2019 Annual Groundwater Monitoring and Corrective Action Report

Tennessee Valley Authority
Bull Run Fossil Plant Dry Fly Ash
Stack Lateral Expansion CCR Unit

Prepared for:
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January 31, 2020

Reference: **2019 Annual Groundwater Monitoring Report**
TVA Bull Run Fossil Plant Dry Fly Ash Stack Lateral Expansion CCR Unit

In accordance with 40 CFR § 257.90(e) of the Disposal of Coal Combustion Residuals from Electric Utilities final rule (CCR Rule), this 2019 Annual Groundwater Monitoring and Corrective Action Report (2019 Annual Report) documents 2019 groundwater monitoring activities at the Dry Fly Ash Stack (DFAS) Lateral Expansion CCR Unit at the Tennessee Valley Authority (TVA) Bull Run Fossil Plant (BRF). In 2017, TVA established a groundwater monitoring network and program at the BRF DFAS Lateral Expansion 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).

An overview of the current status of groundwater monitoring and corrective action program for the DFAS Lateral Expansion is provided below.

- At the start and end of the current annual reporting period, the DFAS Lateral Expansion was operating under the detection monitoring program in 40 CFR § § 257.94.
- In the 2018 detection monitoring sampling, a statistically significant increase (SSI) over background levels for one or more constituents listed in Appendix III to this part pursuant to 40 CFR § 257.94(e) was observed for boron, calcium, sulfate and total dissolved solids (TDS) in monitoring wells BRF-107 and well J. In addition, SSIs were observed for boron, fluoride, sulfate and TDS at monitoring well MW-3H/P-3. An assessment monitoring program was not initiated for the DFAS Lateral Expansion because of a successful Appendix III alternate source demonstration in April 2018.
- For the 2019 detection monitoring events, the same SSIs of Appendix III CCR constituents at the downgradient monitoring wells were identified. The alternate source demonstration was re-evaluated in 2019 and supports that the SSIs are attributable to another source and not the Dry Fly Ash Lateral Expansion.

During 2019, TVA performed the following groundwater monitoring activities:

- Conducted a statistical analysis of the 2018 detection monitoring groundwater sampling data in accordance with 40 CFR § 257.93(h), and it was concluded that there were SSIs over background levels for certain Appendix III constituents. The results were included in Table 6 of the 2018 Annual Groundwater Monitoring and Corrective Action Report, which was placed on the CCR Rule Compliance Data and Information website (https://www.tva.gov/Environment/Environmental-Stewardship/Coal-Combustion-Residuals).
- Continued under the detection monitoring program and performed four groundwater sampling events between February and October 2019 of the certified monitoring network in accordance with the CCR Rule [40 CFR § 257.93 and 257.94].
- Performed further site characterization to improve the BRF 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 third-year phase of the TVA groundwater quality monitoring program, and therefore, no actions have been recommended except for the planned key activities for 2020 that are outlined below.

The projected key activities for 2020 are:

- Perform further site characterization to improve the BRF CSM.
- Continue semiannual detection monitoring with retesting of the certified groundwater monitoring network consistent with 40 CFR § 257.94.
- 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

The DFAS area is located to the northeast of the main plant and coal yard and is comprised of multiple phased landfills built in sequence. The DFAS Phase I and II areas were permitted together as a Class II Landfill and went into operation in 1983 (permit No. IDL 01-103-0080). Construction of the Phase I area cap was completed in 1992. The Phase II area stacking began in 1989, overlapping the Phase I area, and continued through 2015. Construction began on the DFAS Lateral Expansion in 2012 and placement of ash within the unit began in 2015 and is currently ongoing, which classifies it as the only active landfill at the BRF site per the CCR Rule.

The monitoring well network for the BRF DFAS Lateral Expansion CCR Unit consists of two background wells (I and MWC) and three downgradient wells (BRF-107, J, and MW-3H/P-3). The downgradient wells are installed at the waste boundary. Figure 1 is an aerial photograph that shows the DFAS Lateral Expansion and the groundwater monitoring well locations. The monitoring well network was designed for a single CCR Unit (DFAS Lateral Expansion).

No monitoring wells were installed or decommissioned during the 2019 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 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 and includes, as required by 40 CFR § 257.93(a), 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 semiannual detection monitoring was completed in compliance with 40 CFR § 257.94. Groundwater sampling was conducted between February and October 2019 and the results are summarized in Table 1. 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 Clinch River surface water elevations are summarized in Table 3. Groundwater flow directions were determined for each sampling event, and a generalized depiction of groundwater flow direction is illustrated on Figure 2. The regional groundwater directional flow at BRF is influenced by the Clinch River to the west/southwest of the site and then locally by Worthington Branch that runs to the south of the DFAS Lateral Expansion at the base of Bull Run Ridge. Worthington Branch flows west-southwest, discharging to the Clinch River. The primary groundwater flow direction is to the west/southwest toward the Clinch River. Locally, groundwater flows south beneath the DFAS Lateral Expansion towards Worthington Branch.

The uppermost aquifer at the BRF DFAS Lateral Expansion CCR Unit consists of a thin layer of residuum underlain by fractured Chickamauga Limestone. Groundwater occurrence is variable and controlled by a series of interconnected bedrock fractures shallower than 300 feet (AECOM, 2015).

