accordance with 40 CFR § 257.95(g) and § 257.105(h)(8); provided notification to the State of Alabama in accordance with 40 CFR §257.106(h)(6); and placed notification on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6).
- Installed monitoring wells COF-111 and COF-116 downgradient and upgradient of Ash Disposal Area 4 in 2019 and these wells are being evaluated for inclusion in the CCR groundwater monitoring network. Well COF-111 will aid in the further characterization of nature and extent of Appendix IV concentrations observed at wells COF-102 and COF-105 and assist in the remedy selection process.
- As there have been no indications of offsite migration of arsenic- or cobalt-impacted groundwater onto adjacent parcels of land, there is no current obligation to notify persons who own or reside on adjacent land pursuant to 40 CFR § 257.95(g)(2).
- An Appendix IV alternate source demonstration was performed under 40 CFR § 257.95(g)(3)(ii) but was not completed within the 90-day period of time specified under 40 CFR § 257.95(g)(4).
- Initiated Assessment of Corrective Measures in accordance with 40 CFR § 257.95(g)(3)(i) and 40 CFR § 257.96.
- Completed the Assessment of Corrective Measures in accordance with 40 CFR § 257.96(d), which was placed on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(8).
- Sampled and analyzed wells in the certified monitoring network for CCR constituents (Appendix III and Appendix IV constituents) for the 2019 semiannual assessment monitoring events in accordance with 40 CFR § 257.95(d)(1). The sampling results were placed in the operating record as required by 40 CFR § 257.95(d)(1) and 257.105(h)(6). Additionally, these results are included in Table 1 of this 2019 Annual Report in accordance with 40 CFR § 257.95(d)(3).
- Placed notification of exceedances of groundwater protection standards in the facility operating record in accordance with 40 CFR § 257.95(g) and 257.105(h)(8); provided notification to the State of Alabama in accordance with 40 CFR § 257.106(h)(6); and placed the notification on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6)².

² Table 6 in this 2019 Annual Groundwater Monitoring and Corrective Action Report meets this notification requirement for the second semiannual assessment monitoring sampling event conducted in 2019.

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- 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).

Background monitoring well CA5 has not consistently yielded sufficient volumes of groundwater for sampling purposes. Monitoring well COF-116 has been installed as a potential background monitoring well and is being evaluated for inclusion into the CCR certified monitoring well network. No other problems were encountered during the third year of the Groundwater Quality Monitoring Program; therefore, no further action has been recommended, except for the planned key activities for 2020 that are outlined below.

The projected key activities for 2020 are:

- Continue semiannual assessment monitoring at the certified groundwater monitoring network consistent with 40 CFR § 257.95 and place the sampling results in the operating record as required by 40 CFR § 257.95(d)(1) and 257.105(h)(6).
- Evaluate 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).
- Continue to refine the characterization of the nature and extent of the release in accordance with 40 CFR § 257.95(g)(1).
- Place notification of exceedances of groundwater protection standards in the facility operating record in accordance with 40 CFR § 257.95(g) and 257.105(h)(8); provide notification to the State of Alabama in accordance with 40 CFR § 257.106(h)(6); and place notification on the CCR Rule Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR § 257.107(h)(6).
- Perform further site characterization to improve the COF Conceptual Site Model (CSM).
- Prepare and place in the operating record a Semiannual Report on the Progress of Remedy Selection on July 15, 2020 in accordance with 40 CFR § 257.97(a) to document the progress made toward selection and design of the remedy.
- 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).

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GROUNDWATER MONITORING WELL NETWORK

Ash Disposal Area 4 is not in use and has been closed and capped. The unit was built in 1972 to receive sluiced bottom ash and minor amounts of fly ash from COF. From 1994 to March 2016, the pond only received bottom ash due to the installation of a bag house and the subsequent management of the fly ash in a dry manner. When it was in operation, Ash Disposal Area 4 consisted of a sluicing area for bottom ash management, a main pond and adjoining stilling pond. Ash Disposal Area 4 also received COF process water, gray water, and waters from the Coal Yard Runoff Pond. The COF ceased coal burning operations on March 23, 2016. As a result, bottom ash is no longer sluiced to Ash Disposal Area 4.

The monitoring well network for the COF Ash Disposal Area 4 CCR Unit consists of one background well (CA5) and four downgradient wells (COF-102, COF-104, COF-105, and COF-106). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows the groundwater monitoring well locations. The monitoring well network was designed for a single CCR Unit (Ash Disposal Area 4).

No monitoring wells in the CCR network were installed or decommissioned during the 2019 reporting period³. The certification of the groundwater monitoring system required under 40 CFR 257.91(f) is included in the facility operating record and on the CCR Rule Compliance Data and Information website: <https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>.

GROUNDWATER SAMPLING AND LABORATORY ANALYTICAL TESTING

A groundwater sampling and analysis program was developed in 2016-2017, as required by 40 CFR § 257.93(a), 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). 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 2019 assessment monitoring groundwater sampling was conducted between February and October 2019 and the results are summarized in Table 1. Two semiannual assessment monitoring groundwater sampling events were each followed by retesting groundwater sampling events. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates and monitoring program status is provided in Table 2.

Groundwater elevations were measured in each monitoring well immediately prior to purging during each sampling event as required by 40 CFR § 257.93(c). Groundwater elevations and Tennessee River surface water elevations are summarized in Table 3. Groundwater flow directions were evaluated for each sampling event, and a generalized depiction of groundwater flow direction is illustrated on Figure 2. The groundwater flow at the COF Ash Disposal Area 4 is influenced by the Tennessee River to the north of the site and Cane

³ Table 1 contains the groundwater monitoring data that was obtained from the CCR Rule groundwater monitoring well network for the 2019 assessment monitoring sampling events required by the CCR Rule. Monitoring wells COF-111 and COF-116 (which are not part of the CCR Rule network) were installed downgradient and upgradient of Ash Disposal Area 4 in 2019 and are being evaluated for possible inclusion in the CCR Rule network. The sampling data obtained from wells COF-111 and COF-116 in 2019 are included in Appendix A. Existing monitoring wells COF-107 through COF-110 (which are not part of the CCR Rule network) were previously installed north and west of the CCR unit and were sampled periodically in 2019. This sampling data is included in Appendix A. Additionally, the monitoring wells in the CCR Rule network (CA5, COF-102, COF-104, COF-105 and COF-106) were sampled periodically in 2019 for programs other than the CCR Rule. This groundwater monitoring data collected in 2019 for these other programs is included in Appendix A.

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Creek which meanders through the middle of the site in a north-northwesterly direction. The general groundwater flow direction for the bedrock aquifer in the area is to the north towards the Tennessee River; however, there is localized groundwater flow for the uppermost aquifer associated with the CCR unit towards Cane Creek on both sides of the creek.

The uppermost aquifer at Ash Disposal Area 4 is the alluvial aquifer. These alluvial deposits are comprised of predominantly weathered in place (residual) unconsolidated clays, sands, and gravels along with alluvial terrace deposits from Cane Creek made up of mainly sands, silts, and clays. The alluvial deposits are underlain by the Tusculumbia Limestone, a light grey limestone of Mississippian age which is the regional aquifer. Testing for hydraulic conductivity at the background or downgradient groundwater monitoring wells, as summarized in Table 5, was conducted during a 2018 hydrogeologic evaluation (Terracon, 2018). Testing data indicates the uppermost saturated zone within the alluvial deposits has a geometric mean hydraulic conductivity of 3.41×10^{-3} centimeters per second (cm/sec). Linear groundwater flow velocity was calculated for the uppermost aquifer using:

- the geometric mean hydraulic conductivity calculated from hydraulic testing (3.41×10^{-3} cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0026 to 0.0038 feet per foot (ft/ft); and,
- an effective porosity of 20% (assumed effective porosity value in silty clayey sand and lean clay with sand [URS, 2012]).

The average linear flow velocity in the uppermost aquifer ranges from approximately 47 to 67 feet per year. The rate and direction of groundwater flow for each groundwater sampling event is summarized in Table 5 in accordance with 40 CFR § 257.93(c).

