

**2018 Annual Groundwater  
Monitoring and Corrective  
Action Report**



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



Prepared for:  
Tennessee Valley Authority  
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January 31, 2019

January 31, 2019

**Reference: 2018 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 Federal Coal Combustion Residuals (CCR) Rule (CCR Rule), this 2018 Annual Groundwater Monitoring and Corrective Action Report (2018 Annual Report) documents 2018 groundwater monitoring activities at the Ash Disposal Area 4 CCR Unit at the Tennessee Valley Authority (TVA) Colbert Fossil Plant (COF). 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 2018, TVA performed the following groundwater monitoring activities:

- Conducted a statistical analysis of the 2017 detection monitoring groundwater sampling data in accordance with 40 CFR 257.93(h), and it was 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 2017 Annual Groundwater Monitoring and Corrective Action Report, which was placed on the CCR Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>).
- 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)(1) 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 Alabama in accordance with 40 CFR 257.106(h)(4); and placed notification on the CCR Compliance Data and Information website <https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals> in accordance with 40 CFR 257.107(h)(4).
- Sampled and analyzed groundwater in the certified monitoring network for Appendix IV constituents in accordance with 40 CFR 257.95(b)<sup>1</sup>.
- Baseline monitoring was initiated for background monitoring wells COF-109 and COF-110 to obtain a minimum of eight independent baseline samples pursuant to 40 CFR 257.94(b)<sup>2</sup>.

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<sup>1</sup> Monitoring well CA5 had insufficient water volume for groundwater sampling between May and September 2018 due to seasonal water table fluctuations.

<sup>2</sup> Monitoring wells COF-109 and COF-110 were sampled to support the background well in the certified network. Six rounds of baseline sampling were completed in 2018 and the additional two rounds of baseline sampling will be completed in 2019.

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- Sampled wells in the certified monitoring network and analyzed samples for CCR constituents (Appendix III and Appendix IV constituents) 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 2018 Annual Report in accordance with 257.95(d)(3).
- Established groundwater protection standards in accordance with 40 CFR 257.95(d)(2) and included the standards in this 2018 Annual Report in accordance with 257.95(d)(3).
- Performed field and desktop site characterization investigations to improve the COF 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).

No problems were encountered during the second year of the TVA Groundwater Quality Monitoring Program and therefore, no further action has been recommended, except for the planned key activities for 2019 that are outlined below.

The projected key activities for 2019 are:

- Complete an evaluation of whether one or more Appendix IV constituents are detected at statistically significant levels (SSLs) above the established groundwater protection standards in accordance with 40 CFR 257.95(g).
- Complete baseline monitoring at background monitoring wells COF-109 and COF-110 to obtain a minimum of eight independent baseline samples pursuant to 40 CFR 257.94(b).
- Monitoring wells COF-109 and COF-110 will be evaluated for inclusion in the certified monitoring well network since background well CA5 had insufficient water volume for groundwater sampling in 2018.
- Perform an alternate source demonstration for the SSLs over groundwater protection standards (Appendix IV constituents) in accordance with 40 CFR 257.95(g)(3)(ii).
- Initiate characterization of the nature and extent of the release in accordance with 40 CFR 257.95(g)(1) if the Appendix IV alternate source demonstration performed under 40 CFR 257.95(g)(3)(ii) is not successful.
- Notification of the exceedances of established groundwater protection standards will be placed in the facility operating record in accordance with 40 CFR 257.95(g) and 257.105(h)(8); will be provided to the State of Alabama in accordance with 40 CFR 257.106(h)(6); and will be placed on the CCR Compliance Data and Information website (<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR 257.107(h)(6).

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- All persons who own the land or reside on the land that directly overlies any part of the plume of contamination if contaminants have migrated off-site will be notified in accordance with 40 CFR 257.95(g)(2) if the Appendix IV alternate source demonstration performed under 40 CFR 257.95(g)(3)(ii) is not successful.
- Initiate Assessment of Corrective Measures in accordance with 40 CFR 257.95(g)(3)(i) and 40 CFR 257.96.
- Perform further field and desktop site characterization investigations to improve the COF CSM.
- Continue semi-annual assessment monitoring at the certified groundwater monitoring network consistent with 40 CFR 257.95.
- 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 WELL NETWORK

Ash Disposal Area 4 is not in use. 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. 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 2017 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 CCR 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 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.