Hydraulic conductivity values at the background or downgradient groundwater monitoring wells, as summarized in Table 4, are documented in a 2018 hydrogeologic evaluation (Terracon, 2019). Testing data indicates the uppermost saturated zone has a geometric mean hydraulic conductivity of 3.19×10^{-4} 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 (3.19×10^{-4} cm/sec);
- horizontal hydraulic gradients measured during the implementation of the groundwater sampling and analysis program, ranging from 0.033 to 0.0368 feet per foot (ft/ft); and,
- an effective porosity of approximately 1% (AECOM, 2015).

The average linear flow velocity in the uppermost aquifer ranges from approximately 1,089 to 1,214 feet per year. The rate and direction of groundwater flow in the bedrock 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 was 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. Background groundwater quality was established for the background monitoring wells MWC and Well I.

Baseline and detection monitoring data sets for Year-One (2017), Year-Two (2018) and those results obtained during Year-Three (2019) of the CCR Rule Groundwater Quality Monitoring Program were evaluated in order to establish upper prediction limits (UPLs) on background data, and then to compare Year-Three (2019) compliance measurements against these statistical limits to assess any SSIs above background. To assess whether any SSIs occurred during the 2019 Detection Monitoring, the routine sampling events from sampling rounds 1 and 3 at each well-constituent pair were compared against their respective UPL. Under a 1-of-2 retesting strategy, sampling rounds 2 and 4 were included as resamples. A summary of the detection monitoring statistical evaluation is provided in Table 6. The Statistical Analysis Report is provided as Appendix A.

NARRATIVE DISCUSSION OF ANY TRANSITION BETWEEN MONITORING PROGRAMS

TVA evaluated the groundwater monitoring data for SSIs over background levels for the constituents listed in Appendix III[1] as required by 40 CFR § 257.93(h). The groundwater analytical results from the 2019 rounds of detection monitoring indicated identical SSIs of Appendix III CCR constituents at the downgradient monitoring wells compared to the 2018 monitoring results. TVA performed confirmation of the SSIs via retesting procedures and 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). Following the 2017 groundwater data collection, TVA performed investigations to determine whether a source other than the CCR materials contained in the BRF DFAS Lateral Expansion CCR Unit were the cause of any verified SSI over background as specified in 40 CFR § 257.94(e)(2). The Appendix III alternate source demonstration study was successfully completed in April 2018, certified by a qualified professional engineer, and determined that the SSIs were a result of another source and not attributable to the DFAS Lateral Expansion. Alternate source demonstration documentation is provided in Appendix B. The alternate source demonstration was re-evaluated in 2019 and supports that the SSIs are attributable to another source and not the Dry Fly Ash Lateral Expansion. 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.

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

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:

AECOM, 2015. Part II Permit Application Hydrogeologic Site Investigation CCP Proposal Landfill. June 12, 2015.

Terracon, 2019. Aquifer Testing and Equipment Blank Results. TVA CCR Rule – Bull Run Fossil Plant (BRF). Terracon Consultants, Inc. January 15, 2019.

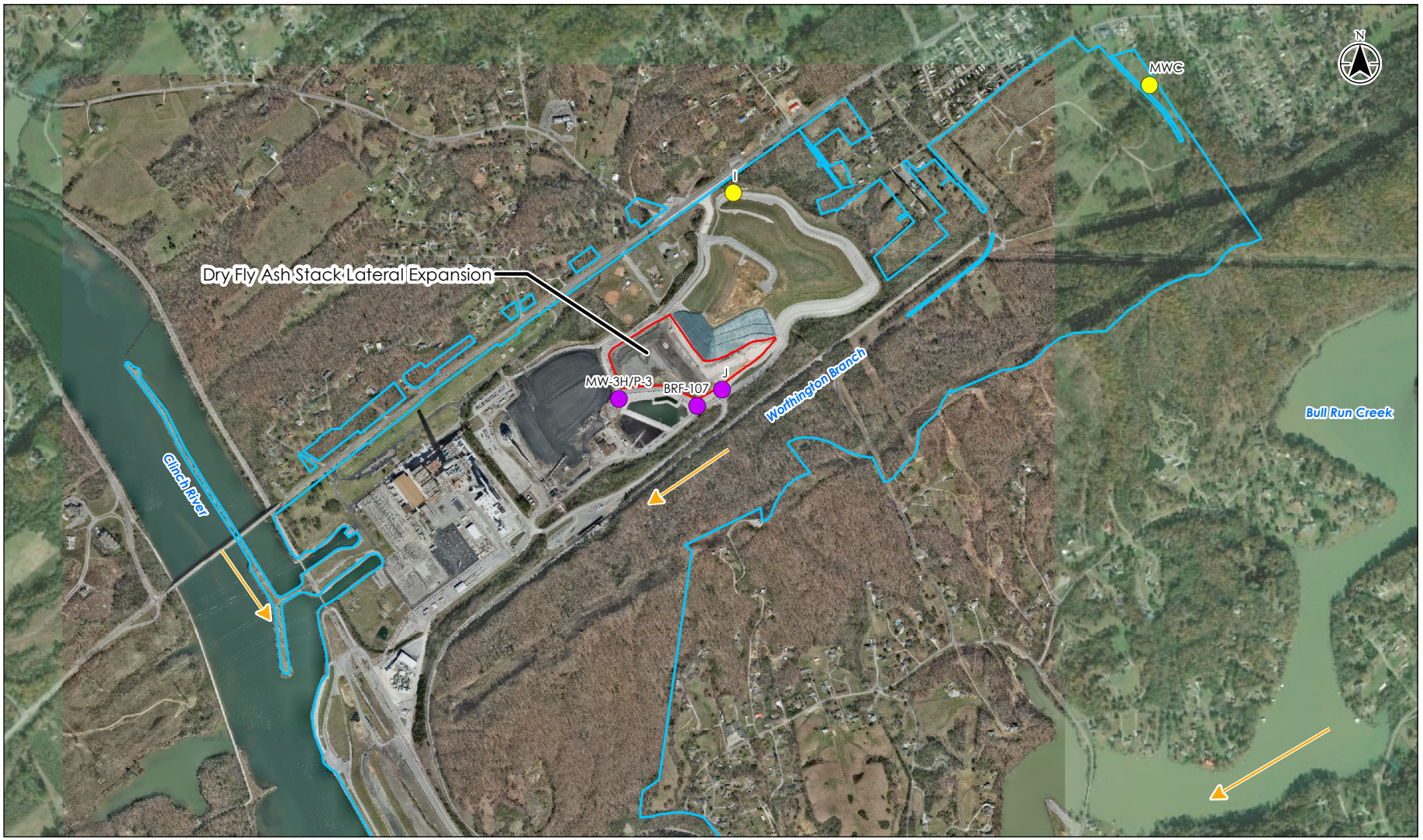
Attachments:

