2018 ANNUAL GROUNDWATER MONITORING REPORT

FEDERAL CCR RULE

CARDINAL PLANT – FLY ASH RESERVOIR II
BRILLIANT, OHIO

Submitted to

Cardinal Operating Compnay
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
ESP	Electrostatic Precipitator
FAD	Fly Ash Dam
FAR	Fly Ash Reservoir
FGD	Flue Gas Desulfurization
GWPS	Groundwater Protection Standards
LPL	Lower Prediction Limit
MCL	Maximum Contaminant Level
MW	Megawatt
NPDES	National Pollutant Discharge Elimination System
RSL	Regional Screening Level
RSW	Residual Solid Waste
SCR	Selective Catalytic Reduction
SSI	Statistically Significant Increase
SSL	Statistically Significant Level
UPL	Upper Prediction Limit
USEPA	United States Environmental Protection Agency

1. INTRODUCTION

The Federal Coal Combustion Residuals (CCR) Rule (40 Code of Federal Regulations [CFR] Part 257.90(e)) (USEPA, 2015) requires owners and or operators of existing CCR landfills and surface impoundments to prepare a Groundwater Monitoring and Corrective Action Report (Report) no later than January 31, 2019. Geosyntec Consultants (Geosyntec) has prepared this Report for the Fly Ash Reservoir (FAR) II, an existing CCR unit at the Cardinal Plant in Brilliant, Ohio (Site). This Report summarizes the groundwater monitoring activities conducted pursuant to the CCR Rule through December 31, 2018.

2. SITE DESCRIPTION

2.1 Site Description

The Site is located one mile south of Brilliant, Ohio in Jefferson County (**Figure 1**) and is operated by Buckeye Power, Inc. (Buckeye Power). Located along the Ohio River, the generating station consists of three coal-powered units with an 1,800 megawatt capacity and annual coal use of 5.2 million tons (Geosyntec, 2017). Units 1 and 2 began operation in 1967 and Unit 3 began operation in 1977. As of 2012, all three units were equipped with an electrostatic precipitator (ESP), a selective catalytic reduction (SCR) system, and a flue gas desulfurization (FGD) system.

FAR II is an existing wet fly ash disposal reservoir that is located approximately one mile north of the plant site and east of FAR I Residual Solid Waste (RSW) Landfill. The reservoir is contained within Blockhouse Hollow (also referred to as Blockhouse Run in references and drawings) by Fly Ash Dam (FAD) 2 and the decommissioned FAD I. FAR II receives sluiced fly ash from the generating unit's ESPs and collected stormwater and leachate from the FAR I RSW Landfill. FAR II/FAD 2 has a permitted discharge through the national pollutant discharge elimination system (NPDES) Outfall 019 (Geosyntec, 2017).

2.2 Regional Physiographic Setting

The Site is underlain by horizontal sequences of lower Permian and upper Pennsylvanian sedimentary rock. The Conemaugh Group, 500 feet (ft) thick in Jefferson County, consists of shale, sandstone, limestone, claystone, and coal. This group includes the Morgantown Sandstone underlain by the Elk Lick Limestone, the Skelly Limestone and Shale, the Ames Limestone, and the Cow Run Sandstone (Geosyntec, 2017). Above the current grade of the RSW Landfill lies the Monongahela Group consisting of shale, sandstone, limestone, coal, claystone, and siltstone. Overlying the Monongahela Group, at approximately 1,250 feet in elevation, is the Permian-age Dunkard Group.

The uppermost aquifer at the Site lies within the Morgantown Sandstone, overlain by a shale aquitard. Groundwater in the uppermost aquifer generally flows south-southeast towards the Ohio River with hydraulic conductivity ranging from 1×10^{-1} to 1×10^{-4} centimeters per second (cm/s).

The hydraulic conductivity of the confining shale layer ranges from 1×10^{-7} to 1×10^{-9} cm/s (AEP, 2006).

3. GROUNDWATER MONITORING SYSTEM

The FAR II's groundwater monitoring network was designed to comply with 40 CFR 257.91. The groundwater monitoring network utilizes monitoring wells initially installed as part of a separate site-wide hydrogeologic investigation and is used to monitor groundwater quality in the uppermost aquifer at the Site. Monitoring well construction and soil boring logs were provided in *Groundwater Monitoring Network Design Report* (Geosyntec, 2017).

The FAR II groundwater monitoring network consists of twenty-three monitoring wells, as shown in **Figure 2.** Five upgradient monitoring wells (CA-0622A, M-12, M-1302, M-6, and MGS-5) are used to measure background conditions and eighteen downgradient monitoring wells (FA-8, M-10, M-1003, M-1004, M-11, M-13, M-1309, M-14, M-15, M-16, M-21, M-22, M-23, M-8, MGS-1, MGS-2, MGS-3, and MGS-4) are used as compliance wells.

4. CCR RULE GROUNDWATER KEY ACTIVITIES COMPLETED

Eight background monitoring events were conducted between October 2016 and July 2017. Following the eight background monitoring events, the FAR II progressed into detection monitoring. The first detection monitoring event was conducted in September 2017 and January 2018. Based on the results of the detection monitoring event, the unit transitioned to assessment monitoring in 2018. Assessment monitoring sampling events were completed in May and August 2018. Analytical results from the 2018 sampling events are summarized in **Table 1**.

4.1 Groundwater Elevation and Flow Velocities

Prior to sampling, a synoptic round of groundwater measurements was collected from the compliance and background monitoring wells. Potentiometric surface maps based on groundwater elevations measured during the May and August 2018 assessment monitoring event are presented on **Figures 3 and Figure 4**. Potentiometric map figures show overall groundwater around the FAR II flows southeast, towards the Ohio River. The groundwater residence times within the wells at the FAR II ranged from 0.2 days at M-15 to 16.6 days at M-11. A summary of hydraulic gradients and groundwater residence times at the FAR II is provided in **Table 2**.