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Assessment monitoring groundwater sampling was conducted between May and September 2018 and the results are summarized in Table 1. Six baseline samples for wells COF-109 and COF-110 were obtained between June and September 2018. Baseline groundwater sampling results are summarized in Table 2. A summary of groundwater sample locations, well designations, analytes sampled, sampling dates and monitoring program status is provided in Table 3.

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 4. Groundwater flow directions were determined 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 Creek which meanders through the middle of the site in a north-northwesterly direction. The general groundwater flow direction in the area is to the north towards the Tennessee River; however, there is localized groundwater flow 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 determined by a 2018 hydrogeologic evaluation (Terracon, 2018). Testing data indicates the uppermost saturated zone within the alluvial deposits has a geometric mean hydraulic conductivity of  $3.41 \times 10^{-3}$  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 ( $3.41 \times 10^{-3}$  cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.0002 to 0.0029 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 3.5 to 51 feet per year.

### 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 CCR 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

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standard depending on background well concentrations for each Appendix IV<sup>3</sup> constituent<sup>4</sup>. The 2018 Statistical Analysis Report is included in Appendix A.

The sampling results used to identify potential groundwater protection standards exceedances were obtained during eight distinct monitoring events that were performed between May and September of 2018<sup>5</sup>. Comparisons were made against a fixed groundwater protection standard via a confidence interval or confidence interval band. No retesting was conducted and none of the individual compliance point measurements were directly compared against the groundwater protection standard. All of the Appendix IV monitoring data collected both in Year-One and Year-Two 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. During Assessment Monitoring, SSLs were recorded at monitoring well COF-102 for cobalt and monitoring well COF-105 for arsenic.

### NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

In January 2018, TVA evaluated the groundwater monitoring data for SSLs over background levels for the constituents listed in Appendix III<sup>6</sup> as required by 40 CFR 257.93(h). The groundwater analytical results from the initial round of detection monitoring indicated SSLs of Appendix III CCR constituents at the downgradient monitoring wells. TVA performed error checking and investigated whether the SSL 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). TVA also performed investigations to determine whether a source other than the CCR materials contained within the COF Ash Disposal Area 4 was the cause of the SSL. The alternate source demonstration study did not demonstrate that the SSL was 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 Alabama and

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<sup>3</sup> Appendix IV CCR Constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and radium 228 combined

<sup>4</sup> 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 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.

<sup>5</sup> The CCR rule requires a minimum of two semi-annual sampling events per well once the required background data has been obtained. Groundwater aquifers can be quite complex, with significant changes and heterogeneity over both time and space. Two events per well per year is sometimes inadequate to reasonably characterize groundwater quality. Much greater flexibility in statistical approach, as well critical information about groundwater variability, can be gained from more frequent sampling. Six baseline samples for wells COF-109 and COF-110 were obtained between June and September 2018 to supplement the background data set.

<sup>6</sup> Appendix III CCR Constituents: boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids (TDS).

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placed on the CCR Compliance Data and Information website

(<https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals>) in accordance with 40 CFR 257.106(h)(4) and 40 CFR 257.107(h)(4), respectively.

In accordance with assessment monitoring program requirements, groundwater in wells in the certified monitoring network was sampled and analyzed for Appendix IV constituents in accordance with 40 CFR 257.95(b) within 90 days of triggering assessment monitoring. 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 were placed in the facility operating record in accordance with 40 CFR 257.105(h)(6) and are summarized in Table 1. Groundwater protection standards were established in accordance with 40 CFR 257.95(d)(2) and are summarized in Table 5. In January 2019, 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). Although not required to be included in this 2018 Annual Report, during Assessment Monitoring, SSLs were recorded at monitoring well COF-102 for cobalt and monitoring well COF-105 for arsenic. 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.