Figure 1 – Map with CCR Unit Background and Downgradient Wells
Figure 2 – Generalized Groundwater Flow Direction Map

Table 1 – Detection 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 – Detection Monitoring Statistical Evaluation

Appendix A – Statistical Analysis Report
Appendix B –Alternate Source Demonstration Documentation

FIGURES



Background Well

Downgradient Well

Surface Water Flow Direction

CCR Unit Subject to CCR Rule

TVA Property Boundary

0 750 1,500 Feet

1:18,000 (At original document size of 8.5x11)

Notes

1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-16) and Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location	182603523
Claxton Anderson County, Tennessee	Prepared by LMB on 2020-01-24 Technical Review by MD on 2020-01-24 Independent Review by TR on 2020-01-24

Client/Project

Tennessee Valley Authority
Bull Run Fossil Plant
CCR Rule

Figure No.

1

Title

Map with CCR Unit Background and Downgradient Wells

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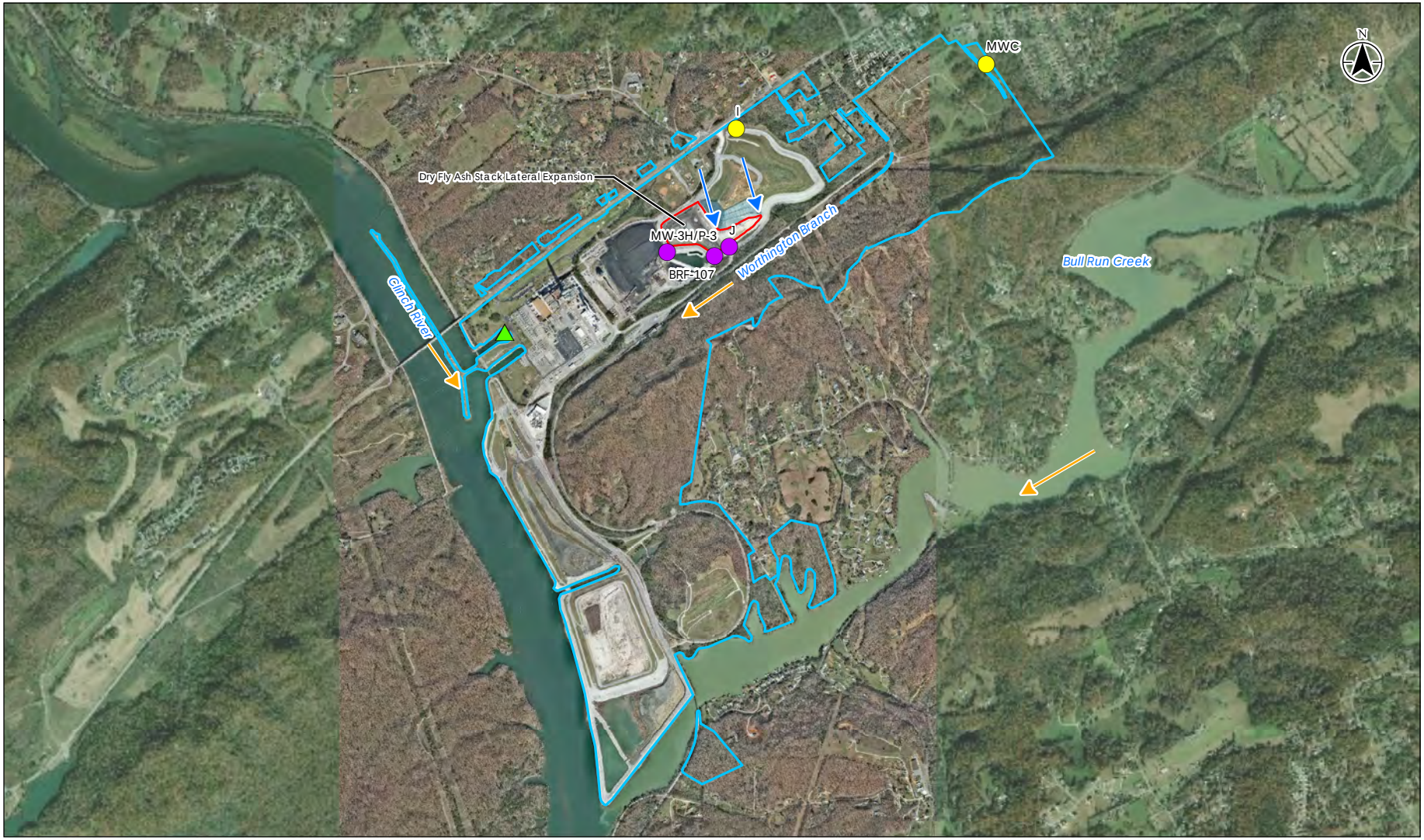