4.2 Data Usability

Upon receipt of laboratory analytical reports, the data were evaluated for usability. Analytical data were checked for the following:

- Samples were analyzed within the method specified hold times;
- Samples were received within holding temperature;

- The chain of custody form was complete;
- Precision was within control limits using relative percent differences of blind duplicate samples;
- Matrix spike and matrix spike duplicate recoveries and laboratory control samples were within the control limits; and
- Potential for positive bias was evaluated using method blanks.

Upon completion of the data usability assessment, the data were qualified as needed and added to the data tables. All data received during 2018 were considered complete and usable.

4.3 Background Statistical Evaluation

In accordance with 40 CFR 257.94(b), groundwater samples collected during the background groundwater monitoring period were analyzed for 40 CFR 257 Appendix III and Appendix IV list parameters. The results were used to statistically determine upper prediction limits (UPLs) for all Appendix III parameters and a lower prediction limit (LPL) for pH. The *Statistical Analysis Summary-Fly Ash Reservoir II* report (Geosyntec, 2018) summarizes the analysis and results of the background statistical evaluation.

4.4 Detection Monitoring Program

Detection monitoring events at the FAR II were conducted in accordance with 40 CFR 257.94(a) of the CCR Rule. Samples collected during the detection monitoring event were analyzed for Appendix III parameters only. A statistical analysis was performed following the first detection monitoring event. Detection monitoring data was compared to the calculated UPLs and LPL, developed from background monitoring data to identify statistically significant increases (SSIs) at the CCR unit.

The first detection monitoring program event was conducted in September 2017 and January 2018 and is described in the *Annual Groundwater Monitoring Report* (AEP, 2018). SSIs were identified using a 1-of-2 retesting procedure. An evaluation of detection monitoring analytical results is shown in **Table 3**. Boron was detected above the UPL at seven of the network's compliance wells. An alternate source was not identified for the SSIs and the CCR unit transitioned into assessment monitoring.

4.5 Assessment Monitoring Program

Assessment sampling events were conducted in May and August 2018 in accordance with 40 CFR 257.95(b) and 40 CFR 257.95(d)(1). Samples from both events were analyzed for all Appendix III and Appendix IV parameters, with results provided in **Table 1**.

4.6 Establishment of GWPS

A Groundwater Protection Standard (GWPS) was established for each Appendix IV parameter in accordance with the United States Environmental Protection Agency (USEPA's) *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance* (Unified Guidance; USEPA, 2009). The established GWPS were determined to be the greater value of the background concentration and the maximum contaminant level (MCL) or regional screening level (RSL) for each Appendix IV parameter. The GWPS are summarized in **Table 4**. A statistical evaluation of the 2018 assessment monitoring data compared against the GWPS is ongoing and will be completed outside of the timeframe of this report.

5. PROBLEMS ENCOUNTERED AND RESOLUTIONS

No problems were encountered during 2018 which were related to detection monitoring or assessment monitoring activities at the FAR II. No monitoring wells were gauged dry, abandoned, or added to the well network during 2018. All analytical data received were deemed to be of acceptable quality.

6. STATUS OF MONITORING PROGRAM

The Site was in the detection monitoring program from September 2017 through January 2018. An SSI for boron was identified at seven compliance wells at the FAR II and the CCR unit transitioned into assessment monitoring. An assessment monitoring event was conducted in May and August 2018. The FAR II's monitoring status will be re-evaluated after the completion of the ongoing statistical evaluation.

7. PLANNED KEY ACTIVITIES FOR 2019

The following activities are planned for 2019 at the FAR II.

- The 2018 Annual Groundwater Monitoring Report will be entered into the facility's operating record and posted to the public internet site;

- A statistical evaluation of the 2018 assessment monitoring event will be completed in January 2019 which will evaluate potential SSIs against the established GWPS. The FAR II's monitoring status will be confirmed following the evaluation;

- Assuming the unit remains in assessment monitoring, two semi-annual groundwater assessment monitoring program events will be conducted and tested for a potential Statistically Significant Level (SSL) or SSI. Additionally, the detection monitoring statistics will be revised and potential for SSIs over background will be evaluated. The FAR II's monitoring status will be confirmed following the evaluation; and

- The 2019 Annual Groundwater Monitoring Report will be prepared for submittal in January 2020.

8. REFERENCES

American Electric Power (AEP) and Geosyntec Consultants, Inc., May 2006. Hydrogeological Investigation Report.

American Electric Power (AEP). 2018. Annual Groundwater Monitoring Report, Cardinal Operating Company, Cardinal Plant, Fly Ash Reservoir II, January.

