

**2020 ANNUAL GROUNDWATER
MONITORING REPORT**

FEDERAL CCR RULE

**CARDINAL PLANT – FLY ASH RESERVOIR II
BRILLIANT, OHIO**

Submitted to



Cardinal Operating Company

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LIST OF ACRONYMS AND ABBREVIATIONS

ACM	Assessment of Corrective Measures
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
cm/s	centimeters per second
ESP	Electrostatic Precipitator
FAD	Fly Ash Dam
FAR	Fly Ash Reservoir
FGD	Flue Gas Desulfurization
GWPS	Groundwater Protection Standards
MCL	Maximum Contaminant Level
MW	Megawatt
NPDES	National Pollutant Discharge Elimination System
RSL	Risk-Based Screening Level
RSW	Residual Solid Waste
SCR	Selective Catalytic Reduction
SSI	Statistically Significant Increase
SSL	Statistically Significant Level
USEPA	United States Environmental Protection Agency

1. EXECUTIVE SUMMARY

Geosyntec Consultants (Geosyntec) has prepared this 2020 Annual Groundwater Monitoring Report (Report) for the Fly Ash Reservoir II (FAR II), an existing CCR unit at the Cardinal Generating Plant in Brilliant, Ohio (Site). This Report summarizes the groundwater monitoring activities conducted pursuant to the CCR Rule from January 1, 2020 through December 31, 2020 (the 2020 annual reporting period). This Report was prepared in accordance with 40 CFR 257.90(e).

At the start of the 2020 annual reporting period, FAR II was operating under the assessment monitoring program (40 CFR 257.95). FAR II remained in the assessment monitoring program throughout the 2020 annual reporting period. Statistical evaluations of two assessment monitoring events were completed during this annual reporting period – the second semiannual event of 2019 (October 2019) and the first semiannual event of 2020 (April 2020). The statistical analysis of the second semi-annual sampling event of 2020 (October 2020) will be completed in 2021 and presented in next year's Annual Groundwater Monitoring Report.

For the second semiannual assessment monitoring event of 2019, statistically significant levels (SSLs) above the groundwater protection standard were identified for lithium and molybdenum at downgradient monitoring wells FA-8 and M-11. The following statistically significant increases (SSIs) over background were identified:

- Boron SSIs were identified at FA-8, M-10, M-1004, M-11, M-21, M-22, M-23, and MGS-3.
- Calcium SSIs were identified at M-1004, M-13, MGS-1, and MGS-2.
- A chloride SSI was identified at MGS-1.
- Fluoride SSIs were identified at M-13 and M-21.
- A pH SSI was identified at M-13, where the reported value was below the lower prediction limit.
- A sulfate SSI was identified at M-13.
- A TDS SSI was identified at MGS-2.

For the first semiannual event of 2020, SSLs were identified for lithium and molybdenum at downgradient monitoring wells FA-8 and M-11. The following SSIs over background were identified:

- Boron SSIs were identified at FA-8, M-10, M-1004, M-11, M-21, M-22, M-23, and MGS-3.
- Calcium SSIs were identified at M-1003 and M-1004.
- Chloride SSIs were identified at M-8, M-16, M-23, M-1003, M-1004, MGS-3, and MGS-4.
- Fluoride SSIs were identified at M-8, M-10, M-11, M-13, and M-21.
- Sulfate SSIs were identified at M-8, M-13, M-16, and M-1003.

The assessment of corrective measures for the lithium and molybdenum SSLs was completed on July 9, 2019 and a revised version was posted to the public website on November 30, 2020. The public meeting for the assessment of corrective measures was held on September 4, 2019 in Steubenville, Ohio. A remedy was selected on October 27, 2020. Remedial activities were not initiated in the current annual reporting period and instead are planned to begin in 2021.

2. 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 annually. Geosyntec Consultants (Geosyntec) has prepared this Report for the Fly Ash Reservoir II (FAR II), an existing CCR unit at the Cardinal Generating Plant in Brilliant, Ohio (Site). This Report summarizes the groundwater monitoring activities conducted pursuant to the CCR Rule through December 31, 2020.

3. SITE SUMMARY

3.1 Site Description

The Site is located one mile south of Brilliant, Ohio in Jefferson County (**Figure 1**) and is operated by Cardinal Operating Company (Cardinal). Located along the Ohio River, the generating station consists of three coal-powered units with an 1,800-megawatt (MW) 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 immediately east of the 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 units' 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).