Staff Gauge
Background Well
Downgradient Well
Groundwater Flow Direction
Surface Water Flow Direction
CCR Unit Subject to CCR Rule
TVA Property Boundary

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

0 1,250 2,500 Feet

1:30,000 (At original document size of 8.5x11)

Notes
1. Coordinate System: NAD 1983 StatePlane Tennessee FIPS 4100 Feet
2. Imagery Source: Tucker Mapping Solutions, INC (2017-03-16) and Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location
Claxton
Anderson County,
Tennessee

182603523
Prepared by LMB on 2020-01-22
Technical Review by MD on 2020-01-22
Independent Review by TR on 2020-01-22

Client/Project
Tennessee Valley Authority
Bull Run Fossil Plant
CCR Rule

Figure No.
2

Title
Generalized Groundwater Flow Direction Map

TABLES

Monitoring Well		BRF-107							
Sample Date		13-Feb-19		16-May-19		13-Aug-19		15-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									
Boron	ug/L	550		550		746		617	
Calcium	ug/L	197000		195000		196000		190000	
Anions									
Chloride	mg/L	7.82		6.49		7.8		7.7	
Fluoride	mg/L	0.0553	J	0.0453	J	0.0525	J	0.0506	J
Sulfate	mg/L	237		219		226		236	J
General Chemistry									
Total Dissolved Solids	mg/L	733		729		755		726	
Field Parameters									
Temperature, Water	DEG_C	14.9		16.7		18.4		18.3	
Turbidity (field)	NTU	0.16		0.55		0.36		0.12	
ORP	mV	148.9		79.4		85.5		115.7	
Specific Conductivity (field)	mS/cm	1.02		1		1.06		1.02	
Dissolved Oxygen	mg/L	1.18		0.32		0.24		0.42	
pH (field)	SU	6.72		6.97		6.61		6.81	

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

U - Analyte not detected

ug/L - micrograms per liter

mg/L - milligrams per liter

DEG_C - degrees Celsius

NTU - Nephelometric Turbidity Units

mV - millivolts

mS/cm - milliseimens per centimeter

SU - Standard Unit

Monitoring Well		I							
Sample Date		12-Feb-19		16-May-19		13-Aug-19		15-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Background		Background		Background		Background	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Boron	ug/L	< 30.3	U	33.5	J	51.5	J	< 60.1	U*
Calcium	ug/L	77100		84200		82200		80200	
Anions									
Chloride	mg/L	24.2		22.1		25.8		27.2	
Fluoride	mg/L	0.0509	J	0.0584	J	0.0586	J	0.0543	J
Sulfate	mg/L	4.78		3.92		4.63		4.82	J
General Chemistry									
Total Dissolved Solids	mg/L	308		312		339		341	
Field Parameters									
Temperature, Water	DEG_C	15.1		16.5		19.7		19.7	
Turbidity (field)	NTU	0.13		1.75		1.74		1.76	
ORP	mV	108.7		87.8		137.5		121.4	
Specific Conductivity (field)	mS/cm	0.574		0.575		0.62		0.61	
Dissolved Oxygen	mg/L	0.61		0.49		0.57		0.58	
pH (field)	SU	7.38		7.39		6.91		7.21	

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Table 1
Detection Monitoring
Groundwater Sampling
Results

Monitoring Well		J							
Sample Date		13-Feb-19		16-May-19		13-Aug-19		15-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									
Boron	ug/L	2230		2200		3130		2210	
Calcium	ug/L	287000		287000		321000		286000	
Anions									
Chloride	mg/L	14.8		15.1		15.4		14.6	
Fluoride	mg/L	0.0586	J	0.0492	J	0.0533	J	0.0494	J
Sulfate	mg/L	655		713		682		696	J
General Chemistry									
Total Dissolved Solids	mg/L	1270		1280		1360		1280	
Field Parameters									
Temperature, Water	DEG_C	15.3		16.5		18.5		17.5	
Turbidity (field)	NTU	0.12		0.95		0.68		0.08	
ORP	mV	125.5		83.4		100.5		132.2	
Specific Conductivity (field)	mS/cm	1.49		1.42		1.58		1.49	
Dissolved Oxygen	mg/L	0.85		0.28		0.42		0.31	
pH (field)	SU	6.72		7.19		6.86		6.98	