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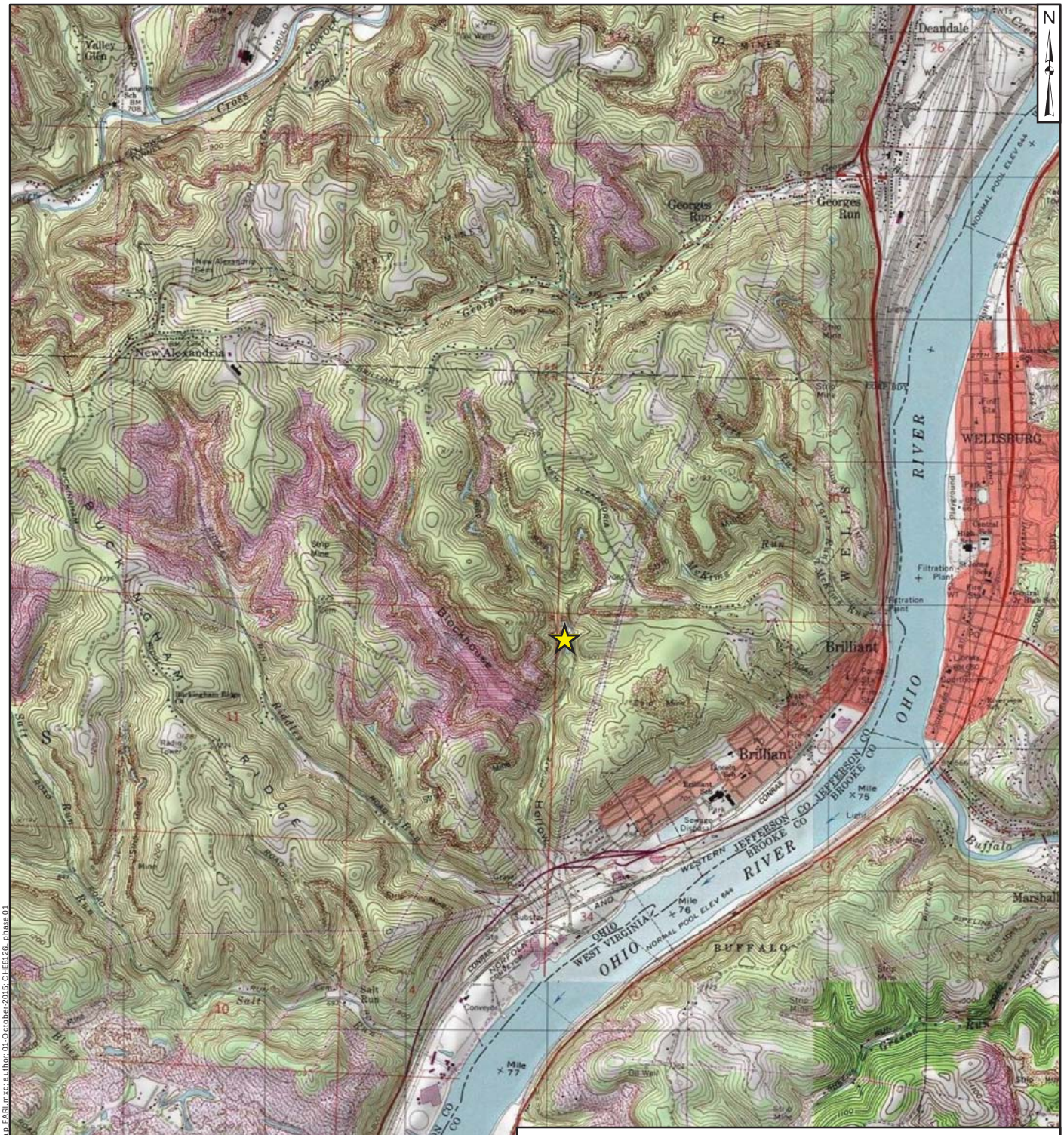
United States Environmental Protection Agency (USEPA). 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (Final Rule). Fed. Reg. 80 FR 21301, pp. 21301-21501, 40 CFR Parts 257 and 261, April.

FIGURES



Legend

★ Site Location

Notes
- All locations are approximate.
- Topographic maps courtesy of National Geographic Society.

Site Location Map
FAR II

Cardinal Power Plant
Brilliant, Ohio

Geosyntec consultants

Ann Arbor, Michigan | 01-October-2015

Figure 1

P:\Projects\AEP\Cardinal\CCR Compliance Document\Figures\Site Location Map_FARII.mxd; author: 01-October-2015; CHE8126, phase 01

Monitoring Well Network

- Compliance Sampling Location
- Background Sampling Location
- Jules Verne Seep
- Fly Ash Reservoir (FAR) II

Notes

- Monitoring well coordinates provided by Buckeye Power.
-Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Former Fly Ash Reservoir I - Residual Solid Waste Landfill (Geosyntec, 2016) provided by Buckeye Power.