STATISTICAL ANALYSIS OF GROUNDWATER DATA

The groundwater monitoring data for the 2019 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 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 IV⁴ constituent.⁵ The 2019 Statistical Analysis Report is included in Appendix A.

⁴ Appendix IV CCR Constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228 combined.

⁵ 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 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, then 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 levels: 1.) Cobalt - 6 µg/L; 2.) Lithium - 40 µg/L; 3.) Molybdenum - 100 µg/L; and, 4.) Lead - 15 µg/L.

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The sampling results used to identify potential groundwater protection standards exceedances were obtained during four monitoring events that were performed between February and October of 2019.⁶ Comparisons were made against a fixed groundwater protection standard via a confidence interval band. Retesting was conducted after each semiannual sampling event and none of the individual compliance point measurements were directly compared against the groundwater protection standard. The Appendix IV monitoring data collected in Year-One (2017), Year-Two (2018), and Year-Three (2019)⁷ 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 in each case for the purpose of identifying any 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.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

An Assessment Monitoring Program was established on August 15, 2018 and implemented as specified in 40 CFR § 257.95. Notification of the assessment monitoring program was provided to the State of Alabama and placed on the CCR Rule Compliance Data and Information website: (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) on September 14, 2018, in accordance with 40 CFR § 257.106(h)(4) and 40 CFR § 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, subsequent sampling and analysis of all wells in the certified monitoring network for Appendix III and IV constituents occurred in accordance with 40 CFR § 257.95(d)(1). Appendix III and IV constituent concentrations from 2019 assessment monitoring are summarized in Table 1. Groundwater protection standards were established in accordance with 40 CFR § 257.95(d)(2) and are summarized along with Appendix IV SSLs in Table 6. Based on the statistical analysis, there continues to be SSLs above the groundwater protection standards for arsenic in well COF-105 and for cobalt in well COF-102. These are the same SSLs at the same wells as were previously identified. 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.

ADDITIONAL INFORMATION ON 2018 STATISTICAL ANALYSIS

At the time of the 2018 evaluation, groundwater data sets for well CA5 were limited to only four sampling events, and samples could not be collected in 2018 due to insufficient water. However, for background upgradient bedrock wells COF-109 and COF-110, TVA was able to conduct six groundwater sampling events in 2018, and data sets were also available from 2017. A decision was made to use the more ample data set for COF-109 and COF-110 for the statistics in the 2018 reporting period as a replacement for CA5. In 2019, samples were obtained from CA5 and the use of COF-109 and COF-110 as replacement wells was discontinued. The 2019 statistical analysis identified the same SSLs for cobalt and arsenic at the same wells as previously identified from the 2018 assessment monitoring period. TVA intends to continue to use the certified background well CA5 and is evaluating adding the newly installed COF-116 as an additional background well as it should yield more sustainable groundwater for sampling.

⁶ The CCR rule requires a minimum of two semiannual sampling events per well once the required background data has been obtained. In 2019, two semiannual assessment monitoring groundwater sampling events were each followed by retesting groundwater sampling events.

⁷ The October 2019 retest groundwater sampling event that followed the second semiannual sampling event was not included in the statistical evaluation. This information will be included in the statistical evaluation of 2020 assessment monitoring sampling events.


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LIMITATIONS

This document entitled 2019 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.

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References:

URS, 2012. *Part D Hydrogeologic Evaluation Ash Stack 5 Expansion*. November 2012.

Terracon, 2018. Aquifer Testing and Equipment Blank Results. TVA CCR Rule – Colbert Fossil Plant (COF). Terracon Consultants, Inc. December 13, 2018.

Attachments:

Figure 1 – Map with CCR Unit Background and Downgradient Wells

Figure 2 – Generalized Groundwater Flow Direction Map

Table 1 – Assessment Monitoring Groundwater Sampling Results

Table 2 – Groundwater Sampling Summary

Table 3 – Groundwater and Surface Water Elevation Summary

Table 4 – Hydraulic Conductivity Data Summary

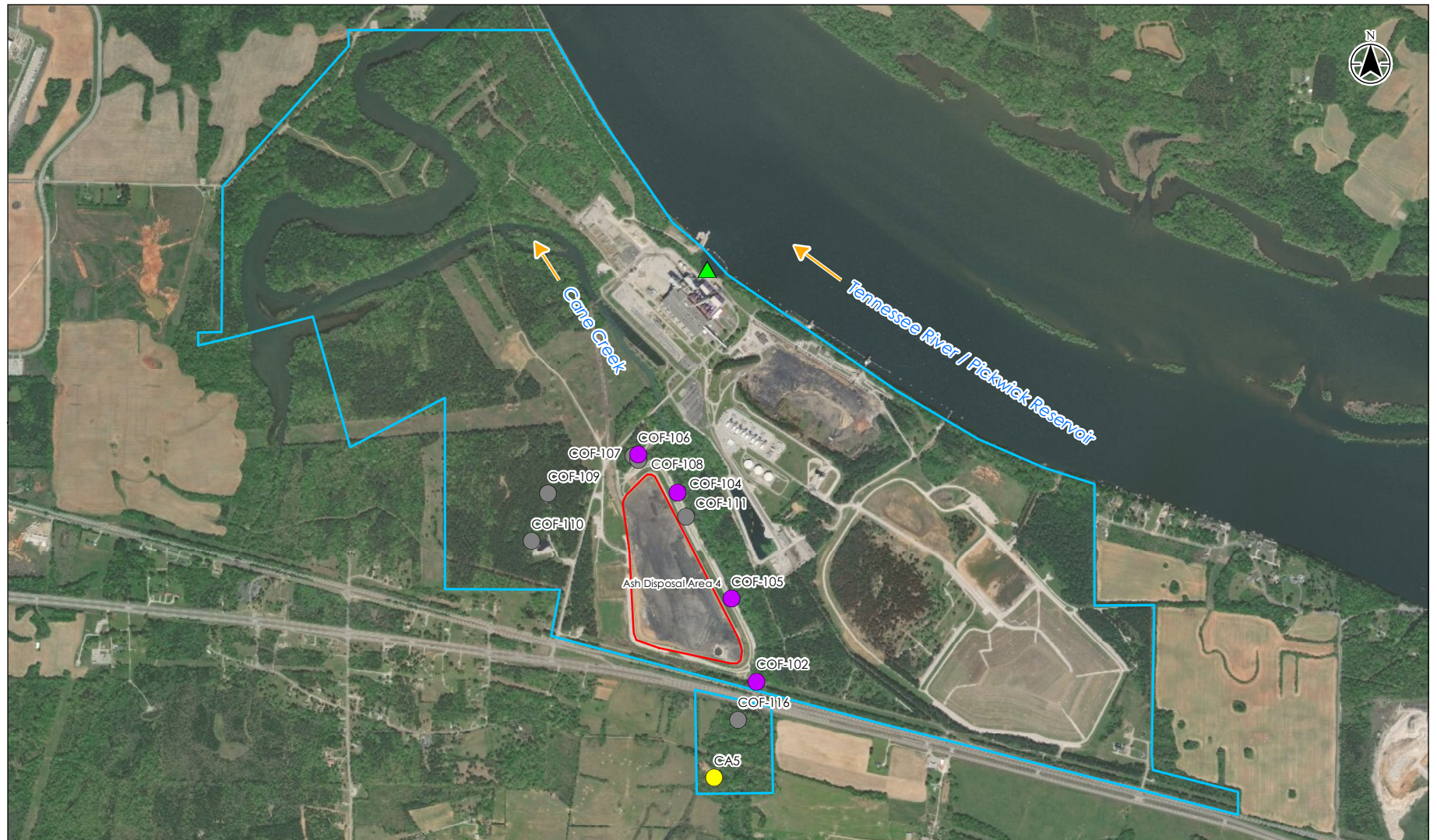
Table 5 – Rate and Direction of Groundwater Flow Summary