3.2 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 is comprised of unconsolidated mine waste and shallow sandstone and limestone deposits overlying a discontinuous shale aquitard above the Morgantown Sandstone. Groundwater in the uppermost aquifer generally flows south-southeast towards the Ohio River with hydraulic conductivity ranging from 1×10^{-1} to 1×10^{-9} 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).

4. 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 the *Groundwater Monitoring Network Design Report* (Geosyntec, 2017a).

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 M-GS-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, M-GS-1, M-GS-2, M-GS-3, and M-GS-4) are used as compliance wells. Monitoring well M-2000 was installed in 2019 to facilitate characterization of the nature and extent of the release within the corrective measures program.

5. CCR RULE GROUNDWATER KEY ACTIVITIES COMPLETED

5.1 Statistical Analysis Plan Revision

A statistical analysis plan was previously prepared for the FAR II during the background monitoring period (Geosyntec, 2017b). Geosyntec's *Statistical Analysis Plan* (Geosyntec, 2020a) describes a logic process regarding the statistical analysis of groundwater data collected in compliance with the Federal CCR Rule. The revised statistical analysis plan primarily incorporates statistical procedures and reporting requirements for corrective action monitoring and incorporates a revision to the CCR rules that specifies screening levels for constituents that do not have a maximum contaminant level.

5.2 2020 Statistical Evaluation Activities

For each assessment monitoring event, 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) and the Site's *Statistical Analysis Plan* (Geosyntec, 2020a). The established GWPSs were determined to be the greater value of the background concentration and the maximum contaminant level (MCL) or risk-based screening level (RSL) for each Appendix IV parameter. The current GWPSs are presented in **Table 1**.

A statistical evaluation of the October 2019 assessment monitoring data was completed in January 2020 and is described in the *Statistical Analysis Summary – Fly Ash Reservoir* (Geosyntec, 2020b). The statistical analysis report included an evaluation of statistically significant levels (SSLs) for

Appendix IV parameters and statistically significant increases (SSIs) for Appendix III parameters. Additionally, prediction limits for interwell tests were recalculated using data collected during the 2019 assessment monitoring events. The statistical analysis report identified SSLs of lithium and molybdenum above their respective GWPSs at monitoring wells FA-8 and M-11. SSIs of all Appendix III constituents were identified.

A statistical evaluation of the April 2020 assessment monitoring data was completed in August 2020 and is described in the *Statistical Analysis Summary – Fly Ash Reservoir* (Geosyntec, 2020c). The GWPSs were recalculated using the April 2020 data, with these GWPSs presented in **Table 1**. The statistical analysis report included an evaluation of SSLs for Appendix IV parameters and an evaluation of SSIs for Appendix III parameters. The interwell prediction limit for boron was updated; however, the remaining Appendix III constituents were not updated due to insufficient data. The statistical analysis report identified SSLs of lithium and molybdenum above their respective GWPS at monitoring wells FA-8 and M-11. Additional exceedances were identified for boron, calcium, chloride, fluoride, and sulfate.

An alternate source was not identified for the SSLs following either assessment monitoring event and the CCR unit continued the selection and implementation of corrective measures, as discussed in **Section 5**.

5.3 2020 Sampling and Data Evaluation Activities

5.3.1 Assessment Monitoring Program

Assessment monitoring sampling events were conducted in April and October 2020 in accordance with 40 CFR 257.95(b) and 40 CFR 257.95(d)(1). Samples were analyzed for all Appendix III and Appendix IV parameters, with results provided in **Table 2**. A revision of the GWPS and statistical evaluation of the October 2020 assessment monitoring data is ongoing and will be completed outside of the timeframe of this report.

5.3.2 Groundwater Elevation and Flow Velocities

Prior to sampling, a synoptic round of groundwater level measurements was collected from the compliance and background monitoring wells. Potentiometric surface maps based on groundwater elevations measured during the April and October 2020 assessment monitoring events are presented on **Figure 3** and **Figure 4**, respectively. The potentiometric maps show that groundwater near FAR II flows southeast towards the Ohio River. The groundwater residence times within the wells at the FAR II ranged from 0.6 days at M-10 to 16.6 days at M-23. A summary of hydraulic gradients and groundwater residence times at the FAR II is provided in **Table 3**.

5.3.3 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;
- Chain of custody forms were 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.

All data received during 2020 were considered complete and usable.