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### LIMITATIONS

This document entitled 2018 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 – Baseline Monitoring Groundwater Sampling Results

Table 3 – Groundwater Sampling Summary

Table 4 – Groundwater and Surface Water Elevation Summary

Table 5 – Hydraulic Conductivity Data Summary

Table 6 – Groundwater Protection Standards

Appendix A – 2018 Statistical Analysis Report

## FIGURES



- Background Well
- Downgradient Well
- 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, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



Project Location 182603174  
City of Tusculum Prepared by WSW on 2018-01-30  
Colbert County, Technical Review by MD on 2018-01-30  
Alabama Independent Review by JK on 2018-01-30

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
- ➔ Groundwater Flow Direction
- CCR Unit Subject to CCR Rule
- TVA Property Boundary

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CCR Rule

Figure No.

**2**

Title

**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  
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Monitoring Well		COF-102															
Sample Date		31-May-18		13-Jun-18		27-Jun-18		11-Jul-18		25-Jul-18		08-Aug-18		22-Aug-18		05-Sep-18	
Sample Round		1		2		3		4		5		6		7		8	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>																	
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.000359	J	0.000996	J	< 0.00130	U*	0.00290		0.00130		0.000974	J	< 0.00180	U*	0.00131	
Barium	mg/L	0.0215		0.0235		0.0274		0.0298		0.0279		0.0347		0.0341		0.0329	
Beryllium	mg/L	< 0.000256	U*	0.000556	J	0.000298	J	0.000339	J	< 0.000170	U*	0.0000830	J	0.000156	J	0.000139	J
Boron	mg/L	3.60		3.32		2.88		2.92		3.30		3.57		3.53		3.95	
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	114		97.6		112		110		132		146		146		135	
Chromium	mg/L	< 0.000631	U	< 0.00200	U*	< 0.00188	U*	< 0.00173	U*	< 0.000631	U	< 0.00146	U*	< 0.00214	U*	< 0.00197	U*
Cobalt	mg/L	0.0250		0.0287		0.0358		0.0346		0.0334		0.0387		0.0356		0.0225	
Lead	mg/L	< 0.000940	U	< 0.000100	U*	0.000131	J	0.000189	J	< 0.000940	U	< 0.000940	U	0.000163	J	0.000114	J
Lithium	mg/L	< 0.00659	U*	< 0.00568	U*	0.00338	J	< 0.00469	U*	0.00345	J	< 0.00334	U*	0.00328	J	0.00345	J
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U	< 0.000474	U
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.257	J	0.609		0.597	U*	0.550	U*	0.820	U*	0.964	U*	0.681	U*	0.542	U*
<b>Anions</b>																	
Chloride	mg/L	15.0		10.4		13.2		11.1		14.8		11.3		15.1		14.2	
Fluoride	mg/L	< 0.0530	U*	0.0508	J	0.0302	J	0.0329	J	0.114		< 0.0263	U	0.0545	J	0.0555	J
Sulfate	mg/L	302		263		272		266		294		290		285		269	
<b>General Chemistry</b>																	
Total Dissolved Solids	mg/L	535		489		486		511		522		545		609		571	
<b>Field pH</b>																	
pH (field)	SU	5.50		5.40		5.57		5.62		5.82		6.17		6.14		5.95	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was detected in an associated field or laboratory blank at a similar concentration

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 - Concentration not detected

mg/L - milligrams per liter

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**Table 1 - Assessment  
Monitoring Groundwater  
Sampling Results**

**CCR Annual Groundwater Monitoring and Corrective  
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Monitoring Well		COF-104															
Sample Date		31-May-18		13-Jun-18		28-Jun-18		12-Jul-18		26-Jul-18		09-Aug-18		23-Aug-18		06-Sep-18	
Sample Round		1		2		3		4		5		6		7		8	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals																	
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.00206		0.00357		0.00343		0.00296		0.00279		0.00402		0.00297		0.00251	
Barium	mg/L	0.0487		0.0619		0.0600		0.0969		0.0914		0.0700		0.105		0.115	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	UJ	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	2.43		1.06		1.26		0.698		0.432		1.29		0.359		0.987	
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	88.4		107		108		130		145		96.0		155		138	
Chromium	mg/L	< 0.000631	U	< 0.00184	U*	< 0.00194	U*	< 0.00337	U*	< 0.000631	U	< 0.00169	U*	< 0.00196	U*	< 0.00174	U*
Cobalt	mg/L	0.00330	J	0.00858		0.00751		0.00407		0.00254		0.00539		0.00258		0.00396	
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	< 0.00293	U*	< 0.00256	UJ	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.0775	J	0.0369		0.0256		0.0177		0.0153		0.0220		0.0132		0.0171	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.572	J	0.770		0.476	U*	0.976	U*	1.15	J	1.07	J	0.762	U*	0.879	U*
Anions																	
Chloride	mg/L	36.7		16.1		33.1		15.2		10.1		21.6		7.36		16.2	
Fluoride	mg/L	< 0.0491	U*	0.0551	J	0.109		0.335		0.628		0.181		0.651		0.401	
Sulfate	mg/L	152		123		186		75.6		77.8		140		59.2		116	
General Chemistry																	
Total Dissolved Solids	mg/L	404		515		444		495		507		463		546		571	
Field pH																	
pH (field)	SU	6.29		5.96		5.91		6.13		6.28		6.00		6.50		6.01	