1,000 500 0 1,000 Feet

Site Layout
Fly Ash Reservoir II

Buckeye Power Cardinal Generating Plant
Brilliant, Ohio

Geosyntec consultants

Columbus, Ohio | 2019/01/25

Figure **2**

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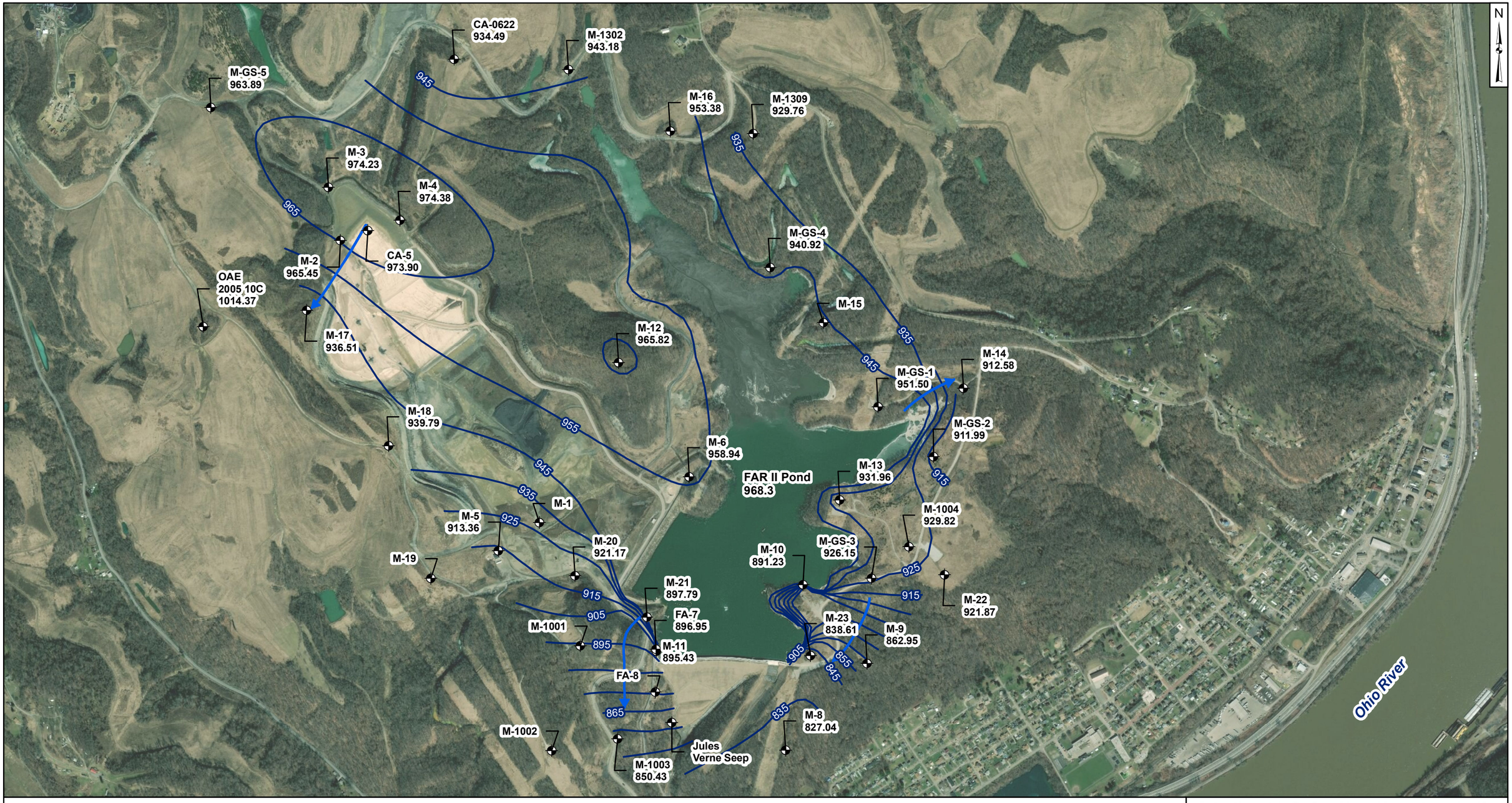

Legend

- Groundwater Monitoring Well
- Groundwater Elevation Contour
- Approximate Groundwater Flow Direction

Notes

- Monitoring well coordinates and water level data (collected on May 14, 2018) provided by Buckeye Power.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017) provided by Buckeye Power.
- Groundwater discharge observed from Jules Verne Seep location.
- Groundwater elevation units are feet above mean sea level.
- Data for M-15 was not used for contouring due to an anomalous reading.

1,000 500 0 1,000 Feet

Potentiometric Surface Map - Morgantown Aquifer
Fly Ash Reservoir II
May 2018

Buckeye Power Cardinal Generating Plant
Brilliant, Ohio

Geosyntec consultants

Columbus, Ohio | 2019/01/10

Figure **3**

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Legend

- Groundwater Monitoring Well
- Approximate Groundwater Flow Direction
- Groundwater Elevation Contour
- Groundwater Elevation Contour (Inferred)

Notes

- Monitoring well coordinates and water level data (collected on August 21, 2018) provided by Buckeye Power.
- Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017) provided by Buckeye Power.
- Groundwater discharge observed from Jules Verne Seep location.
- Groundwater elevation units are feet above mean sea level.