Table 6 – Statistically Significant Levels (SSLs) Above GWPSs

Appendix A – Additional 2019 Groundwater Monitoring Data for Monitoring Wells Proximal to Ash Disposal Area 4 (CCR network wells, COF-107 through COF-111, and COF-116) Taken for Programs Other than the CCR Rule

Appendix B – 2019 Statistical Analysis Report

FIGURES



- ▲ Staff Gauge
- Background Well
- Downgradient Well
- Investigation Well
- Surface Water Flow Direction
- CCR Unit Subject to CCR Rule

TVA Property Boundary

0 1,000 2,000
Feet
1:24,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Alabama West FIPS 0102 Feet
2. Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



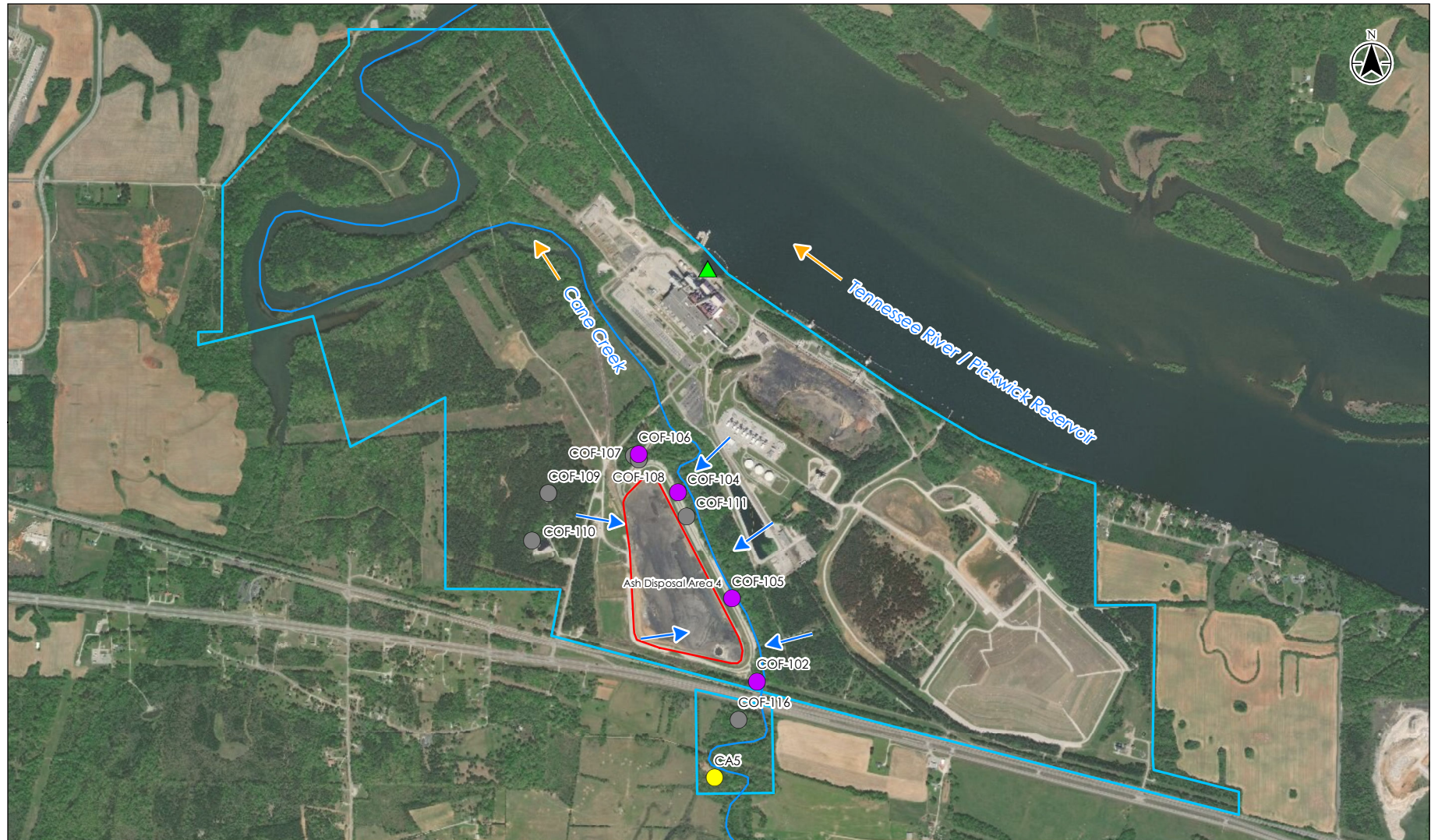
Project Location
City of Tusculuma
Colbert County,
Alabama
182603534
Prepared by LMB on 2020-01-29
Technical Review by MD on 2020-01-29
Independent Review by TR on 2020-01-29

Client/Project
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

Figure No.
1

Title
**Map with CCR Unit Background
and Downgradient Wells**

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- ▲ Staff Gauge
- Background Well
- Downgradient Well
- Investigation Well
- Groundwater Flow Direction
- Stream Centerline
- Surface Water Flow Direction
- CCR Unit Subject to CCR Rule
- TVA Property Boundary

0 1,000 2,000 Feet
1:24,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Alabama West FIPS 0102 Feet
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Client/Project
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

Figure No.
2

**Generalized Groundwater
Flow Direction Map**



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

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TABLES

Table 1
Assessment Monitoring
Groundwater Sampling
Results

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

Monitoring Well		CA5			
Sample Date		05-Feb-19		06-May-19	
Sample Round		1		1 - Retest	
Well Designation		Background		Background	
Analyte	Units	Result	Q	Result	Q
Total Metals					
Antimony	ug/L	< 0.378	U*	< 0.378	U
Arsenic	ug/L	< 0.323	U	< 0.403	U*
Barium	ug/L	45.6		36.6	
Beryllium	ug/L	< 0.155	U	< 0.155	U
Boron	ug/L	32	J	< 30.3	U
Cadmium	ug/L	< 0.125	U	< 0.125	U
Calcium	ug/L	12500		8690	
Chromium	ug/L	< 1.66	U*	< 2.47	U*
Cobalt	ug/L	< 0.075	U	0.08	J
Lead	ug/L	< 0.128	U	0.268	J
Lithium	ug/L	< 3.14	U	3.42	J
Mercury	ug/L	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U
Thallium	ug/L	< 0.128	U	< 0.128	U
Radium 226 + Radium 228	pCi/L	0.438	J	0.158	J
Anions					
Chloride	mg/L	2.5		1.73	
Fluoride	mg/L	< 0.0263	U	< 0.0263	U
Sulfate	mg/L	9.53		7.7	
General Chemistry					
Total Dissolved Solids	mg/L	81		31	
Field Parameters					
Temperature, Water	DEG_C	12.8		15.3	
Turbidity (field)	NTU	0.83		4.1	
ORP	mV	235.8		195.1	
Specific Conductivity (field)	mS/cm	0.085		0.067	
Dissolved Oxygen	mg/L	6.45		3.46	
pH (field)	SU	5.76		5.27	

Notes:

Q - Data Qualifier

U* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at similar level

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

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams 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 1
Assessment Monitoring
Groundwater Sampling
Results