6. CORRECTIVE MEASURES PROGRAM

Following detection of lithium and molybdenum SSLs at FA-8 and M-11, a Notification of Exceedance of Groundwater Protection Standards was published to the public internet site on February 7, 2019 in accordance with 40 CFR 257.105(h) (Buckeye Power, 2019). Monitoring well installation and sampling efforts to characterize the nature and extent of the release were described in the *Groundwater Characterization Report, Cardinal Site – Fly Ash Reservoir II* (Geosyntec, 2019a). An Assessment of Corrective Measures (ACM) Report was completed in July 2019 in accordance with 40 CFR 257.96 and published to the public internet site (Geosyntec, 2019b). The ACM report listed four potential corrective measures that may be appropriate for addressing the elevated lithium and molybdenum concentrations in Site groundwater. A public meeting was held on September 4, 2019 in Steubenville, Ohio where the selection and implementation of potential corrective measures outlined in the ACM Report were reviewed and discussed.

A semi-annual progress report which was completed in March 2020 and published to the public internet site indicated that Cardinal was continuing evaluation of groundwater flow conditions at the facility to determine the most effective remedy (Cardinal, 2020a). Additionally, a semi-annual progress report which was completed in September 2020 and published to the public internet site indicated that Cardinal was in the final phases of selecting a remedy and in progress of preparing a Remedy Selection Report (Cardinal, 2020b). The conclusions of the ACM and public comments resulted in the selection of closure of the FAR II unit with long-term monitoring as the selected remedial approach as detailed in the *Remedy Selection Report, Cardinal Site – Fly Ash Reservoir II* (Geosyntec, 2020d).

7. PROBLEMS ENCOUNTERED AND RESOLUTIONS

No problems were encountered during 2020 related to assessment monitoring activities at the FAR II. No monitoring wells were gauged dry or abandoned within the well network during 2020.

8. STATUS OF MONITORING PROGRAM

The Site was in the assessment monitoring program from May 2018 through January 2019 and transitioned to the corrective measures program in February 2019. The Site remained in the corrective measures program through 2020. Assessment monitoring events were conducted in April and October 2020. FAR II will remain in the corrective measures program in 2021.

9. PLANNED KEY ACTIVITIES FOR 2021

The following activities are planned for 2021 at the FAR II:

- The 2020 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 October 2020 assessment monitoring event will be completed, including a recalculation of the Site-specific GWPSs in accordance with the *Statistical Analysis Plan* (Geosyntec, 2020a). The FAR II's monitoring status will be confirmed following the evaluation;
- Two semi-annual groundwater assessment monitoring program events will be conducted;
- Implementation of the selected remedy will commence in 2021; and
- The 2021 Annual Groundwater Monitoring Report will be prepared for submittal in January 2022.

10. REFERENCES

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

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TABLES

**Table 1 - Groundwater Protection Standards
Cardinal Plant - Fly Ash Reservoir II**

Constituent	MCL	CCR- Rule Specified	Background Limit	GWPS
Antimony, Total (mg/L)	0.006	n/a	0.0025	0.006
Arsenic, Total (mg/L)	0.01	n/a	0.0372	0.0372
Barium, Total (mg/L)	2	n/a	1.24	2
Beryllium, Total (mg/L)	0.004	n/a	0.00202	0.004
Cadmium, Total (mg/L)	0.005	n/a	0.00022	0.005
Chromium, Total (mg/L)	0.1	n/a	0.0150	0.1
Cobalt, Total (mg/L)	n/a	0.006	0.0324	0.0324
Combined Radium, Total (pCi/L)	5	n/a	13.43	13.43
Fluoride, Total (mg/L)	4	n/a	6.6	6.6
Lead, Total (mg/L)	n/a	0.015	0.0572	0.0572
Lithium, Total (mg/L)	n/a	0.04	0.149	0.149
Mercury, Total (mg/L)	0.002	n/a	0.0000166	0.002
Molybdenum, Total (mg/L)	n/a	0.1	0.0812	0.1
Selenium, Total (mg/L)	0.05	n/a	0.00178	0.05
Thallium, Total (mg/L)	0.002	n/a	0.001	0.002

Notes:

MCL: Maximum Contaminant Level

CCR: Coal Combustion Residual

GWPS: Groundwater Protection Standard

Grey cell indicates background is higher than MCL.