Notes:

NA - Not Available

Q - Data Qualifier

U\* - This result should be considered not detected because it was detected in an associated field or laboratory blank at a similar concentration

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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 - Concentration not detected

mg/L - milligrams per liter

pCi/L - picoCurie per liter

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		31-May-18		13-Jun-18		28-Jun-18		11-Jul-18		26-Jul-18		08-Aug-18		23-Aug-18		05-Sep-18	
Sample Round		1		2		3		4		5		6		7		8	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals																	
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.0362		0.0413		0.0397		0.0490		0.0374		0.0378		0.0515		0.0428	
Barium	mg/L	0.253		0.248		0.289		0.251		0.216		0.238		0.254		0.214	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	1.24		0.941		1.14		1.46		1.72		1.66		1.92		2.56	
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	103		98.3		112		105		96.4		97.9		103		95.8	
Chromium	mg/L	< 0.000631	U	< 0.00190	U*	< 0.00198	U*	< 0.00139	U*	< 0.000631	U	< 0.00168	U*	< 0.00191	U*	< 0.00182	U*
Cobalt	mg/L	0.00418		0.00429		0.00341		0.00206		0.00132		0.00174		0.00167		0.000879	
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	< 0.00256	UJ	< 0.00282	U*	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.00959		0.0109		0.0101		0.00868		0.00847		0.00998		0.0115		0.0101	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.534	J	0.540	J	1.40	J	0.864	U*	1.05	U*	1.41	J	0.615	U*	1.21	
Anions																	
Chloride	mg/L	14.4		12.7		19.4		19.9		26.6		22.2		28.9		31.6	
Fluoride	mg/L	< 0.245	U*	0.375		0.279		0.245		0.270		0.192		0.184		0.230	
Sulfate	mg/L	14.8		8.67		3.87		2.20		2.24		1.21		1.07		< 0.380	U
General Chemistry																	
Total Dissolved Solids	mg/L	465		441		469		426		428		435		421		393	
Field pH																	
pH (field)	SU	6.59		6.64		6.59		6.55		6.30		6.61		6.65		6.59	

Notes:

NA - Not Available

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U - Concentration not detected

mg/L - milligrams per liter

pCi/L - picoCurie per liter

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-106															
Sample Date		31-May-18		13-Jun-18		28-Jun-18		12-Jul-18		26-Jul-18		09-Aug-18		23-Aug-18		06-Sep-18	
Sample Round		1		2		3		4		5		6		7		8	
Well Designation		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient		Downgradient	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals																	
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	0.00139	J	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	0.00412		0.00474		0.00429		0.00638		0.00500		0.00330		0.00383		0.00472	
Barium	mg/L	0.0385		0.0445		0.0388		0.0526		0.0431		0.0346		0.0303		0.0497	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	UJ	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	0.335		0.933		0.480		0.727		0.624		0.326		0.324		0.821	
Cadmium	mg/L	0.000296	J	0.000390	J	0.000339	J	0.000383	J	0.000294	J	0.000241	J	0.000590	J	0.000638	J
Calcium	mg/L	19.9		59.7		47.3		63.9		51.2		36.8		39.4		62.4	
Chromium	mg/L	< 0.000631	U	< 0.00174	U*	< 0.00182	U*	< 0.00139	U*	< 0.000631	U	< 0.00176	U*	< 0.00179	U*	< 0.00203	U*
Cobalt	mg/L	0.000645		0.00122		0.000986		0.00114		0.00127		< 0.000309	U*	0.000559		0.000846	
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U
Lithium	mg/L	< 0.00329	U*	< 0.00294	U*	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.00831		0.0432		0.0192		0.0337		0.0265		0.0103		0.0135		0.0376	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.215	J	0.395	J	0.539	U*	0.495	U*	0.539	U*	0.541	U*	0.272	U*	0.717	U*
Anions																	
Chloride	mg/L	6.93		10.9		5.89		14.5		10.1		3.64		5.76		13.3	
Fluoride	mg/L	< 0.0760	U*	0.114		0.103		0.101		0.0935	J	0.0544	J	< 0.0861	U*	0.137	
Sulfate	mg/L	53.8		96.2		46.4		103		73.6		39.3		53.8		98.2	
General Chemistry																	
Total Dissolved Solids	mg/L	186		48.0		196		299		243		194		231		309	
Field pH																	
pH (field)	SU	5.71		6.63		6.18		6.52		6.14		6.32		6.30		6.38	