Potentiometric Surface Map - Morgantown Aquifer
Fly Ash Reservoir II
August 2018

Buckeye Power Cardinal Generating Plant
Brilliant, Ohio

Geosyntec consultants

Columbus, Ohio | 2019/01/10

Figure **4**

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TABLES

Table 1: Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	CA-0622A		FA-8			M-6		M-8		M-10			M-11		
		5/15/2018	8/27/2018	1/24/2018	5/17/2018	8/29/2018	5/16/2018	8/28/2018	5/17/2018	8/27/2018	1/24/2018	5/17/2018	8/23/2018	1/24/2018	5/16/2018	8/27/2018
		Assessment		Detection	Assessment		Assessment		Assessment		Detection	Assessment		Detection	Assessment	
Antimony	µg/L	0.100 J	0.5 U	-	0.460	0.530	0.110	0.5 U	0.0400 J	0.5 U	-	0.0200 J	0.5 U	-	0.570	0.5 U
Arsenic	µg/L	37.2	24.4	-	5.49	6.60	4.58	0.5 U	2.65	2.40	-	0.200	0.5 U	-	4.62	4.70
Barium	µg/L	1060	1240	-	25.1	23.1	413	189	120	126	-	69.7	88.4	-	26.0	26.1
Beryllium	µg/L	0.100	0.140	-	0.02 U	0.1 U	1.35	0.1 U	0.0300	0.1 U	-	0.0100 J	0.120	-	0.02 U	0.1 U
Boron	mg/L	0.368	0.331	5.16	4.97	5.47	0.247	0.229	0.0800	0.0282	0.599	0.663	0.591	5.10	5.17	5.24
Cadmium	µg/L	0.0300 J	0.1 U	-	0.0300	0.140	0.280	0.1 U	0.0400	0.1 U	-	0.0300	0.370	-	0.0300	0.160
Calcium	mg/L	80.8	67.8	-	214	196	17.1	5.51	102	89.6	-	12.6	12.6	-	224	205
Chloride	mg/L	3930	4300	-	54.7	6.80	37.1	37.5	6.15	52.3	-	13.4	13.8	-	53.3	50.4
Chromium	µg/L	1.98	3.70	-	0.206	1.30	3.35	1 U	1.14	1 U	-	0.208	1 U	-	0.149	1 U
Cobalt	µg/L	1.61	1.40	-	0.570	0.760	3.39	0.5 U	1.34	1.30	-	0.0360	0.5 U	-	0.699	0.760
Combined Radium	pCi/L	4.76	8.73	-	0.530	0.524	93.3	2.69	1.19	1.44	-	0.758	0.885	-	0.712	0.775
Fluoride	mg/L	0.600 J	0.05 U	-	0.590	0.0940	1.24	1.20	0.100 J	0.510	-	0.790	0.710	-	0.590	0.500
Lead	µg/L	2.63	2.30	-	0.167	0.5 U	22.7	0.520	1.35	1.20	-	0.664	5.10	-	0.315	0.5 U
Lithium	mg/L	0.0820	0.0738	-	0.204	0.218	0.00700	10 U	0.001 U	10 U	-	0.0150	0.0198	-	0.213	0.211
Mercury	µg/L	0.005 U	0.0123	-	0.005 U	0.5 U	0.00900	0.0166	0.00200 J	0.00179	-	0.005 U	0.00300	-	0.005 U	0.000530
Molybdenum	µg/L	18.9	8.00	-	285	336	0.510	0.5 U	0.550	0.900	-	2.25	2.30	-	324	337
pH	SU	7.63	7.98	7.34	7.29	7.29	8.15	8.35	7.29	7.30	8.01	8.13	7.42	7.75	7.47	7.11
Selenium	µg/L	0.400 J	0.5 U	-	2.20	0.810	2.40	0.5 U	0.100	0.5 U	-	0.0400 J	0.5 U	-	2.80	0.5 U
Total Dissolved Solids	mg/L	5960	6980	-	1530	1520	598	548	428	437	-	749	726	-	1600	1550
Sulfate	mg/L	57.8	62.5	945	937	99.3	1.30	0.370	99.1	959	-	128	146	-	942	849
Thallium	µg/L	0.0600 J	0.5 U	-	0.148	0.5 U	0.146	0.5 U	0.0400 J	0.5 U	-	0.0200 J	0.5 U	-	0.343	0.5 U

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
-: Not sampled

Table 1: Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Geosyntec Consultants, Inc.

Parameter	Unit	M-12		M-13		M-14		M-15		M-16		M-21			M-22		
		5/16/2018	8/27/2018	5/16/2018	8/23/2018	5/16/2018	8/23/2018	5/16/2018	8/22/2018	5/16/2018	8/22/2018	1/24/2018	5/22/2018	8/28/2018	1/24/2018	5/17/2018	8/23/2018
		Assessment		Assessment		Assessment		Assessment		Assessment		Detection	Assessment		Detection	Assessment	
Antimony	µg/L	0.0500 J	0.5 U	0.0200 J	0.5 U	0.05 U	0.5 U	0.0200 J	0.5 U	0.05 U	0.5 U	-	0.0800 J	0.5 U	-	0.0100 J	0.5 U
Arsenic	µg/L	7.18	4.30	0.860	0.690	0.120	0.5 U	2.50	2.00	0.300	0.5 U	-	1.90	2.80	-	0.460	0.5 U
Barium	µg/L	58.6	27.2	100	122	14.1	14.3	50.2	46.3	39.4	37.8	-	9.87	13.0	-	26.3	27.8
Beryllium	µg/L	0.0740	0.1 U	0.0620	0.1 U	0.02 U	0.1 U	0.0100 J	0.1 U	0.02 U	0.1 U	-	0.419	0.1 U	-	0.0380	0.1 U
Boron	mg/L	0.388	0.364	0.285	0.242	0.350	0.225	0.341	0.262	0.215	0.180	3.24	3.41	3.37	4.26	4.35	4.38
Cadmium	µg/L	0.0700	0.1 U	0.0100 J	0.1 U	0.00800 J	0.1 U	0.00900 J	0.1 U	0.02 U	0.1 U	-	0.0200 J	0.1 U	-	0.0100 J	0.1 U
Calcium	mg/L	320	285	9.17	11.2	0.587	0.534	1.85	1.61	2.49	2.15	-	266	180	-	187	177
Chloride	mg/L	237	284	2.79	3.70	1.56	1.90	27.0	28.2	9.72	10.7	-	59.4	61.1	-	52.6	50.7
Chromium	µg/L	0.496	1 U	0.359	1 U	0.175	1 U	0.237	1 U	0.148	1 U	-	0.212	1 U	-	0.211	1 U
Cobalt	µg/L	13.6	9.00	0.131	0.5 U	0.00900 J	0.5 U	0.0630	0.5 U	0.0100 J	0.5 U	-	2.66	1.60	-	0.985	0.5 U
Combined Radium	pCi/L	1.12	0.450	2.21	0.997	0.414	0.491	0.887	0.806	0.755	1.51	-	1.17	0.738	-	2.12	2.17
Fluoride	mg/L	1.12	0.990	1.24	1.30	0.800	0.810	1.34	1.40	0.410	0.350	0.100 J	0.100 J	0.05 U	-	0.450	0.460
Lead	µg/L	0.770	0.5 U	0.465	0.5 U	0.0350	0.5 U	0.245	0.5 U	0.0290	0.5 U	-	0.791	0.5 U	-	0.0300	0.5 U
Lithium	mg/L	0.136	0.116	0.00500	0.0103	0.001 U	10 U	0.00500	10 U	0.00800	0.0108	-	0.0960	0.0699	-	0.0650	0.0655
Mercury	µg/L	0.005 U	0.00201	0.005 U	0.000880	0.005 U	0.5 U	0.005 U	0.00130	0.005 U	0.5 U	-	0.005 U	0.000940	-	0.005 U	0.000920
Molybdenum	µg/L	0.590	0.5 U	0.390	0.5 U	0.260	0.5 U	0.650	0.520	0.210	0.5 U	-	15.5	15.5	-	83.2	82.9
pH	SU	6.73	6.83	8.64	8.42	9.01	9.34	8.88	8.92	8.82	8.91	7.14	7.09	7.29	7.02	6.92	7.40
Selenium	µg/L	0.100 J	0.5 U	0.0700 J	0.5 U	0.1 U	0.5 U	0.0400 J	0.5 U	0.0300 J	0.5 U	-	0.300	0.5 U	-	0.1 U	0.5 U
Total Dissolved Solids	mg/L	2800	2800	465	450	376	365	573	548	770	784	-	1780	1840	-	961	914
Sulfate	mg/L	1470	1510	10.1	13.8	0.400	0.800	3.60	4.40	255	287	-	1020	1060	421	415	437
Thallium	µg/L	0.0400 J	0.5 U	0.05 U	0.5 U	0.05 U	0.5 U	0.0100 J	0.5 U	0.0200 J	0.5 U	-	0.0400 J	0.5 U	-	0.05 U	0.5 U