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

Monitoring Well		COF-102							
Sample Date		04-Feb-19		06-May-19		07-Aug-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 0.414	U*	0.381	J	< 0.378	U	0.446	J
Arsenic	ug/L	< 0.323	U	< 0.323	U	0.598	J	0.449	J
Barium	ug/L	21.8		19.2		53.6		33.3	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	3940		2690		3350		3180	
Cadmium	ug/L	0.125	J	< 0.125	U	< 0.125	U	0.144	J
Calcium	ug/L	133000		117000		166000		138000	
Chromium	ug/L	< 1.63	U*	< 1.73	U*	2.01		< 2.25	U*
Cobalt	ug/L	1.18		0.527		20.2		11.2	
Lead	ug/L	< 0.24	U*	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	< 0.125	UJ	< 0.180	U	< 0.252	U	< 0.885	U
Anions									
Chloride	mg/L	14.5		9.64		11.3		9.35	
Fluoride	mg/L	< 0.0263	U	< 0.0263	U	< 0.0593	U*	< 0.0554	U*
Sulfate	mg/L	325		276		268		285	
General Chemistry									
Total Dissolved Solids	mg/L	515		481		630		575	
Field Parameters									
Temperature, Water	DEG_C	14.7		18.2		24.2		22.5	
Turbidity (field)	NTU	4.76		1.4		0.77		0.34	
ORP	mV	161.4		202.9		21.5		47.4	
Specific Conductivity (field)	mS/cm	0.73		0.646		0.842		0.818	
Dissolved Oxygen	mg/L	2.99		1.33		0.41		0.35	
pH (field)	SU	5.88		5.65		6.35		6.26	

Notes:

Q - Data Qualifier

U* - Result should be considered "not-detected" because it was detected in a rinsate blank or laboratory blank at similar level

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

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams 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 1
Assessment Monitoring
Groundwater Sampling
Results

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

Monitoring Well		COF-104							
Sample Date		05-Feb-19		07-May-19		08-Aug-19		08-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	0.883	J
Arsenic	ug/L	1.75		2.05		2.16		2.07	
Barium	ug/L	71.7		62.2		54.5		156	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	1770		1460		1750		333	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	90800		86200		91800		240000	
Chromium	ug/L	< 1.53	U	< 2.52	U*	< 1.53	U	< 2.08	U*
Cobalt	ug/L	4.35		6.18		6.56		13.3	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	25.6		22.5		36.1		30.2	
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.577	J	0.404	J	< 0.129	U	0.761	J
Anions									
Chloride	mg/L	18		21.9		24.4		3.15	
Fluoride	mg/L	0.0517	J	0.0422	J	< 0.0537	U*	0.513	
Sulfate	mg/L	154		132		132		371	
General Chemistry									
Total Dissolved Solids	mg/L	339		391		375		959	
Field Parameters									
Temperature, Water	DEG_C	15.3		16.5		20.7		23.6	
Turbidity (field)	NTU	14.8		0.52		0.48		2.14	
ORP	mV	9.4		-16.6		-50.7		-8.2	
Specific Conductivity (field)	mS/cm	0.579		0.588		0.568		1.249	
Dissolved Oxygen	mg/L	0.54		0.37		0.26		0.3	
pH (field)	SU	6.09		6.16		6.22		6.5	

Notes:

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mg/L - milligrams 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 1
Assessment Monitoring
Groundwater Sampling
Results

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

Monitoring Well		COF-105							
Sample Date		04-Feb-19		07-May-19		07-Aug-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	33.3		32		54.6		64	
Barium	ug/L	372		260		269		255	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	543		368		473		500	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	111000		79700		82400		89000	
Chromium	ug/L	< 1.78	U*	< 1.53	U	< 1.53	U	< 2.4	U*
Cobalt	ug/L	4.56		1.63		1.41		0.671	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	8.94		8.8		14.3		12.4	
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.667	J	0.474	J	< 0.686	U	0.834	J
Anions									
Chloride	mg/L	4.76		4.39		4.07		4.28	
Fluoride	mg/L	0.253		0.233		0.245		0.18	
Sulfate	mg/L	25.4		12.5		2.13		3.81	
General Chemistry									
Total Dissolved Solids	mg/L	466		340		321		349	
Field Parameters									
Temperature, Water	DEG_C	15.7		15.7		22.8		21.5	
Turbidity (field)	NTU	30.3		3.02		4.36		2.14	
ORP	mV	-82.9		-106.6		-115.7		-108.3	
Specific Conductivity (field)	mS/cm	0.86		0.659		0.615		0.684	
Dissolved Oxygen	mg/L	0.12		0.82		0.3		0.34	
pH (field)	SU	6.61		6.63		6.67		6.79	

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pCi/L - picoCurie per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 1
Assessment Monitoring
Groundwater Sampling
Results

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

Monitoring Well		COF-106							
Sample Date		05-Feb-19		07-May-19		08-Aug-19		09-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Antimony	ug/L	< 0.725	U*	0.493	J	< 0.378	U	0.707	J
Arsenic	ug/L	1.8		< 1.49	U*	1.75		2.42	
Barium	ug/L	41.9		30.9		25.7		32.2	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	813		389		< 170	U*	268	
Cadmium	ug/L	0.526	J	0.168	J	0.248	J	1.79	
Calcium	ug/L	59300		36200		9250		30500	
Chromium	ug/L	< 1.53	U	< 1.84	U*	1.67	J	< 2.31	U*
Cobalt	ug/L	< 0.384	U*	0.097	J	< 0.114	U*	0.431	J
Lead	ug/L	< 0.128	U	< 0.128	U	0.235	J	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.14	U	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	26.5		8.69		0.977	J	13.3	
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium 226 + Radium 228	pCi/L	0.507	J	0.119	J	< 0.00	U	< 0.442	U
Anions									
Chloride	mg/L	8.87		4.8		< 0.715	U	2.05	
Fluoride	mg/L	0.0619	J	0.0492	J	< 0.0448	U*	< 0.0613	U*
Sulfate	mg/L	66.8		37.7		14.7		26.1	
General Chemistry									
Total Dissolved Solids	mg/L	133		136		46		129	
Field Parameters									
Temperature, Water	DEG_C	15.9		17		21.3		22.3	
Turbidity (field)	NTU	0.75		0.74		3.71		1.27	
ORP	mV	114.5		101.9		267.5		148.4	
Specific Conductivity (field)	mS/cm	0.374		0.23		0.084		0.204	
Dissolved Oxygen	mg/L	0.38		1.59		4.37		0.4	
pH (field)	SU	6.56		6.24		5.32		6.17	

Notes:

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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 2
Groundwater Sampling Summary

**CCR Annual Groundwater Monitoring and Corrective
Action Report - TVA Colbert Fossil Plant**

Well ID	Well Designation	Number of Samples Collected	February 4-5, 2019	May 6-7, 2019	August 7-8, 2019	October 7-9, 2019	Monitoring Program
Sample Round			1	1 - Retest	2	2 - Retest	
CA5	Background	2	X	X			Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-102	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-104	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-105	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-106	Downgradient	4	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents

Notes:

Assessment Monitoring groundwater samples analyzed for Appendix III and Appendix IV constituents

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 combined

Table 3
Groundwater and Surface Water
Elevation Summary

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

Groundwater Elevation Collection Date		04-Feb-19	06-May-19	07-Aug-19	07-Oct-19
Monitoring Well	Units				
CA5	ft-MSL	421.67	420.78	415.58	414.98
COF-102	ft-MSL	416.02	415.89	415.69	414.63
COF-104	ft-MSL	417.19	417.32	417.44	417.16
COF-105	ft-MSL	413.71	415.00	415.66	413.35
COF-106	ft-MSL	419.01	416.92	416.25	414.32
		Surface Water			
Tennessee River	ft-MSL	410.81	414.08	414.83	412.3

Notes:

ft-MSL - feet above mean sea level

Table 4
Hydraulic Conductivity Data
Summary

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

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)
CA5	Background	Not Performed
COF-102	Downgradient	1.12E-03
COF-104	Downgradient	2.15E-03
COF-105	Downgradient	1.52E-03
COF-106	Downgradient	3.71E-02
Geometric Mean of Hydraulic Conductivity (cm/sec)		3.41E-03

Notes:

cm/sec - centimeters per second

Table 5
Rate and Direction of Groundwater
Flow Summary

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

Groundwater Elevation Collection Date	4-Feb-19	6-May-19	7-Aug-19	7-Oct-19
Sample Round	1	1 - Retest	2	2 - Retest
Horizontal Gradient	0.0028	0.0026	0.0038	0.0034
Hydraulic Conductivity (cm/sec)	3.41E-03	3.41E-03	3.41E-03	3.41E-03
Effective Porosity	20%	20%	20%	20%
Flow Direction (cardinal)	East	East	East	East
Linear Velocity (ft/yr)	49.2	46.6	67.2	60.5