Notes:

NA - Not Available

Q - Data Qualifier

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U - Concentration not detected

mg/L - milligrams per liter

pCi/L - picoCurie per liter

SU - Standard Unit

**ASSESSMENT  
MONITORING**

**Table 2 - Baseline Monitoring  
Groundwater Sampling  
Results**

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

Monitoring Well		COF-109											
Sample Date		27-Jun-18		11-Jul-18		25-Jul-18		08-Aug-18		22-Aug-18		05-Sep-18	
Sample Round		3		4		5		6		7		8	
Well Designation		Baseline		Baseline		Baseline		Baseline		Baseline		Baseline	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>													
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	< 0.00214	U*	0.00222		0.00275		0.00139		0.00306		0.00201	
Barium	mg/L	0.0411		0.0411		0.0402		0.0301		0.0371		0.0397	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	0.265		0.356		0.308		0.158		0.272		0.404	
Cadmium	mg/L	0.000590	J	0.000270	J	0.000512	J	0.000231	J	0.000299	J	0.000413	J
Calcium	mg/L	126		136		144		95.9		143		152	
Chromium	mg/L	< 0.00196	U*	< 0.00163	U*	< 0.000631	U	< 0.00226	U*	< 0.00223	U*	< 0.00188	U*
Cobalt	mg/L	0.000609		0.000596		0.00110		< 0.000192	U*	0.000616		0.000368	J
Lead	mg/L	< 0.0000940	U	< 0.0000940	U	< 0.0000940	U	0.000170	J	0.000100	J	< 0.0000940	U
Lithium	mg/L	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U	< 0.00256	U
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.0185		0.0218		0.0218		0.00918		0.0189		0.0218	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	0.0000640	J	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.588	U*	0.504	U*	0.666	U*	0.676	U*	0.696	U*	0.349	U*
<b>Anions</b>													
Chloride	mg/L	4.09		3.84		4.32		1.47		3.31		5.35	
Fluoride	mg/L	0.0515	J	0.0418	J	0.0397	J	< 0.0263	U	0.0789	J	0.0507	J
Sulfate	mg/L	11.9		12.1		12.7		4.60		9.65		12.9	
<b>General Chemistry</b>													
Total Dissolved Solids	mg/L	344		421		415		308		420		445	
<b>Field pH</b>													
pH (field)	SU	6.59		6.33		6.35		6.61		6.51		6.28	

Notes:

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U - Concentration not detected