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mS/cm - milliseimens per centimeter

SU - Standard Unit

Table 1
Detection Monitoring
Groundwater Sampling
Results

Monitoring Well		MW-3H/P-3							
Sample Date		13-Feb-19		16-May-19		13-Aug-19		16-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									
Boron	ug/L	551		556		779		577	
Calcium	ug/L	40100		37300		36200		36800	
Anions									
Chloride	mg/L	10.4		8.36		9.57		9.89	
Fluoride	mg/L	0.509		0.429		0.449		0.386	
Sulfate	mg/L	57		57.9		54.2		56.5	
General Chemistry									
Total Dissolved Solids	mg/L	376		383		397		404	
Field Parameters									
Temperature, Water	DEG_C	14.8		17.9		21.7		19.6	
Turbidity (field)	NTU	0.31		1.2		0.8		0.51	
ORP	mV	1.3		-78.6		-122.4		-182.2	
Specific Conductivity (field)	mS/cm	0.66		0.68		0.7		0.69	
Dissolved Oxygen	mg/L	2.21		0.38		0.52		0.35	
pH (field)	SU	7.54		7.51		7.43		7.57	

Notes:

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Monitoring Well		MWC							
Sample Date		12-Feb-19		15-May-19		12-Aug-19		14-Oct-19	
Sample Round		1		1 - Retest		2		2 - Retest	
Well Designation		Background		Background		Background		Background	
Analyte	Units	Result	Q	Result	Q	Result	Q	Result	Q
Total Metals									
Boron	ug/L	107		167		146		< 209	U*
Calcium	ug/L	95400		101000		85600		88300	
Anions									
Chloride	mg/L	5.14		5.07		3.22		4.23	
Fluoride	mg/L	0.118		0.157		0.125		0.0809	J
Sulfate	mg/L	24.7		18.2		4.66		3.44	
General Chemistry									
Total Dissolved Solids	mg/L	368		366		339		339	
Field Parameters									
Temperature, Water	DEG_C	13.8		16.8		21.5		20.6	
Turbidity (field)	NTU	1.58		1.49		0.34		0.12	
ORP	mV	99.8		-21		-68		-111.3	
Specific Conductivity (field)	mS/cm	0.68		0.63		0.61		0.56	
Dissolved Oxygen	mg/L	0.64		0.95		0.4		0.62	
pH (field)	SU	7.13		7.15		6.87		6.92	

Notes:

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Table 2
Groundwater Sampling Summary

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

Well ID	Well Designation	Number of Samples Collected	February 12-13, 2019	May 15-16, 2019	August 12-13, 2019	October 14-16, 2019	Monitoring Program
Sample Round			**1**	**1 - Retest**	**2**	**2 - Retest**	
BRF-107	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
I	Background	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
J	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
MW-3H/ P-3	Downgradient	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III Constituents
MWC	Background	4	X	X	X	X	Detection Monitoring - 257.94(a); 257.94(b) - Appendix III 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 Bull Run Fossil Plant

Groundwater Elevation Collection Date		12-Feb-19	15-May-19	12-Aug-19	14-Oct-19
Monitoring Well	**Units**				
BRF-107	ft-MSL	812.20	812.14	811.46	810.34
I	ft-MSL	873.27	872.26	871.23	868.85
J	ft-MSL	815.05	814.38	811.46	810.66
MWC	ft-MSL	859.71	858.63	857.39	856.15
MW-3H/P-3	ft-MSL	821.35	821.06	821.33	820.89
		Surface Water			
Clinch River	ft-MSL	794.03	793.49	793.80	793.50

Notes:

ft-MSL - feet above mean sea level

Table 4
Hydraulic Conductivity Data Summary

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

Well ID	Well Designation	Slug Test Hydraulic Conductivity (cm/sec)	Pumping Test Hydraulic Conductivity (cm/sec)
BRF-107	Downgradient	2.45E-04	NA
I	Background	NA	4.80E-05
J	Downgradient	NA	NA
MW-3H/ P-3	Downgradient	NA	1.20E-04
MWC	Background	4.15E-04	NA
Geometric Mean of Hydraulic Conductivity (cm/sec)		**3.19E-04**	**7.59E-05**

Notes:

cm/sec - centimeters per second

NA - Not available

Sources for Hydrogeologic Evaluation Included in the Text:
Part II Permit Application Hydrogeologic Site Investigation CCP Proposal Landfill. AECOM June 12, 2015

Groundwater Elevation Collection Date	12-Feb-19	15-May-19	12-Aug-19	14-Oct-19
Sample Round	**1**	**1 - Retest**	**2**	**2 - Retest**
Horizontal Gradient	0.0334	0.0330	0.0368	0.0351
Hydraulic Conductivity (cm/sec)	3.19E-04	3.19E-04	3.19E-04	3.19E-04
Effective Porosity	1%	1%	1%	1%
Flow Direction (cardinal)	South	South	South	South
Linear Velocity (ft/yr)	1102	1089	1214	1157