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

**TABLE 6: Statistically Significant Levels (SSLs)
Above GWPSs**

**CCR Annual Groundwater Monitoring and Corrective Action Report -
TVA Colbert Fossil Plant**

Appendix IV Parameter*	GWPS (a)	Updated GWPS (b)	Downgradient wells with analytical results above GWPS (c)	Updated LCBs (d)	SSL LCB > GWPS (e)
Antimony (mg/l)	0.006	0.006	None	NA	NA
Arsenic (mg/l)	0.01	0.01	COF-105	0.0386	YES
			COF-106	-0.013	NO
Barium (mg/l)	2	2	None	NA	NA
Beryllium (mg/l)	0.004	0.004	None	NA	NA
Cadmium (mg/l)	0.005	0.005	None	NA	NA
Chromium (mg/l)	0.1	0.1	None	NA	NA
Cobalt (mg/l)	0.006	0.006	COF-102	0.0101	YES
			COF-104	0.0033	NO
			COF-105	-0.0023	NO
Fluoride (mg/l)	4	4	None	NA	NA
Lead (mg/l)	0.015	0.015	None	NA	NA
Lithium (mg/l)	0.04	0.04	None	NA	NA
Mercury (mg/l)	0.002	0.002	None	NA	NA
Molybdenum (mg/l)	0.1	0.1	None	NA	NA
Radium-226+228 (pCi/l)	5	6.569	None	NA	NA
Selenium (mg/l)	0.05	0.05	None	NA	NA
Thallium (mg/l)	0.002	0.002	None	NA	NA

Notes:

NA – Not applicable

* - Total Metals concentrations presented in Table 1 are reported in micrograms per liter (µg/L)

(a) GWPSs documented in notice dated 10/15/2018 [reported in milligrams per liter (mg/L)]

(b) GWPSs updated as of 11/1/2019 with 3 additional sample results collected on January 7-11, 2019, March 4-7, 2019 and August 5-7, 2019 [reported in mg/L]

(c) Downgradient wells with analytical results above GWPS November 2016 through August 5-7, 2019 (per 40 CFR 257.95(b) and (d))

(d) Most recent value of 99% lower confidence band (LCB) on the mean of Appendix IV groundwater sampling events between November 2016 and August 5-7, 2019. Upper confidence band (UCB) not shown as it is greater than LCB [reported in mg/L]

(e) SSL: "statistically significant level over GWPS" occurs when the updated LCB value at the last sampling event exceeds the updated GWPS

**APPENDIX A
ADDITIONAL 2019 GROUNDWATER MONITORING
DATA FOR MONITORING WELLS PROXIMAL TO
ASH DISPOSAL AREA 4 (CCR NETWORK WELLS,
COF-107 THROUGH COF-111, AND COF-116)
TAKEN FOR PROGRAMS OTHER THAN THE CCR
RULE**

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		CA5			
Sample Date		05-Feb-19		21-Aug-19	
Total Metals					
Antimony	ug/L	0.563	J	< 0.378	U
Arsenic	ug/L	< 0.323	U	< 0.323	U
Barium	ug/L	38		102	
Beryllium	ug/L	< 0.155	U	< 0.182	U
Boron	ug/L	< 30.3	U	< 38.6	U
Cadmium	ug/L	0.149	J	< 0.125	U
Calcium	ug/L	10000		61100	
Chromium	ug/L	< 1.53	U	< 1.53	U
Cobalt	ug/L	< 0.075	U	0.143	J
Lead	ug/L	0.128	J	< 0.128	U
Lithium	ug/L	< 3.14	U	57.5	
Mercury	ug/L	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	0.616	J
Selenium	ug/L	< 2.62	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.423	U*
Radium-226+228	pCi/L	< 0.492	U*	1.14	J
Anions					
Chloride	mg/L	2.43		2.39	
Fluoride	mg/L	< 0.0263	U	< 0.658	U*
Sulfate	mg/L	8.19		8.73	
General Chemistry					
Total Dissolved Solids	mg/L	51		176	
Field Parameters					
Temperature, Water	DEG_C	12.9		21.9	
Turbidity (field)	NTU	0.85		8.1	
ORP	mV	66.1		143	
Specific Conductivity (field)	mS/cm	0.86		0.2863	
Dissolved Oxygen	mg/L	9.63		4.52	
pH (field)	SU	5.87		5.54	

Notes:

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mg/L - milligrams 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

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-102							
Sample Date		07-Feb-19		04-Jun-19		20-Aug-19		05-Nov-19	
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.548	U*	< 0.553	U*	0.574	J
Arsenic	ug/L	< 0.323	U	0.424	J	< 0.357	U*	< 0.323	U
Barium	ug/L	19.2		23.5		97		26	
Beryllium	ug/L	< 0.155	U	< 0.256	U*	< 0.182	U	< 0.182	U
Boron	ug/L	3620		3170		3650	J	3720	
Cadmium	ug/L	< 0.125	U	0.238	J	0.195	J	< 0.125	U
Calcium	ug/L	133000	J	115000		133000		146000	
Chromium	ug/L	< 1.53	U	1.89	J	< 2.1	U*	< 1.53	U
Cobalt	ug/L	1.41		1.52		4		3.38	
Lead	ug/L	< 0.128	U	0.223	J	< 0.128	U	< 0.128	U
Lithium	ug/L	4.18	J	4.03	J	< 5.64	U*	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 0.61	U	< 0.61	U	< 0.61	U	< 0.61	U
Selenium	ug/L	< 2.62	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium-226+228	pCi/L	< 0.134	UJ	< 0.0478	U	< 0.240	U	< 0.0321	U
Anions									
Chloride	mg/L	14.1		9.04		8.58		8.89	
Fluoride	mg/L	< 0.0263	U	0.0284	J	< 0.0395	U*	0.0322	J
Sulfate	mg/L	310		243		282		268	
General Chemistry									
Total Dissolved Solids	mg/L	556		482		534		515	
Field Parameters									
Temperature, Water	DEG_C	15.9		19		23.7		20.7	
Turbidity (field)	NTU	1.37		21.8		13		11.7	
ORP	mV	7.5		61.8		157.6		202.6	
Specific Conductivity (field)	mS/cm	0.579		0.638		0.832		0.81	
Dissolved Oxygen	mg/L	3.41		0.37		0.52		2.71	
pH (field)	SU	6.14		5.9		6.29		6.34	

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mg/L - milligrams 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

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-104									
Sample Date		05-Feb-19		26-Aug-19		05-Feb-19		26-Aug-19		14-Nov-19	
Total Metals											
Antimony	ug/L	0.392	J	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	2.74		1.49		2.49		1.69		1.97	
Barium	ug/L	84.3		52		82.1		51.6		76.2	
Beryllium	ug/L	< 0.155	U	< 0.251	U*	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	1420		2200		1330		2130		512	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	117000		84800		113000		88900		149000	
Chromium	ug/L	2.71		< 1.53	U	2.04		< 1.53	U	< 1.85	U*
Cobalt	ug/L	6.71		3.83		6.62		3.65		3.41	
Lead	ug/L	< 0.344	U*	< 0.128	U	< 0.639	U*	0.657	J	< 0.128	U
Lithium	ug/L	< 3.14	U	3.82	J	< 3.14	U	3.65	J	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	28.2		48.2		27.5		47.4		31.9	
Selenium	ug/L	< 2.62	U	< 1.51	U	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.148	U	< 0.128	U	< 0.148	U	< 0.148	U
Radium-226+228	pCi/L	0.611	J	< 0.387	U	0.464	J	< 0.445	U	< 0.670	U
Anions											
Chloride	mg/L	11.8		26.7		12.2		27.5		4.62	
Fluoride	mg/L	0.0327	J	0.0551	J	0.0305	J	0.0565	J	0.782	
Sulfate	mg/L	139		127		139		129		119	
General Chemistry											
Total Dissolved Solids	mg/L	441		334		445		331		430	
Field Parameters											
Temperature, Water	DEG_C	15.6		21.1		15.6		21.1		17.8	
Turbidity (field)	NTU	15.2		1.61		15.2		1.61		11.5	
ORP	mV	29.2		-32.4		29.2		-32.4		-26.8	
Specific Conductivity (field)	mS/cm	0.631		0.5352		0.631		0.5352		0.799	
Dissolved Oxygen	mg/L	0.28		0.92		0.28		0.92		0.28	
pH (field)	SU	6.41		6.11		6.41		6.11		6.77	