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
-: Not sampled

Table 1: Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	M-23			M-1003		M-1004			M-1302		M-1309		MGS-1		
		1/24/2018	5/17/2018	8/24/2018	5/16/2018	8/28/2018	1/24/2018	5/17/2018	8/27/2018	5/16/2018	8/22/2018	5/16/2018	8/29/2018	1/23/2018	5/16/2018	8/28/2018
		Detection	Assessment		Assessment		Detection	Assessment		Assessment		Assessment		Detection	Assessment	
Antimony	µg/L	-	0.0200 J	0.5 U	0.0100 J	0.5 U	-	0.0100 J	0.5 U	0.05 U	0.5 U	0.0100 J	0.5 U	-	0.05 U	0.5 U
Arsenic	µg/L	-	0.510	0.750	0.440	0.5 U	-	1.81	1.80	0.0400 J	0.5 U	2.54	2.40	-	0.0500	0.5 U
Barium	µg/L	-	8.99	8.40	77.0	76.7	-	48.6	48.1	72.9	92.1	36.9	34.4	-	89.7	90.7
Beryllium	µg/L	-	0.0100 J	0.1 U	0.0200	0.1 U	-	0.0600	0.1 U	0.02 U	0.1 U	0.0200 J	0.1 U	-	0.00900 J	0.1 U
Boron	mg/L	0.684	0.748	0.731	0.150	0.159	1.89	2.37	2.56	0.284	0.283	0.313	0.296	-	0.326	0.314
Cadmium	µg/L	-	0.02 U	0.1 U	0.0300	0.1 U	-	0.0100 J	0.1 U	0.00700 J	0.1 U	0.0100 J	0.1 U	-	0.02 U	0.1 U
Calcium	mg/L	-	118	104	61.8	47.6	-	99.6	89.6	4.17	3.58	6.90	5.49	-	10.3	10.0
Chloride	mg/L	-	13.4	15.5	5.73	6.60	-	33.6	35.0	26.5	27.7	41.5	41.9	35.8	36.8	37.3
Chromium	µg/L	-	0.0860	1 U	0.268	1 U	-	0.775	1 U	0.135	1 U	0.277	1 U	-	0.104	1 U
Cobalt	µg/L	-	0.432	0.5 U	0.168	0.5 U	-	0.197	0.5 U	0.00700 J	0.5 U	0.285	0.5 U	-	0.0100 J	0.5 U
Combined Radium	pCi/L	-	2.49	3.51	4.13	2.77	-	1.62	0.929	0.684	0.253	0.576	0.547	-	0.267	1.11
Fluoride	mg/L	-	0.590	0.300	0.220	0.190	-	1.40	1.30	1.16	1.60	1.26	1.20	-	0.630	0.590
Lead	µg/L	-	0.0320	0.5 U	0.200	0.5 U	-	0.202	0.5 U	0.0210	0.5 U	0.200	0.5 U	-	0.0100 J	0.5 U
Lithium	mg/L	-	0.0470	0.0549	0.00900	10 U	-	0.0150	0.0165	0.0110	0.0140	0.0150	0.0182	-	0.0130	0.0184
Mercury	µg/L	-	0.005 U	0.000600	0.005 U	0.00178	-	0.005 U	0.000730	0.005 U	0.51 U	0.005 U	0.00356	-	0.005 U	0.5 U
Molybdenum	µg/L	-	0.450	0.5 U	0.120	0.5 U	-	9.89	10.4	0.0700 J	0.5 U	1.76	1.70	-	0.320	0.5 U
pH	SU	7.21	7.09	7.35	7.82	7.53	7.42	7.16	7.72	8.57	8.70	8.24	7.64	7.49	7.42	7.30
Selenium	µg/L	-	0.0300 J	0.5 U	0.1 U	0.5 U	-	0.0600 J	0.5 U	0.1 U	0.5 U	0.0600 J	0.5 U	-	0.1 U	0.5 U
Total Dissolved Solids	mg/L	-	3190	3450	459	433	-	871	876	774	671	755	713	-	614	604
Sulfate	mg/L	-	1580	1690	92.7	96.7	-	290	315	141	97.8	123	121	-	78.9	83.9
Thallium	µg/L	-	0.0200 J	0.5 U	0.05 U	0.5 U	-	0.0100 J	0.5 U	0.05 U	0.5 U	0.0100 J	0.5 U	-	0.05 U	0.5 U