**Table 2: 2020 Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II**

Parameter	Unit	CA-0622A		FA-8		M-6		M-8		M-10		M-11		M-12	
		4/9/2020	10/15/2020	4/20/2020	10/13/2020	4/14/2020	10/7/2020	4/15/2020	10/12/2020	4/15/2020	10/9/2020	4/17/2020	10/9/2020	4/15/2020	10/16/2020
Antimony	µg/L	2.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.63	0.5 U	0.5 U	0.5 U
Arsenic	µg/L	25.8	20.4	8.6	12.3	3.7	4	0.65	1.2	0.5 U	0.5 U	3.3	3.7	3.6	1.5
Barium	µg/L	1080	1160	24.3	26.9	381	392	116	112	78.8	80	22.2	23.1	71.1	28.1
Beryllium	µg/L	0.5 U	0.1 U	0.1 U	0.1 U	1.6	1.5	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Boron	mg/L	0.279	0.316	4.77	4.94	0.209	0.252	0.0257	0.0276	0.537	0.579	4.76	4.99	0.316	0.258
Cadmium	µg/L	0.5 U	0.1 U	0.1 U	0.1 U	0.2	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.15	0.1 U
Calcium	mg/L	76.7	74.6	208	202	14.5	14.2	101	101	11.9	12.6	206	217	368	143
Chloride	mg/L	4450	3670	48.5	49.3	36.7	42.1	6.9	6.7	13.7	13.3	53.4	47.5	163	332
Chromium	µg/L	5 U	1 U	1.3	1.2	10	10.5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Cobalt	µg/L	2.5 U	0.5 U	0.92	1.5	4.6	4.5	0.5 U	0.5 U	0.5 U	0.5 U	0.97	1	32.4	3.9
Combined Radium	pCi/L	10.5	9.12	0.755	0.767	7.41	7.25	1.4	0.929	0.792	0.787	0.5	0.44	0.41	1.3
Fluoride	mg/L	0.05 U	0.44	0.59	0.68	1.2	1.2	0.16	0.11	0.81	0.77	0.68	0.67	1.3	2
Lead	µg/L	0.5 U	0.5 U	0.5 U	0.78	21.2	21.9	0.5 U	0.5 U	1.1	0.88	0.5 U	0.57	1.1	0.5 U
Lithium	µg/L	99.5	84.2	194	192	22.3	23.9	10 U	10 U	20.4	22.8	191	189	149	79.9
Mercury	ng/L	0.00073	0.0011	0.00062	0.00181	0.00819	0.0126	0.0018	0.0005 U	0.00066	0.0007	0.00103	0.00064	0.00187	0.00089
Molybdenum	µg/L	2.5 U	2.3	298	297	1.1	1.4	0.5 U	0.5 U	2.2	2.2	289	307	0.5 U	0.55
Selenium	µg/L	2.5 U	0.5 U	1.4	0.66	1	2.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3.2	1.6	0.5 U	0.5 U
Sulfate	mg/L	47	62.1	740	717	5.2	16.7	103	103	133	139	778	775	1630	785
Thallium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Total Dissolved Solids	mg/L	6890	6290	1300	1320	606	652	422	432	710	712	1290	1290	2600	2130
pH	SU	7.5	8.0	7.1	8.2	7.4	7.9	7.2	7.9	8.4	8.1	7.2	9.3	7.2	6.3

Notes:

mg/L: milligrams per liter

µg/L: micrograms per liter

ng/L: nanogram 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

All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

**Table 2: 2020 Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II**

Parameter	Unit	M-13		M-14		M-15		M-16		M-21		M-22	
		4/16/2020	10/12/2020	4/21/2020	10/13/2020	4/8/2020	10/5/2020	4/9/2020	10/5/2020	4/21/2020	10/7/2020	4/15/2020	10/14/2020
Antimony	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.8	0.5 U	0.5 U	0.5 U
Arsenic	µg/L	0.57	0.67	0.5 U	0.5 U	1.8	1.7	0.5 U	0.5 U	440	2.6	0.5 U	0.5 U
Barium	µg/L	127	130	13.7	13.7	45.2	43.3	36.7	35.5	1650	14.3	24.1	24
Beryllium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	168	0.22	0.1 U	0.1 U
Boron	mg/L	0.24	0.248	0.219	0.217	0.25	0.278	0.175	0.201	3.78	3.16	3.79	3.8
Cadmium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	12.3	0.1 U	0.1 U	0.1 U
Calcium	mg/L	11.5	11.4	500 U	500 U	1.66	1.63	2.34	2.36	352	149	170	178
Chloride	mg/L	2.6	2.2	1.8	1.8	28.7	26.4	11	10.7	61	56	51.5	48.7
Chromium	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	95.7	1 U	1 U	1 U
Cobalt	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	143	0.9	1	1
Combined Radium	pCi/L	1.44	1.61	0.205	0.124	1.35	0.566	0.592	0.383	8.46	0.521	1.52	1.61
Fluoride	mg/L	1.9	2.1	0.85	0.78	1.3	1.3	0.37	0.4	0.14	0.16	0.49	0.44
Lead	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	689	0.57	0.5 U	0.5 U
Lithium	µg/L	11.8	12.8	10 U	10 U	10 U	10 U	12.2	10 U	122	73	65.1	54.5
Mercury	ng/L	0.00139	0.00072	0.00077	0.0005 U	0.0005 U	0.000806	0.0005 U	0.00093	0.679	0.00211	0.0005 U	0.0005 U
Molybdenum	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	707	20.8	77.2	70.8
Selenium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	79.8	0.5 U	0.5 U	0.5 U
Sulfate	mg/L	29.7	33.7	0.85	1	1.2	2.5	300	257	1030	866	403	373
Thallium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.5 U	0.5 U	0.5 U	0.5 U
Total Dissolved Solids	mg/L	511	535	340	327	548	555	791	768	900	1630	942	886
pH	SU	8.0	8.7	9.0	9.4	8.9	8.9	8.7	8.9	6.8	6.8	6.9	7.2