Notes:

Q - Data Qualifier

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

U - Analyte not detected

ug/L - micrograms per liter

NTU - Nephelometric Turbidity Units

mg/L - milligrams per liter

mV - millivolts

pCi/L - picoCurie per liter

mS/cm - milliseimens per centimeter

DEG_C - degrees Celsius

SU - Standard Unit

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-105					
Sample Date		05-Feb-19		27-Aug-19		13-Nov-19	
Total Metals							
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	39.5		49		28.8	
Barium	ug/L	383		276		372	
Beryllium	ug/L	< 0.155	U	< 0.182	U	< 0.182	U
Boron	ug/L	834		525		690	J
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	121000		79000		109000	
Chromium	ug/L	1.89	J	< 2.44	U*	< 2.02	U*
Cobalt	ug/L	3.53		1.59		5.69	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	< 3.39	U	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	10.2		13		8.02	
Selenium	ug/L	< 2.62	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.148	U	< 0.148	U
Radium-226+228	pCi/L	< 0.719	U*	0.355	J	< 1.14	U*
Anions							
Chloride	mg/L	4.94		2.9		6.55	
Fluoride	mg/L	0.209		0.258		0.253	
Sulfate	mg/L	21.3		3.59		6.66	
General Chemistry							
Total Dissolved Solids	mg/L	481		357		407	J
Field Parameters							
Temperature, Water	DEG_C	16.5		22.7		16.4	
Turbidity (field)	NTU	12.3		7.63		21	
ORP	mV	-97.1		-121.4		-92.3	
Specific Conductivity (field)	mS/cm	0.931		0.655		0.814	
Dissolved Oxygen	mg/L	0.4		1.06		0.32	
pH (field)	SU	6.82		6.95		6.8	

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ug/L - micrograms per liter

mg/L - milligrams 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

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-106				COF-107	
Sample Date		05-Feb-19		26-Aug-19		06-Feb-19	
Total Metals							
Antimony	ug/L	0.931	J	< 0.378	U	0.9	J
Arsenic	ug/L	1.73		1.54		10.9	
Barium	ug/L	46		38.2		47.9	
Beryllium	ug/L	< 0.155	U	< 0.182	U	< 0.155	U
Boron	ug/L	786		478		1080	
Cadmium	ug/L	0.511	J	0.932	J	< 0.125	U
Calcium	ug/L	60700		40900		85500	
Chromium	ug/L	< 1.53	U	< 1.53	U	1.66	J
Cobalt	ug/L	0.414	J	0.765		1.21	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.277	U*
Lithium	ug/L	5.11		< 3.39	U	3.38	J
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	26.2		14.5		33.6	
Selenium	ug/L	< 2.62	U	< 1.51	U	< 2.62	U
Thallium	ug/L	< 0.128	U	0.524	J	< 0.128	U
Radium-226+228	pCi/L	0.226	J	< 0.357	U	0.366	J
Anions							
Chloride	mg/L	7.98		4.2		11.7	
Fluoride	mg/L	0.0454	J	0.0683	J	0.0893	J
Sulfate	mg/L	61.3		43.8		88.2	
General Chemistry							
Total Dissolved Solids	mg/L	228		173		306	
Field Parameters							
Temperature, Water	DEG_C	15.5		22.2		17.7	
Turbidity (field)	NTU	1.74		7.82		10.9	
ORP	mV	192.4		269.2		100.4	
Specific Conductivity (field)	mS/cm	0.377		0.1997		0.503	
Dissolved Oxygen	mg/L	0.7		2.23		1.8	
pH (field)	SU	6.21		5.26		7.09	

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ug/L - micrograms per liter

mg/L - milligrams 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

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-108				COF-109		COF-110			
Sample Date		06-Feb-19		26-Aug-19		06-Feb-19		06-Feb-19		21-Aug-19	
Total Metals											
Antimony	ug/L	0.513	J	0.768	J	< 0.378	U	0.499	J	< 0.378	U
Arsenic	ug/L	14.8		19.4		1.48		0.502	J	< 0.608	U*
Barium	ug/L	66.1		59.2		20.9		53		50.9	
Beryllium	ug/L	< 0.155	U	< 0.487	U*	< 0.155	U	< 0.155	U	< 0.182	U
Boron	ug/L	1030		746		165		712		< 136	U*
Cadmium	ug/L	< 0.125	U	< 0.125	U	0.144	J	< 0.125	U	0.137	J
Calcium	ug/L	85300		83800		103000		82500		113000	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 1.53	U	< 1.53	U	< 1.53	U
Cobalt	ug/L	3.15		2.59		0.156	J	0.125	J	0.196	J
Lead	ug/L	< 0.142	U*	< 0.128	U	< 0.151	U*	< 0.165	U*	0.334	J
Lithium	ug/L	< 3.14	U	4.44	J	< 3.14	U	3.23	J	< 6.07	U*
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	46		28.9		20.9		51.7		4.21	J
Selenium	ug/L	< 2.62	U	< 1.51	U	< 2.62	U	< 2.62	U	< 1.51	U
Thallium	ug/L	< 0.128	U	0.428	J	< 0.128	U	< 0.128	U	< 0.16	U*
Radium-226+228	pCi/L	0.224	J	< 0.403	U	< 0.199	U	0.519	J	< 0.411	U*
Anions											
Chloride	mg/L	11.5		4.04		3.53		18		5.26	
Fluoride	mg/L	0.114		0.0779	J	0.0508	J	0.206		< 0.101	U*
Sulfate	mg/L	86.4		53.1		11.6		63.8		40.6	
General Chemistry											
Total Dissolved Solids	mg/L	306		269		292		287		393	
Field Parameters											
Temperature, Water	DEG_C	18		19.7		16		16.2		20.1	
Turbidity (field)	NTU	10.3		12.8		1.58		1.63		16.2	
ORP	mV	13.9		-27.5		212.2		148		103.7	
Specific Conductivity (field)	mS/cm	0.5		0.4368		0.492		0.509		0.582	
Dissolved Oxygen	mg/L	0.29		0.66		0.4		4.59		7.41	
pH (field)	SU	7.01		6.2		6.73		7.11		7.28	

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DEG_C - degrees Celsius

SU - Standard Unit

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-111							
Sample Date		12-Feb-19		14-Mar-19		04-Apr-19		23-Apr-19	
Total Metals									
Antimony	ug/L	< 0.378	U	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	4.01		11.3		7.04		10.2	
Barium	ug/L	77.2		68.9		69.3		68.2	
Beryllium	ug/L	< 0.155	U	< 0.155	U	< 0.155	U	< 0.155	U
Boron	ug/L	1710		1500		1860		1740	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	111000		102000		101000		104000	
Chromium	ug/L	< 1.53	U	< 2.34	U*	< 1.53	U	< 1.53	U
Cobalt	ug/L	1.24		0.846		1.09		0.888	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Lithium	ug/L	< 3.14	U	3.85	J	< 3.57	U*	4.82	J
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	< 2.3	U*	2.47	J	< 2.13	U*	< 2.35	U*
Selenium	ug/L	< 2.62	U	< 2.62	U	< 2.62	U	< 2.62	U
Thallium	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	< 0.128	U
Radium-226+228	pCi/L	0.339	J	< 0.243	U	0.484	J	0.172	J
Anions									
Chloride	mg/L	22.4		21.1		6.35		23.2	
Fluoride	mg/L	0.0662	J	< 0.0263	U	0.112		0.0421	J
Sulfate	mg/L	90.7		91.8		129		91.9	
General Chemistry									
Total Dissolved Solids	mg/L	347		342		357		320	
Field Parameters									
Temperature, Water	DEG_C	15.2		18.1		14.5		16.7	
Turbidity (field)	NTU	41.9		21.9		13.7		2.03	
ORP	mV	-27.3		-13.5		-64.9		-83.7	
Specific Conductivity (field)	mS/cm	0.4728		0.576		0.6209		0.6016	
Dissolved Oxygen	mg/L	3.19		0.42		1.74		1.86	
pH (field)	SU	6.92		6.94		7.11		6.89	