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
-: Not sampled

Table 1: Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II

Parameter	Unit	MGS-2		MGS-3			MGS-4		MGS-5	
		5/16/2018	8/28/2018	1/24/2018	5/17/2018	8/28/2018	5/16/2018	8/23/2018	5/15/2018	8/21/2018
		Assessment		Detection	Assessment		Assessment		Assessment	
Antimony	µg/L	0.100	0.5 U	-	0.220	0.5 U	0.0400 J	0.5 U	0.0400 J	0.5 U
Arsenic	µg/L	9.29	8.00	-	8.68	10.8	9.52	7.10	18.7	16.0
Barium	µg/L	28.5	27.1	-	11.8	10.4	12.1	11.7	91.9	104
Beryllium	µg/L	0.02 U	0.1 U	-	0.02 U	0.1 U	0.02 U	0.1 U	0.02 U	0.1 U
Boron	mg/L	0.313	0.238	0.338	0.444	0.924	0.319	0.192	0.433	0.331
Cadmium	µg/L	0.02 U	0.1 U	-	0.0100 J	0.1 U	0.02 U	0.1 U	0.02 U	0.1 U
Calcium	mg/L	8.83	9.21	-	327	150	9.39	6.45	3.15	2.92
Chloride	mg/L	25.7	26.2	-	11.3	24.2	11.5	12.2	167	171
Chromium	µg/L	0.156	1 U	-	0.152	1 U	0.157	1 U	0.272	1 U
Cobalt	µg/L	0.426	0.5 U	-	0.359	1.60	0.142	0.5 U	0.0260	0.5 U
Combined Radium	pCi/L	0.709	0.456	-	1.94	1.15	0.228	0.941	1.62	1.43
Fluoride	mg/L	0.470	0.420	-	0.210	0.110	0.610	0.610	5.50	5.10
Lead	µg/L	0.0250	0.5 U	-	0.0780	0.5 U	0.0310	0.5 U	0.0430	0.650
Lithium	mg/L	0.0110	0.0152	-	0.0280	0.0514	0.00600	10 U	0.0100	0.0151
Mercury	µg/L	0.005 U	0.5 U	-	0.005 U	0.5 U	0.005 U	0.000800	0.005 U	0.000760
Molybdenum	µg/L	1.26	1.40	-	1.66	1.30	2.72	2.10	3.26	2.90
pH	SU	7.58	7.53	6.81	6.74	6.47	8.16	8.50	8.36	8.52
Selenium	µg/L	0.1 U	0.5 U	-	0.0400 J	0.5 U	0.1 U	0.5 U	0.1 U	0.5 U
Total Dissolved Solids	mg/L	630	583	-	1870	2220	600	519	1100	1090
Sulfate	mg/L	117	115	-	1100	1380	121	73.1	3.60	3.80
Thallium	µg/L	0.05 U	0.5 U	-	0.0890	0.5 U	0.0100 J	0.5 U	0.0100 J	0.5 U

Notes:
mg/L: milligrams per liter
µg/L: micrograms per liter
SU: standard unit
pCi/L: picocuries per liter
U: Parameter was not present in concentrations above method detection limit and is reported as the reporting limit
J: Estimated value. Parameter was detected in concentrations below the reporting limit
-: Not sampled

Table 2: Residence Time Calculation Summary
Cardinal Plant - Fly Ash Reservoir II

Geosyntec Consultants, Inc.

			2018-05		2018-08	
CCR Management Unit	Monitoring Well	Well Diameter (inches)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)
Fly Ash Reservoir II	CA-0622A [1]	2.0	9.0	6.7	7.7	7.9
	FA-8 [2]	2.0	16.3	3.7	19.9	3.1
	M-10 [2]	0.75	35.4	0.6	56.9	0.4
	M-1003 [2]	2.0	8.8	6.1	8.7	6.1
	M-1004 [2]	2.0	7.2	8.4	5.8	10.5
	M-11 [2]	1.0	1.8	16.6	16.1	1.9
	M-12 [1]	2.0	4.3	14.2	NC	NC
	M-13 [2]	2.0	11.0	5.5	8.8	7.0
	M-1302 [1]	2.0	4.4	13.8	6.4	9.5
	M-1309 [2]	2.0	9.0	6.8	9.0	6.8
	M-14 [2]	2.0	10.6	5.7	19.8	3.1
	M-15 [2]	2.0	309.3	0.2	8.6	7.0
	M-16 [2]	2.0	9.1	6.7	17.4	3.5
	M-21 [2]	2.0	20.9	2.9	13.7	4.4
	M-22 [2]	2.0	3.8	16.0	5.0	12.1
	M-23 [2]	2.0	30.0	2.0	20.9	2.9
	M-6 [1]	1.0	14.9	2.0	NC	NC
	M-8 [2]	2.0	8.0	7.6	7.6	8.0
	M-GS-1 [2]	2.0	6.2	9.8	304.6	0.2
	M-GS-2 [2]	2.0	17.0	3.6	32.7	1.9
	M-GS-3 [2]	2.0	8.5	7.1	27.7	2.2
	M-GS-4 [2]	2.0	12.7	4.8	7.8	7.8
	M-GS-5 [1]	2.0	5.3	11.5	5.0	12.2

Notes:
[1] - Background Well
[2] - Downgradient Well
NC - Groundwater residence time could not be calculated

Table 3: Detection Monitoring Data Evaluation
Cardinal Plant - Fly Ash Reservoir II