Notes:

cm/sec - centimeters per second

ft/yr - feet per year

Table 6 - Detection Monitoring Statistical Evaluation

Constituent		Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS
Unit		mg/L*	mg/L*	mg/L	mg/L	SU	mg/L	mg/L
2019 UPL		0.212	96.56	28.3	0.149	6.29** – 7.85	24.7	364.6
Well ID	Date							
BRF-107	2/13/2019	**0.55**	**197**	7.82	0.0553	6.72	**237**	**733**
	(5/16/2019)	**(0.55)**	**(195)**	(6.49)	(0.0453)	(6.97)	**(219)**	**(729)**
	8/13/2019	**0.746**	**196**	7.8	0.0525	6.61	**226**	**755**
	(10/15/2019)	**(0.617)**	**(190)**	(7.7)	(0.0506)	(6.81)	**(236)**	**(726)**
J	2/13/2019	**2.23**	**287**	14.8	0.0586	6.72	**655**	**1,270**
	(5/16/2019)	**(2.2)**	**(287)**	(15.1)	(0.0492)	(7.19)	**(713)**	**(1280)**
	8/13/2019	**3.13**	**321**	15.4	0.0533	6.86	**682**	**1,360**
	(10/15/2019)	**(2.21)**	**(286)**	(14.6)	(0.0494)	(6.98)	**(696)**	**(1280)**
MW-3H/P-3	2/13/2019	**0.551**	40.1	10.4	**0.509**	7.54	**57.0**	**376**
	(5/16/2019)	**(0.556)**	(37.3)	(8.36)	**(0.429)**	(7.51)	**(57.9)**	**(383)**
	8/13/2019	**0.779**	36.2	9.57	**0.449**	7.43	**54.2**	**397**
	(10/16/2019)	**(0.577)**	(36.8)	(9.89)	**(0.386)**	(7.57)	**(56.5)**	**(404)**
I	2/12/2019	<0.0303	77.1	24.2	0.0509	7.38	4.78	308
	(5/16/2019)	(0.0335)	(84.2)	(22.1)	(0.0584)	(7.39)	(3.92)	(312)
	8/13/2019	0.0515	82.2	25.8	0.0586	6.91	4.63	339
	(10/15/2019)	(<0.0601)	(80.2)	(27.2)	(0.0543)	(7.21)	(4.82)	(341)
MWC	2/12/2019	0.107	95.4	5.14	0.118	7.13	24.7	368
	(5/15/2019)	(0.167)	(101)	(5.07)	(0.157)	(7.15)	(18.2)	(366)
	8/13/2019	0.146	85.6	3.22	0.125	6.87	4.66	339
	(10/14/2019)	(<0.209)	(88.3)	(4.23)	(0.0809)	(6.92)	(3.44)	(339)

Notes:

Bold and underlined concentration indicates a statistically significant increase (SSI) over background where both the original sample and retest sample exceed the UPL or, for pH, are outside the prediction interval

TDS - Total Dissolved Solids

mg/L - milligrams per liter [* - Boron and calcium concentrations presented in Table 1 are reported in micrograms per liter (µg/L)]

SU - Standard Units

UPL - Upper Prediction Limit

** indicates the lower bound of the range is the lower prediction limit (LPL). The upper bound is the UPL.

"<": analyte was not detected and the Method Detection Limit (MDL) is presented

Parenthesized values represent retest results

Wells I and MWC are background monitoring wells

APPENDIX A
STATISTICAL ANALYSIS REPORT

STATISTICAL ANALYSIS REPORT

FOR BULL RUN FOSSIL PLANT

2019

1/14/2020

Contents

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 Dry Fly Ash Stack Lateral Expansion at the Tennessee Valley Authority (TVA) Bull Run Fossil Plant (BRF). The 2019 Annual GWM Program is the third year of the program. Statistically significant increases (SSIs) were present in several parameters based on the 2017 annual groundwater sampling results. An Alternate Source Determination (ASD) was made, re-confirmed in 2018, and the Unit remains in Detection Monitoring.

At the BRF plant's CCR Unit, the sampling results used to identify potential SSIs were developed based on data obtained from four monitoring events performed between February and October of 2019 by Terracon, with laboratory analysis performed by Test America Laboratories (located at Pittsburg, 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 from AECOM, is presented in **Table 1**.

Table 1. CCR Rule Monitoring Well Network

Background	Downgradient
MWC I	MW-3H/P-3 BRF-107 J

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 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 III of the CCR Rule. Only non-filtered sample results were utilized for the statistical analysis of Appendix III 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 III constituents, filtered samples were also collected to better understand and/or dispel the potential source(s) of falsely-identified SSIs. A summary of constituents included in the data analysis is provided in the first 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 basic steps in the Detection Monitoring analysis for the 2019 data included the following:

1) Calculating the site testing configuration, and determining the statistical power associated with interwell parametric and nonparametric prediction limits under possible retesting schemes;
2) Assessing best-fitting statistical models for each background dataset, including identification of any statistical outliers, then computing interwell prediction limits; and
3) Comparing each prediction limit against 2019 compliance data, including resamples if necessary, to assess whether an SSI occurred.