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NTU - Nephelometric Turbidity Units

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mS/cm - milliseimens per centimeter

SU - Standard Unit

Table A-1
Groundwater Sampling Results

**CCR Annual Groundwater Monitoring
and Corrective Action Report
- TVA Colbert Fossil Plant**

Monitoring Well		COF-111						COF-116	
Sample Date		05-Jun-19		27-Aug-19		12-Nov-19		28-Aug-19	
Total Metals									
Antimony	ug/L	< 0.518	U*	< 0.378	U	< 0.378	U	< 0.378	U
Arsenic	ug/L	11.3		6.52		8.75		4.11	
Barium	ug/L	66.6		72.3		84.4		168	
Beryllium	ug/L	< 0.155	U	< 0.182	U	< 0.182	U	< 0.182	U
Boron	ug/L	1790		2620		2170		499	
Cadmium	ug/L	< 0.125	U	< 0.125	U	< 0.125	U	< 0.125	U
Calcium	ug/L	106000		95100		111000		94000	
Chromium	ug/L	< 1.53	U	< 1.53	U	< 2.18	U*	< 2.26	U*
Cobalt	ug/L	0.738		1.8		1.61		2.84	
Lead	ug/L	< 0.128	U	< 0.128	U	< 0.128	U	0.206	J
Lithium	ug/L	4.93	J	< 3.39	U	3.56	J	< 3.39	U
Mercury	ug/L	< 0.101	U	< 0.101	U	< 0.101	U	< 0.101	U
Molybdenum	ug/L	2.87	J	1.62	J	2.28	J	< 0.61	U
Selenium	ug/L	< 2.62	U	< 1.51	U	< 1.51	U	< 1.51	U
Thallium	ug/L	< 0.128	U	< 0.148	U	< 0.148	U	< 0.148	UJ
Radium-226+228	pCi/L	0.487	J	< 0.144	UJ	< 0.416	U	0.389	J
Anions									
Chloride	mg/L	23.9		25.2		16.4		3.11	
Fluoride	mg/L	0.0589	J	0.0447	J	0.0554	J	0.0753	J
Sulfate	mg/L	90.4		77.1		80.7		2.87	
General Chemistry									
Total Dissolved Solids	mg/L	318		359		375		273	
Field Parameters									
Temperature, Water	DEG_C	18.5		22.6		15.7		21.5	
Turbidity (field)	NTU	1.6		1.98		45.6		56.2	
ORP	mV	-83.5		-59.9		-42.5		-53.9	
Specific Conductivity (field)	mS/cm	0.504		0.568		0.631		0.685	
Dissolved Oxygen	mg/L	1.43		1.04		0.25		0.25	
pH (field)	SU	6.73		6.2		6.73		6.66	

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DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Table A-2
Groundwater and Surface Water
Elevation Summary

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

Groundwater Elevation Collection Date		04-Feb-19	11-Mar-2019	1-Apr-2019	22-Apr-2019	3-Jun-2019	19-Aug-2019	4-Nov-2019
Monitoring Well	Units							
CA5	ft-MSL	417.17	424.08	417.27	423.22	418.05	415.54	415.26
COF-102	ft-MSL	415.50	416.83	415.79	417.15	415.19	415.79	416.06
COF-104	ft-MSL	417.22	417.45	417.07	417.46	416.75	417.28	417.34
COF-105	ft-MSL	413.72	415.04	413.91	415.94	414.80	414.49	413.60
COF-106	ft-MSL	418.91	423.70	416.23	422.79	415.09	417.26	417.33
COF-107	ft-MSL	419.04	423.96	416.23	423.11	415.15	417.35	417.39
COF-108	ft-MSL	419.02	423.97	416.27	423.12	415.17	417.35	417.40
COF-109	ft-MSL	421.30	434.48	420.36	431.74	420.18	420.19	420.16
COF-110	ft-MSL	422.38	429.97	420.64	428.88	418.98	420.76	420.79
COF-111	ft-MSL	na	417.55	415.63	417.93	415.48	416.18	416.18
COF-116	ft-MSL	nm	nm	nm	nm	nm	419.12	417.93
		Surface Water						
Tennessee River	ft-MSL	410.81	413.28	412.69	415.10	414.35	413.22	410.76

Notes:

ft-MSL - feet above mean sea level

na - not available - water level not measured

nm - water level not measured - monitoring well not installed

APPENDIX B

STATISTICAL ANALYSIS REPORT

**STATISTICAL ANALYSIS REPORT FOR
COLBERT FOSSIL PLANT**

2019

1/14/2020

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1 Introduction

This report summarizes the statistical analysis performed on groundwater quality constituents monitored during the Coal Combustion Residuals (CCR) Rule's 2019 Annual Groundwater Monitoring (GWM) Program for the Tennessee Valley Authority (TVA) Colbert Fossil Plant (COF) Ash Disposal Area 4 CCR Unit. The 2019 Annual GWM Program is the third year of the program. Statistically significant increases (SSIs) were identified for one or more parameters based on the 2017 annual groundwater sampling results; therefore, the Ash Disposal Area 4 CCR Unit transitioned to the Assessment Monitoring phase of the monitoring program.

Baseline datasets collected during the first year of monitoring were combined with data collected in 2018 and 2019 and were used to establish statistically-derived Groundwater Protection Standards (GWPS) for the Ash Disposal Area 4 CCR Unit located at COF. Consistent with methods presented in USEPA's Unified Guidance document on the statistical analysis of groundwater monitoring data (2009), confidence-interval (CI) bands were compared against relevant GWPS. An 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.

At the COF plant's CCR Unit, the sampling results used to identify potential GWPS exceedances were obtained during a minimum of two distinct monitoring events that were performed between February and August of 2019 by Terracon, with laboratory analysis performed by Test America Laboratories (located at Pittsburgh, PA, and St. Louis, MO), and Quality Assurance Controls by Environmental Standards, Inc., all under direct contracts to TVA.

The current CCR Rule groundwater monitoring network, as Certified by a Professional Engineer at the firm of AECOM or other, is presented in **Table 1**.

Table 1. CCR Rule Monitoring Well Network

Background	Downgradient	
CA5	COF-102	COF-105
	COF-104	COF-106

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 values and graphs. ProUCL data dumps from TVA's EQIS Professional and Enterprise Database were used to populate the R-based statistical analyses.

Groundwater samples collected as part of the CCR Rule monitoring program were analyzed for constituents listed in Appendix IV of the CCR Rule. Only non-filtered sample results were utilized for the statistical analysis of Appendix IV constituents. As high turbidity measurements during the purging of wells (e.g., values above 5 NTUs) have the propensity to increase the concentrations of Appendix IV constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-named GWPS exceedances. A

summary of constituents included in the data analysis is provided in the second column of **Table 2**.

Table 2. CCR Rule Monitored Constituents

Appendix III Constituents (Detection Monitoring)	Appendix IV Constituents (Assessment Monitoring)
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
pH (field)	Cadmium
Sulfate	Chromium
Total Dissolved Solids (TDS)	Cobalt
	Fluoride
	Lead
	Lithium
	Mercury
	Molybdenum
	Radium 226 + 228
	Selenium
	Thallium

2 Statistical Analysis

The Assessment Monitoring analysis includes the following steps:

- 1) Developing GWPS for each Appendix IV constituent. The GWPS is the published MCL/water quality limit or the background concentration (95% UTL with 95% coverage), whichever is larger;
- 2) Computing trends and associated CI bands for each downgradient well location and Appendix IV constituent (i.e., each well-constituent pair); and
- 3) Comparing each CI band against its respective GWPS to assess whether an exceedance occurred.