Notes:

mg/L: milligrams per liter

µg/L: micrograms per liter

ng/L: nanogram 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

All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

**Table 2: 2020 Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II**

Parameter	Unit	M-23		M-1003		M-1004		M-1302		M-1309		M-2000		MGS-1	
		4/17/2020	10/12/2020	4/21/2020	10/16/2020	4/16/2020	10/9/2020	4/8/2020	10/5/2020	4/20/2020	10/7/2020	4/13/2020	10/13/2020	4/16/2020	10/8/2020
Antimony	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Arsenic	µg/L	0.8	0.94	0.5 U	0.72	1.5	1.4	0.5 U	0.5 U	1.8	2.2	0.91	0.97	0.5 U	0.5 U
Barium	µg/L	7.6	8.3	72.5	85.9	40	44.3	114	108	29.7	39.9	26.1	25.1	81.1	74.2
Beryllium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.1 U	0.1 U	0.1 U	0.1 U
Boron	mg/L	0.666	0.678	0.14	0.12	2.38	2.71	0.27	0.289	0.277	0.288	4.48	4.94	0.273	0.293
Cadmium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Calcium	mg/L	103	99.1	74.5	75.5	108	109	3.18	3.37	3.96	4.92	200	195	11.8	14.1
Chloride	mg/L	15.7	13.6	7.2	7.5	37.6	35.7	30	28.5	39.5	40.5	54.2	52.3	35.4	37.1
Chromium	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2.1	1 U	1 U	1 U	1 U
Cobalt	µg/L	0.5 U	0.5 U	0.5 U	0.52	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.7	1.2	1.1	0.5 U	0.5 U
Combined Radium	pCi/L	2	2.6	2.47	3.22	1.06	0.948	0.963	0.0554	0.0571	1.44	0.623	2.58	0.245	2.01
Fluoride	mg/L	0.63	0.58	0.23	0.19	1.3	1.3	1.8	1.9	1.1	1.3	0.39	0.45	0.67	0.65
Lead	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.5	0.5 U	0.5 U	0.5 U	0.5 U
Lithium	µg/L	54	56.6	11.3	11.3	25.7	24.5	14.8	12.8	19.4	19.3	203	192	17.4	18.6
Mercury	ng/L	0.0005 U	0.00075	0.00091	0.00077	0.0005 U	0.0005 U	0.00051 U	0.00051 U	0.00178	0.00433	0.0005 U	0.0005 U	0.0005 U	0.0005 U
Molybdenum	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	9.9	10.5	0.5 U	0.5 U	1	1	216	212	0.5 U	0.5 U
Selenium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.52
Sulfate	mg/L	1740	1480	125	119	312	300	54.2	46.5	83.7	82.3	779	743	75.7	87.4
Thallium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Total Dissolved Solids	mg/L	3250	3270	440	483	850	870	719	680	679	644	1420	1370	599	618
pH	SU	7.1	7.7	7.3	8.0	7.2	7.4	8.6	8.6	8.2	7.3	7.2	8.2	7.5	7.3