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

Table 3. Summary of Background Dataset Descriptive Statistics

Constituent	Units	N	No. of NDs	Minimum	Maximum	Mean	Median
Boron	mg/L	38	8	0.022	0.212	0.069	0.041
Calcium	mg/L	38	0	71.4	101	83.9	82.1
Chloride	mg/L	38	0	3.06	28.3	15.85	21.15
Fluoride	mg/L	38	5	0.0434	0.157	0.0844	0.0775
pH	SU	38	0	6.29	7.85	7.12	7.15
Sulfate	mg/L	38	0	1.25	24.7	5.40	4.72
TDS	mg/L	38	0	297	374	332.3	329.5

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.

2.1 Site Testing Configuration and Statistical Power

TVA has established a statistical testing approach within its CCR detection monitoring program using the following decision logic:

1. For each Appendix III parameter and compliance well location, a comparison is made between each routinely collected sample and a site-specific upper prediction limit (UPL) computed from upgradient background data (or for pH, against a site-specific prediction interval).
2. If the routine observation exceeds the upper prediction limit (or for pH, is lower than the lower prediction limit), a potential SSI is identified. If the routine observation is within the bounds of the UPL or prediction interval, the test passes.

3. In the event of a potential SSI, one or more resamples — depending on the appropriate value of m — is (are) compared against the UPL or prediction interval. If any of the resamples falls within the bounds of prediction limit/interval, the test passes. If all the resamples exceed the bounds of the limit/interval, an SSI is confirmed for that well and constituent.

To determine the appropriate value of m for use in retesting, four different retesting strategies were assessed by computing the statistical power associated with possible prediction limits under a 1-of-1, 1-of-2, 1-of-3, and 1-of-4 approach (note that a 1-of-1 approach implies the lack of any retesting). Each of the prediction limits was computed under the constraint that the annual site-wide false positive rate (SWFPR) be no more than 10%, thus accounting for the available background sample size for each Appendix III constituent, along with the number of downgradient compliance wells (3), the number of constituents to be tested (7), and the number of statistical evaluations per year (2).

2.2 Background Statistical Models and Prediction Limits

To compute each upper threshold limit (UTL) (or prediction interval for pH), the following steps were taken:

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

At BRF, two possible outliers for sulfate were flagged, but not confirmed due to their similarity to values at other locations at the site.

2) The grouped baseline data were also analyzed to determine whether they could be fit to a known statistical model. If so, a parametric UPL or prediction interval was computed; if not, a nonparametric UPL or interval 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.

3) The final statistical model for each COI was used to compute an upper prediction limit (UPL) or prediction interval associated with a 1-of-2 retesting scheme, and such that the limit or interval met EPA's twin performance criteria of controlling the site-wide false positive rate and having sufficient statistical power.

When a parametric model is appropriate, on the normalized scale, a UPL is computed using the standard normal theory equation (and similarly for a two-sided prediction interval):

$$UPL = \overline{x} + \kappa s$$

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, desired confidence level, retesting strategy, and network configuration (number of downgradient wells, number of constituents, and number of annual evaluations). If the data have been transformed, the final UPL or prediction interval is derived by back-transforming the scaled UPL or interval bounds, e.g., for a log transformation, the result is exponentiated; for a square-root transformation, the result is squared, etc.

For nonparametric models, the normal theory equation does not apply. Instead, the UPL is selected as one of the largest of the sample values, typically the maximum, while the LPL (if applicable) is selected as one of the smallest values (usually the minimum). Because there is no multiplier as in the parametric case, the confidence level associated with a nonparametric UPL is computed 'after the fact,' based on the sample size, desired confidence level, retesting strategy, etc.: the smaller the sample size, the lower the confidence; the bigger the sample size, the higher the confidence level.

For BRF, **Table 4,** included below, lists the calculated UPLs (and LPL for pH) established for this particular CCR Unit.

Table 4. BRF Interwell Prediction Limits

COI	N	ND.PCT	MODEL	1-of-m	FPR	UNITS	LPL	UPL
Boron	38	21.1	NP	2	0.0076	mg/L	0	0.212
Calcium	38	0	Log	2	0.0149	mg/L	0	96.56
Chloride	38	0	NP	2	0.0076	mg/L	0	28.3
Fluoride	38	13.2	Log	2	0.0149	mg/L	0	0.1494
pH	38	0	NP	2	0.0151	SU	6.29	7.85
Sulfate	38	0	NP	2	0.0076	mg/L	0	24.7
TDS	38	0	Log	2	0.0149	mg/L	0	364.57

2.3 Comparing Compliance Data Against Prediction Limits

To assess whether any SSIs occurred during the 2019 Detection Monitoring at TVA's BRF CCR unit, the routine sampling events from sampling rounds 1 and 3 at each COI-well pair were compared against their respective prediction limits. Under a 1-of-2 retesting strategy, sampling rounds 2 and 4 were reserved as possible resamples.

If either routine observation (sampling rounds 1 and 3) exceeded the UPL, or for pH, was outside the bounds of the prediction interval on either side, a potential SSI was flagged. Then the reserved resample associated with the routine event (sampling rounds 2 and 4) was compared against the same limit or interval. Only if the routine observation and its resample both were outside the bounds of the prediction limit/interval was a confirmed SSI identified.

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 III. This summary is useful in planning for mitigation actions. Green cells indicate that no SSI was observed in 2019. Red cells indicate that an SSI was flagged during one or both of the semi-annual evaluation events.