2.1 Developing Groundwater Protection Standards (GWPS)

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.”

On July 17, 2018, EPA unofficially promulgated alternate regulatory limits (i.e., potential GWPS) for four of the Appendix IV chemical Constituents of Interest (COIs) for which the agency has not assigned MCLs to date. In the absence of MCLs or site-specific GWPS, those may be used in place of background levels under 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
4. Lead - 15 µg/L.

An Upper Tolerance Limit (UTL) with 95% confidence and 95% coverage was calculated using pooled 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 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.

For the COF, **Table 3, included below**, lists the calculated UTLs and final GWPS established for this CCR Unit.

Table 3. COF Groundwater Protection Standards (GWPS)

COI	N	ND.PCT	MODEL	COV	CONF	UTL	UNITS	MCL	GWPS
Antimony	6	83.3	NP	0.95	0.265	0.0020	mg/L	0.006	0.006
Arsenic	6	83.3	NP	0.95	0.265	0.0012	mg/L	0.01	0.01
Barium	6	0	Fifth Power	0.95	0.950	0.0574	mg/L	2	2
Beryllium	6	100	NP	0.95	0.265	0.0010	mg/L	0.004	0.004
Cadmium	6	50	NP	0.95	0.265	0.0010	mg/L	0.005	0.005
Chromium	6	66.7	NP	0.95	0.265	0.0025	mg/L	0.1	0.1
Cobalt	6	83.3	NP	0.95	0.265	0.0005	mg/L	0.006	0.006
Fluoride	6	66.7	NP	0.95	0.265	0.1000	mg/L	4	4
Lead	6	66.7	NP	0.95	0.265	0.0010	mg/L	0.015	0.015
Lithium	6	50	NP	0.95	0.265	0.0092	mg/L	0.04	0.04
Mercury	6	100	NP	0.95	0.265	0.0002	mg/L	0.002	0.002
Molybdenum	6	83.3	NP	0.95	0.265	0.0050	mg/L	0.1	0.1
Rad226+228	6	0	Tenth Root	0.95	0.950	6.5692	pCi/L	5	6.57
Selenium	6	100	NP	0.95	0.265	0.0050	mg/L	0.05	0.05
Thallium	6	100	NP	0.95	0.265	0.0010	mg/L	0.002	0.002

* No potential Health Effects provided for these Constituents of Interests (COI) - See Appendix "C"

To compute each UTL, the following steps were taken:

- 1) All baseline data - those from designated up-gradient or background wells collected from the Program's first sampling event through August of 2019 were grouped and checked for possible outliers.

At COF, no likely outliers among the background data were flagged.

- 2) The grouped baseline data were also 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.

Datasets which could not be sufficiently normalized were analyzed using nonparametric methods. In many instances, this may occur when the data includes a large fraction of non-detects. **Table 3** lists a shorthand for the statistical model utilized for each Constituent of Interest (COI) under the Model column (e.g., NP stands for nonparametric, Cube Root is the cube root transformation, Log stands for the logarithm, implying a lognormal model, NORMAL represents the null transformation, implying a normal model, etc.).

- 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.

For nonparametric models, the normal theory equation does not apply. Instead, the UTL is selected as one of the largest of the sample values, typically the maximum. Because there is no multiplier 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.

Table 4. Descriptive Summary Statistics of Background Data

Constituent	Unit	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	6	5	0.0006	0.0020	0.0006	0.0013
Arsenic	mg/L	6	5	0.0003	0.0012	0.0003	0.0008
Barium	mg/L	6	0	0.0366	0.0516	0.0446	0.0463
Beryllium	mg/L	6	6	0.0010	0.0010	0.0005	0.0010
Cadmium	mg/L	6	3	0.0001	0.0010	0.0001	0.0001
Chromium	mg/L	6	4	0.0005	0.0025	0.0007	0.0005
Cobalt	mg/L	6	5	0.0001	0.0005	0.0001	0.0003
Fluoride	mg/L	6	4	0.0306	0.1000	0.0327	0.0306
Lead	mg/L	6	4	0.0003	0.0010	0.0004	0.0003
Lithium	mg/L	6	3	0.0022	0.0092	0.0030	0.0034
Mercury	mg/L	6	6	0.0002	0.0002	0.0001	0.0002
Molybdenum	mg/L	6	5	0.0006	0.0050	0.0006	0.0028
Radium 226 + 228	pCi/L	6	0	0.1580	1.5700	0.6538	0.5455
Selenium	mg/L	6	6	0.0050	0.0050	0.0025	0.0050
Thallium	mg/L	6	6	0.0010	0.0010	0.0005	0.0010

Notes:

1. ND = not detected above the laboratory reporting limit.
2. All computations involving non-detects handled using the Kaplan-Meier adjustment. In the case of 100% NDs, mean is computed by substituting half the reporting limit for each ND.

2.2 Computing Trend Lines and Confidence Interval Bands

The USEPA's Unified Guidance recommends comparing some type of CI against a GWPS in order to assess whether or not the limit has been exceeded with statistical significance. If the

entire interval exceeds the GWPS, an SSI is identified. If none or only part of the interval exceeds the GWPS, no SSI is recorded.

Since groundwater data are collected over time, variation in the measurements may be due to a trend. To 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 COF, CI bands were constructed using equations [21.24] and [21.25] of Section 21.3 in the Unified Guidance for each well-constituent pair using all data collected through September of 2018. 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.

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 are 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 time 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.

2.3 Comparing Confidence Interval Bands Against GWPS

To assess whether any SSIs occurred during the 2018 Assessment Monitoring at COF, the CI bands were compared against the constituent-specific GWPS. An SSI was identified if and only if the CI band fully exceeded the GWPS at 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 statistically significant level (SSL) was observed in 2018. Red cells indicate an SSL was flagged during the most recent sampling events. 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, the CI band cross-section straddles the GWPS in yellow cells.

At the COF site, one arsenic-related SSL during the Assessment Monitoring was recorded at well COF-105. Similarly, one cobalt-related SSL was recorded at well COF-102. Additionally, one warning flag (yellow) was raised for cobalt at well COF-104. In summary, a total of two SSLs and one warning were identified at Program network wells that are located near to the COF plant’s CCR Unit during the Assessment Monitoring.

Table 5. COF Traffic Light Matrix Based on Comparative Analysis of Statistical Analysis Results versus Groundwater Protection Standards (GWPS)

	Constituent of Interest	GROUNDWATER QUALITY MONITORING WELL LOCATIONS				
		CA5	COF-102	COF-104	COF-105	COF-106
1.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN
2.	Arsenic	GREEN	GREEN	GREEN	RED	GREEN
3.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN
4.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN
5.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN
6.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN
7.	Cobalt	GREEN	RED	YELLOW	GREEN	GREEN
8.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN
9.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN
10.	Lithium	GREEN	GREEN	GREEN	GREEN	GREEN
11.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN
12.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN
13.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN
14.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN
15.	Thallium	GREEN	GREEN	GREEN	GREEN	GREEN
COLOR-CODING KEY:						
	Monitored data for the specific COI are deemed to fall below GWPS					
	Monitored data are deemed to fall below GWPS, but an internal warning is issued to TVA staff that CI band lower limit is at least 65% of the GWPS.					
	Monitored data for the specific COI are deemed to exceed GWPS					

4 References

1) US Environmental Protection Agency (2009) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* - Office of Resource Conservation and Recovery EPA 530/R-09-007

2) US Environmental Protection Agency (2007) *Framework for Metals Risk Assessment* EPA 120/R-07/001 Office of the Science Advisor Risk Assessment Forum, Washington, DC 20460