mg/L - milligrams per liter

pCi/L - picoCurie per liter

SU - Standard Unit

**BASELINE  
MONITORING**

**Table 2 - Baseline Monitoring  
Groundwater Sampling  
Results**

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

Monitoring Well		COF-110											
Sample Date		27-Jun-18		11-Jul-18		25-Jul-18		08-Aug-18		22-Aug-18		05-Sep-18	
Sample Round		3		4		5		6		7		8	
Well Designation		Baseline		Baseline		Baseline		Baseline		Baseline		Baseline	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q	Result	Q
<b>Total Metals</b>													
Antimony	mg/L	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U	< 0.00112	U
Arsenic	mg/L	< 0.00115	U*	< 0.000887	U*	0.000675	J	0.000801	J	< 0.00132	U*	0.000719	J
Barium	mg/L	0.0565		0.0852		0.0691		0.0812		0.0713		0.0824	
Beryllium	mg/L	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U	< 0.0000570	U
Boron	mg/L	0.651		0.874		0.737		0.773		0.702		0.965	
Cadmium	mg/L	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U	< 0.000125	U
Calcium	mg/L	97.8		78.4		89.7		91.5		105		81.7	
Chromium	mg/L	< 0.00219	U*	< 0.00191	U*	< 0.000631	U	< 0.00171	U*	< 0.00252	U*	< 0.00192	U*
Cobalt	mg/L	0.000420	J	0.000450	J	0.000265	J	< 0.000344	U*	0.000441	J	0.000268	J
Lead	mg/L	0.000230	J	0.000231	J	< 0.000130	U*	0.000160	J	0.000252	J	0.000157	J
Lithium	mg/L	< 0.00256	U	< 0.00355	U*	0.00305	J	0.00331	J	0.00377	J	0.00401	J
Mercury	mg/L	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U	< 0.0000653	U
Molybdenum	mg/L	0.0597		0.0687		0.0530		0.0599		0.0564		0.0662	
Selenium	mg/L	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U	< 0.000813	U
Thallium	mg/L	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U	< 0.0000630	U
Radium 226 + Radium 228	pCi/L	0.830	U*	1.30	J	0.858	U*	1.05	J	1.08	J	0.939	J
<b>Anions</b>													
Chloride	mg/L	17.0		20.1		20.0		15.5		16.5		20.3	
Fluoride	mg/L	0.241		0.229		0.180		0.170		0.199		0.256	
Sulfate	mg/L	61.8		75.6		69.3		66.8		58.8		66.4	
<b>General Chemistry</b>													
Total Dissolved Solids	mg/L	336		348		348		385		380		352	
<b>Field pH</b>													
pH (field)	SU	6.73		6.85		6.54		6.83		6.75		6.83	

Notes:

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**BASELINE  
MONITORING**

**Table 3 - Groundwater Sampling Summary**

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

Well ID	Well Designation	Number of Samples Collected	May 30-31, 2018	June 13, 2018	June 27-28, 2018	July 11-12, 2018	July 25-26, 2018	August 8-9, 2018	August 22-23, 2018	September 5-6, 2018	Assessment Monitoring Program
CA5	Background	0*									Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-102	Downgradient	8	X	X	X	X	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	8	X	X	X	X	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	8	X	X	X	X	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	8	X	X	X	X	X	X	X	X	Assessment Monitoring - 257.95(a); 257.95(b); 257.95(d)(1) - Appendix III and Appendix IV Constituents
COF-109	Background	6			X	X	X	X	X	X	Baseline Monitoring - 257.94(b) - Appendix III and IV Constituents
COF-110	Background	6			X	X	X	X	X	X	Baseline Monitoring - 257.94(b) - Appendix III and 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

\*Monitoring well CA5 had insufficient water volume for the 2018 sampling rounds due to seasonal water table fluctuation.

Monitoring wells COF-109 and COF-110 were sampled in 2018 to support the background well in the certified network. Six rounds of baseline sampling were completed in 2018 and the additional two rounds of baseline sampling will be completed in 2019.

**Table 4**  
**Groundwater and Surface Water Elevation Summary**

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

Groundwater Elevation Collection Date		30-May-18	13-Jun-18	27-Jun-18	11-Jul-18	25-Jul-18	08-Aug-18	22-Aug-18	05-Sep-18
Monitoring Well	Units								
CA5	ft-MSL	419.63	418.62	417.82	416.94	416.35	415.74	415.36	415.08
COF-102	ft-MSL	417.08	415.50	415.68	415.13	415.19	414.96	415.15	414.58
COF-104	ft-MSL	417.66	417.23	417.40	416.76	417.13	417.38	417.06	415.91
COF-105	ft-MSL	415.99	414.90	415.31	414.90	415.01	415.41	414.82	414.41
COF-106	ft-MSL	419.13	416.37	415.76	415.34	415.06	415.31	414.96	414.72
COF-109	ft-MSL	NA	NA	420.09	419.04	418.93	420.35	418.93	418.83
COF-110	ft-MSL	NA	NA	419.90	419.25	418.94	419.24	418.62	418.24
Tennessee River	ft-MSL	413.64	413.72	413.73	444.72	414.13	413.93	413.82	413.39