At the BRF site, Detection Monitoring SSIs during the 2019 annual sampling were recorded for boron, sulfate, and TDS at all three downgradient wells (MW-3H/P-3, BRF-107, and J). Calcium-related SSIs were recorded at wells BRF-107 and J. SSIs for fluoride were recorded at well MW-3H/P-3. In summary, a total of 24 SSIs were identified at Program network wells that are located near to the BRF plant’s CCR Unit during the 2019 Detection Monitoring phase.

Table 5. Traffic Light Matrix Based on Comparative Analysis of Statistical Analysis Results versus Prediction Limits

ITEM No.	TRAFFIC LIGHT MATRIX			
	Constituent of Interest	GROUNDWATER QUALITY MONITORING WELL LOCATIONS		
		MW-3H/P-3	BRF-107	J
1.	Boron	RED	RED	RED
2.	Calcium	GREEN	RED	RED
3.	Chloride	GREEN	GREEN	GREEN
4.	Fluoride	RED	GREEN	GREEN
5.	pH	GREEN	GREEN	GREEN
6.	Sulfate	RED	RED	RED
7.	TDS	RED	RED	RED

COLOR-CODING KEY:	
	Monitored data for the specific COI are deemed to fall within prediction limit bounds
	Monitored data for the specific COI are deemed to exceed prediction limit bounds

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

APPENDIX B
ALTERNATE SOURCE DEMONSTRATION DOCUMENTATION

NOTICE OF SUCCESSFUL ALTERNATE SOURCE DEMONSTRATION

BULL RUN FOSSIL PLANT

DRY FLY ASH STACK LATERAL EXPANSION

In accordance with the provisions of 40 C.F.R. 257.94(e)(2), Tennessee Valley Authority (TVA) commissioned an Alternate Source Demonstration (ASD) study for the above-named CCR unit located within the Bull Run Fossil plant's reservation. The study provided successful proof that the ASD of Appendix III constituents measured were due to sources other than the CCR unit named above. As required by 40 C.F.R. 257.94(e)(2), TVA will include the demonstration, as certified by the qualified Professional Engineer (PE) named below, in its "Annual Groundwater Monitoring and Corrective Action Report". TVA will continue its detection monitoring program for the Dry Fly Ash Stack Lateral Expansion.

QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Stephen H. Bickel, being a Professional Engineer in good standing in the State of Tennessee do hereby certify, to the best of my knowledge, information, and belief, that the information contained in this certification is prepared in accordance with the accepted practice of engineering; that the information contained herein is accurate as of the date of my signature below; and that the successful Alternate Source Demonstration (ASD) as described above meets the requirements of 40 CFR § 257.94(e)(2). Opinions relating to this ASD, environmental, geologic, and hydrogeologic conditions or other conclusions are based on available data; actual conditions may vary from those encountered at the times and locations where data are obtained, despite the use of due care.

SIGNATURE: _____

PRINTED NAME: Stephen Bickel, PE

ADDRESS: 10509 Timberwood Circle, Suite 100, Louisville, KY 40223

TELEPHONE: (502) 212-5075

Attachments:

ASD for CCR Unit Dry Fly Ash Stack Lateral Expansion located within the boundaries of the Bull Run Fossil Plant's Reservation.

DATE: 4/13/2018

SUCCESSFUL ALTERNATE SOURCE DEMONSTRATION EXECUTIVE SUMMARY

BULL RUN FOSSIL PLANT

DRY FLY ASH STACK LATERAL EXPANSION

A successful Alternate Source Demonstration (ASD) was conducted on behalf of the Tennessee Valley Authority (TVA) for Bull Run Fossil (BRF) Plant in accordance with 40 C.F.R. 257.94(e)(2) of the Coal Combustion Residuals (CCR) rule. This ASD was conducted in response to the identification of potential statistically significant increases (SSIs) during sampling conducted under the Detection Monitoring program [40 C.F.R. 257.94] in connection with the regulated Dry Fly Ash Stack Lateral Expansion unit.

The ASD determined that the potential SSIs identified in the Dry Fly Ash Stack Lateral Expansion Detection Monitoring program were attributable to pre-existing groundwater conditions that long preceded the construction of the regulated CCR unit. The conclusion that the potential SSIs are due to sources other than the Dry Fly Ash Stack Lateral Expansion is supported by the following lines of evidence:

- The Appendix III constituents with potential SSIs had been detected in downgradient Well J beginning in 1991, more than 20 years prior to the construction of Dry Fly Ash Stack Lateral Expansion in 2012.
- The magnitude of historical concentrations of the Appendix III constituents from the 1991-2011 time period in downgradient Well J are comparable to current concentrations (2011 to present).
- The newly-engineered landfill was constructed with a geomembrane liner and leachate collection system. Construction began in 2012.
- The presence of constituents that caused the potential SSIs cannot be attributed to the Dry Fly Ash Stack Lateral Expansion because they were documented to exist prior to the placement of CCR materials into this unit.

SUMMARY

Based on completion of the successful ASD for the Dry Fly Ash Stack Lateral Expansion, and in accordance with 40 C.F.R. 257.94(e)(2), the site will remain in detection monitoring as of April 15, 2018.