Parameter	Units	Description	FA-8		M-8	M-10		M-11		M-13	M-14	M-15	M-16	M-21	
			9/26/2017	1/24/2018	10/3/2017	10/11/2017	1/24/2018	10/4/2017	1/24/2018	9/28/2017	10/10/2017	9/27/2017	10/2/2017	10/2/2017	1/24/2018
Boron	mg/L	Interwell Background Value (UPL)	0.411												
		Detection Monitoring Result	**4.86**	**5.16**	0.017	**0.577**	**0.599**	**4.69**	**5.1**	0.287	0.261	0.272	0.191	**3.07**	**3.24**
Calcium	mg/L	Intrawell Background Value (UPL)	242		109	16.9		233		14.7	1.4	2.5	2.5	329	
		Detection Monitoring Result	211	-	93.7	13.5	-	191	-	7.8	0.485	1.85	2.11	245.5	-
Chloride	mg/L	Intrawell Background Value (UPL)	66.5		5.99	13.6		61.0		3.14	1.52	31.5	9.5	104	
		Detection Monitoring Result	53.1	-	5.68	13.5	-	52.6	-	2.43	1.4	28.5	9.26	62.55	-
Fluoride	mg/L	Intrawell Background Value (UPL)	0.579		0.132	0.823		0.667		1.80	0.868	1.43	0.451	0.1	
		Detection Monitoring Result	0.52	-	0.09	0.66	-	0.49	-	1.19	0.74	1.29	0.33	**0.44**	0.1
pH	SU	Intrawell Background Value (UPL)	7.80		9.24	8.92		8.13		9.03	9.92	9.92	9.54	8.56	
		Intrawell Background Value (LPL)	6.22		5.77	7.35		7.19		7.88	7.96	7.67	8.13	6.00	
		Detection Monitoring Result	-	7.38	8.34	8.58	8.01	**8.44**	7.75	8.63	9.24	-	8.4	7.14	7.14
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	1577		478	815		1655		512	406	619	802	1961	
		Detection Monitoring Result	1560	-	435	732	-	1570	-	485	381	572	737	1835	-
Sulfate	mg/L	Intrawell Background Value (UPL)	946		102	147		1032		25.9	3.30	11.8	276	1113	
		Detection Monitoring Result	**958**	945	94.2	133	-	886	-	12.4	0.5	3.1	247	993	-

Parameter	Units	Description	M-22		M-23		M-1003	M-1004		M-1309	MGS-1		MGS-2		MGS-3		MGS-4
			9/27/2017	1/24/2018	10/3/2017	1/24/2018	9/28/2017	9/27/2017	1/24/2018	9/28/2017	10/5/2017	1/23/2018	10/5/2017	1/23/2018	10/5/2017	1/24/2018	10/2/2017
Boron	mg/L	Interwell Background Value (UPL)	0.411														
		Detection Monitoring Result	**4.14**	**4.26**	**0.601**	**0.684**	0.124	**2.25**	**1.89**	0.278	0.268	-	0.203	-	**0.87**	0.338	0.183
Calcium	mg/L	Intrawell Background Value (UPL)	206		131		73.3	107		20.7	8.21		19.9		290		171
		Detection Monitoring Result	195	-	104	-	61.6	100	-	9.55	7.22	-	3.97	-	94.4	-	11.1
Chloride	mg/L	Intrawell Background Value (UPL)	52.3		14.4		5.00	34		46	36.5		31.7		31.2		17.7
		Detection Monitoring Result	51.8	-	12.8	-	4.9	32.1	-	39.2	**36.7**	35.8	26.5	-	28.7	-	11.5
Fluoride	mg/L	Intrawell Background Value (UPL)	0.485		0.640		0.252	1.96		1.43	0.700		0.502		0.432		0.693
		Detection Monitoring Result	0.35	-	0.48	-	0.19	1.38	-	1.07	0.5	-	0.4	-	0.24	-	0.53
pH	SU	Intrawell Background Value (UPL)	8.19		8.49		8.17	7.81		9.23	8.67		8.21		8.99		9.41
		Intrawell Background Value (LPL)	6.05		6.20		6.73	6.84		6.95	6.43		6.95		5.08		5.85
		Detection Monitoring Result	-	7.02	7.96	7.21	7.47	-	7.42	8.2	8.58	7.49	**8.45**	7.52	7.84	6.81	8.34
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	998		3475		508	1024		896	644		661		2632		2068
		Detection Monitoring Result	985	-	3210	-	488	848	-	769	632	-	600	-	2320	-	586
Sulfate	mg/L	Intrawell Background Value (UPL)	428		1879		123	379		338	94.2		165		1604		1263
		Detection Monitoring Result	**435**	421	1620	-	105	267	-	149	82.4	-	79.6	-	1360	-	98.3

Notes:
-: Not Sampled
UPL: Upper prediction limit
LPL: Lower prediction limit
Bold values exceed the background value.
Background values are shaded gray.

Table 4: Groundwater Protection Standards
Cardinal Plant - Fly Ash Reservoir II

Constituent Name	MCL	RSL	Calculated UTL
Antimony, Total (mg/L)	0.006		0.00037
Arsenic, Total (mg/L)	0.01		0.037
Barium, Total (mg/L)	2		1.06
Beryllium, Total (mg/L)	0.004		0.002
Cadmium, Total (mg/L)	0.005		0.0003
Chromium, Total (mg/L)	0.1		0.016
Cobalt, Total (mg/L)	n/a	0.006	0.027
Combined Radium, Total (pCi/L)	5		9.81
Fluoride, Total (mg/L)	4		5.5
Lead, Total (mg/L)	n/a	0.015	0.03
Lithium, Total (mg/L)	n/a	0.04	0.14
Mercury, Total (mg/L)	0.002		0.00001
Molybdenum, Total (mg/L)	n/a	0.1	0.0601
Selenium, Total (mg/L)	0.05		0.0029
Thallium, Total (mg/L)	0.002		0.00021

Note:
Grey cell indicates calculated UTL is higher than either the MCL or RSL.
MCL = Maximum Contaminant Level
RSL = Regional Screening Level
Calculated UTL (Upper Tolerance Limit) represents site-specific background values.
The higher of the calculated UTL or MCL/RSL is used as the GWPS.