Notes:

NA - Not Available

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

**Table 5 - Hydraulic Conductivity Data Summary**

<b>Well ID</b>	<b>Well Designation</b>	<b>Slug Test Hydraulic Conductivity (cm/sec)</b>
<b>CA5</b>	Background	Not Performed
<b>COF-102</b>	Downgradient	1.12E-03
<b>COF-104</b>	Downgradient	2.15E-03
<b>COF-105</b>	Downgradient	1.52E-03
<b>COF-106</b>	Downgradient	3.71E-02
<b>COF-109</b>	Background	Not Performed
<b>COF-110</b>	Background	Not Performed
<b>Geometric Mean of Hydraulic Conductivity (cm/sec)</b>		<b>3.41E-03</b>

Notes:

cm/sec - centimeters per second

**Table 6 - Groundwater Protection Standards**

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

Chemical Name	Unit	GWPS / BTV*
Antimony	mg/L	0.006
Arsenic	mg/L	0.01
Barium	mg/L	2
Beryllium	mg/L	0.004
Boron	mg/L	0.0409*
Cadmium	mg/L	0.005
Calcium	mg/L	17.6*
Chloride	mg/L	1.42*
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	0.105
pH (field)	SU	5.65 – 6.89*
Radium 226 + Radium 228	pCi/L	5
Selenium	mg/L	0.05
Sulfate	mg/L	10.7*
Thallium	mg/L	0.002
Total Dissolved Solids	mg/L	126*

Notes:

GWPS - groundwater protection standard

\* - BTV - Background Threshold Values for Appendix III Constituents (2017)

mg/L - milligrams per liter

SU - standard units

pCi/L - picocuries per liter

N/A - not applicable

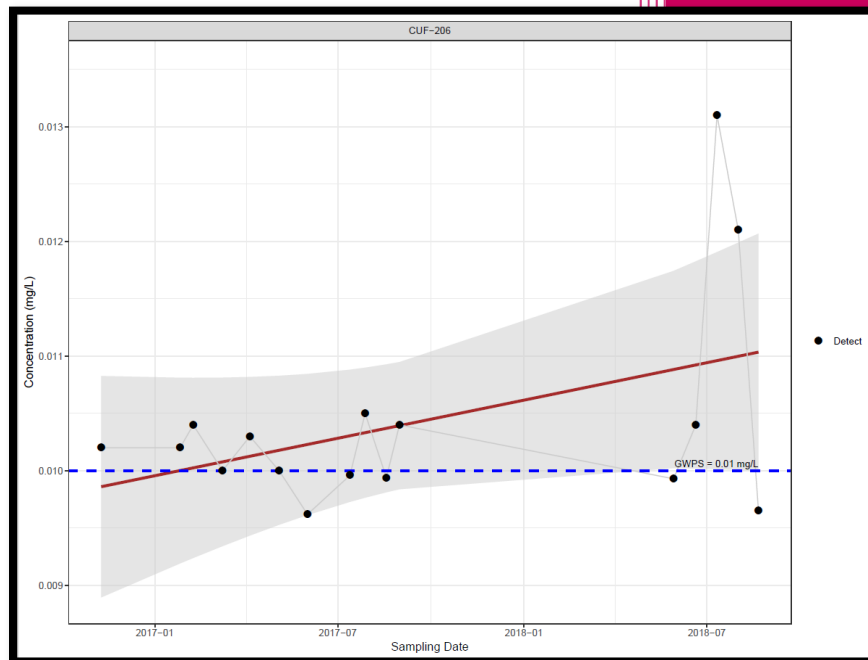
## **APPENDIX A**

### **STATISTICAL ANALYSIS REPORT**



# STATISTICAL ANALYSIS REPORT FOR COLBERT FOSSIL PLANT

# 2018



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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 2018 Annual Groundwater Monitoring (GWM) Program for the Tennessee Valley Authority (TVA) Colbert Fossil Plant (COF) Ash Disposal Area 4 CCR Unit. The 2018 Annual GWM Program is the second 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 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 eight distinct monitoring events that were performed between May of 2018 and September of 2018 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-109	COF-104	COF-106
COF-110		

The 'R' Statistical Analysis package ([www.r-project.org](http://www.r-project.org)) in conjunction with R-Studio ([www.rstudio.com](http://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 EQuIS 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 groundwater protection standards (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 confidence interval (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	32	96.9	NP	0.95	0.8063	0.0020	mg/L	0.006	0.006
Arsenic	32	43.8	Cube Root	0.95	0.9500	0.0028	mg/L	0.01	0.01
Barium	32	0	Tenth Root	0.95	0.9500	0.1014	mg/L	2	2
Beryllium	32	100	NP	0.95	0.8063	0.0010	mg/L	0.004	0.004
Cadmium	32	50	Cube Root	0.95	0.9500	0.0007	mg/L	0.005	0.005
Chromium	32	59.4	NP	0.95	0.8063	0.0025	mg/L	0.1	0.1
Cobalt*	32	40.6	Log	0.95	0.9500	0.0010	mg/L	0.006	0.006
Fluoride	32	12.5	Ninth Root	0.95	0.9500	0.4560	mg/L	4	4
Lead	32	78.1	Log	0.95	0.9500	0.0007	mg/L	0.015	0.015
Lithium*	32	62.5	NORMAL	0.95	0.9500	0.0062	mg/L	0.04	0.04
Mercury	32	100	NP	0.95	0.8063	0.0002	mg/L	0.002	0.002
Molybdenum*	32	9.4	NORMAL	0.95	0.9500	0.1053	mg/L	0.1	0.1053
Rad226+228	30	0	Square Root	0.95	0.9500	2.4979	pCi/L	5	5
Selenium	32	96.9	NP	0.95	0.8063	0.0050	mg/L	0.05	0.05
Thallium	32	81.2	NP	0.95	0.8063	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 upper tolerance limit (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 September of 2018 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  $\kappa$  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	Units	N	No. of NDs	Minimum	Maximum	Mean	Median
Antimony	mg/L	32	31	0.0006	0.0020	0.0006	0.0013
Arsenic	mg/L	32	14	0.0003	0.0031	0.0012	0.0010
Barium	mg/L	32	0	0.0206	0.0852	0.0471	0.0422
Beryllium	mg/L	32	32	0.0010	0.0010	0.0005	0.0010
Cadmium	mg/L	32	16	0.0001	0.0010	0.0003	0.0003
Chromium	mg/L	32	19	0.0005	0.0025	0.0007	0.0006
Cobalt	mg/L	32	13	0.0001	0.0011	0.0003	0.0003
Lead	mg/L	32	4	0.0306	0.2880	0.1295	0.0880
Lithium	mg/L	32	25	0.0001	0.0010	0.0002	0.0002
Mercury	mg/L	32	20	0.0022	0.0099	0.0040	0.0038
Molybdenum	mg/L	32	32	0.0002	0.0002	0.0001	0.0002
Radium 226 + 228	pCi/L	32	3	0.0006	0.0955	0.0413	0.0379
Selenium	mg/L	30	0	0.0190	2.5300	0.8943	0.8175
Thallium	mg/L	32	31	0.0024	0.0050	0.0024	0.0037

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 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 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, a 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 confidence interval (CI) bands were compared against the constituent-specific GWPS. A 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 a 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, warning flags (yellow) were raised for arsenic at well COF-106 and for cobalt at well COF-104. In summary, a total of two SSLs and two warnings 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)

ITEM No.	Constituent of Interest	TRAFFIC LIGHT MATRIX						
		GROUNDWATER QUALITY MONITORING WELL LOCATIONS						
		CA5	COF-109	COF-110	COF-102	COF-104	COF-105	COF-106
1.	Antimony	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
2.	Arsenic	GREEN	GREEN	GREEN	GREEN	GREEN	RED	YELLOW
3.	Barium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
4.	Beryllium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
5.	Cadmium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
6.	Chromium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
7.	Cobalt	GREEN	GREEN	GREEN	RED	YELLOW	GREEN	GREEN
8.	Fluoride	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
9.	Lead	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
10.	Lithium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
11.	Mercury	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
12.	Molybdenum	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
13.	Rad226+228	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
14.	Selenium	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
15.	Thallium	GREEN	GREEN	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