Notes:

mg/L: milligrams per liter

µg/L: micrograms per liter

ng/L: nanogram 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

All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

**Table 2: 2020 Groundwater Data Summary
Cardinal Plant - Fly Ash Reservoir II**

Parameter	Unit	MGS-2		MGS-3		MGS-4		MGS-5		MGS-4		MGS-5	
		4/15/2020	10/8/2020	4/10/2020	10/8/2020	4/9/2020	10/7/2020	4/13/2020	10/15/2020	4/1/2019	10/8/2019	3/26/2019	10/2/2019
Antimony	µg/L	0.5 U	0.5 U	0.5 U	0.6	0.5 U	0.5 U	0.5 U	0.5 U	0.500 U	0.500 U	0.500 U	0.500 U
Arsenic	µg/L	6	6.1	35.9	150	4.1	2.9	8.5	9	5.40	5.10	14.1	12.5
Barium	µg/L	28.1	28.1	9.6	9.8	12.9	14.1	113	126	12.3	13.0	103	105
Beryllium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.100 U	0.100 U	0.100 U	0.100 U
Boron	mg/L	0.219	0.226	0.774	1.14	0.181	0.187	0.31	0.304	193	204	335	271
Cadmium	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.100 U	0.100 U	0.100 U	0.100 U
Calcium	mg/L	7.32	12.7	163	114	4.89	3	2.51	2.72	8,170	8,040	2,950	2,730
Chloride	mg/L	26.6	12.1	35.8	32	21.2	11.4	162	144	12.1	12.1	170	206
Chromium	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1.00 U	1.00 U	1.00 U	1.00 U
Cobalt	µg/L	0.5 U	0.5 U	0.82	0.92	0.5 U	0.5 U	2.5 U	0.5 U	0.500 U	0.500 U	0.500 U	0.500 U
Combined Radium	pCi/L	0.515	1.79	0.886	1.09	0.321	0.337	1.99	0.906	0.0710	0.221	0.181	0.527
Fluoride	mg/L	0.45	0.3	0.19	0.2	0.54	0.57	5.7	5.2	0.510	0.510	5.40	6.60
Lead	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.500 U	0.500 U	0.500 U	0.500 U
Lithium	µg/L	16.5	15.8	54.9	56.5	10 U	10 U	16	16	10.0 U	10.0 U	16.7	14.0
Mercury	ng/L	0.0005 U	0.0005 U	0.0005 U	0.00054	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.000500 U	0.000500 U	0.000500 U	0.000500 U
Molybdenum	µg/L	2.3	4.6	2.4	1.9	4.2	1.1	2.5 U	1.5	4.20	5.50	2.30	1.90
Selenium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.500 U	0.500 U	0.500 U	0.500 U
Sulfate	mg/L	105	392	1400	1460	134	16.6	42.8	142	98.1	86.7	3.50	1.60
Thallium	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.500 U	0.500 U	0.500 U	0.500 U
Total Dissolved Solids	mg/L	613	876	2020	2250	586	463	1130	1170	572	522	1,030	1,070
pH	SU	7.5	7.5	6.7	6.5	8.2	8.5	8.5	8.9	8.46	8.13	8.70	8.50

Notes:

mg/L: milligrams per liter

µg/L: micrograms per liter

ng/L: nanogram 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

All samples were collected as part of the assessment monitoring program in accordance with 40 CFR 257.90(e)(3).

**Table 3: Residence Time Calculation
Summary Cardinal Plant - Fly Ash Reservoir**

			II			
			2020-04		2020-10	
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-0622/A ^[1]	2.0	10.9	5.6	8.9	6.9
	FA-8 ^[2]	2.0	23.4	2.6	23.1	2.6
	M-10 ^[2]	0.75	35.2	0.6	36.0	0.6
	M-1003 ^[2]	2.0	9.2	5.8	11.9	4.5
	M-1004 ^[2]	2.0	11.4	5.3	9.9	6.1
	M-11 ^[2]	1.0	15.0	2.0	11.2	2.7
	M-12 ^[1]	2.0	5.8	10.5	6.2	9.7
	M-13 ^[2]	2.0	53.9	1.1	41.6	1.5
	M-1302 ^[1]	2.0	7.9	7.7	21.7	2.8
	M-1309 ^[2]	2.0	12.8	4.8	12.7	4.8
	M-14 ^[2]	2.0	74.7	0.8	79.9	0.8
	M-15 ^[2]	2.0	18.6	3.3	21.7	2.8
	M-16 ^[2]	2.0	15.0	4.1	14.5	4.2
	M-21 ^[2]	2.0	5.5	11.1	8.3	7.3
	M-22 ^[2]	2.0	12.7	4.8	10.7	5.7
	M-23 ^[2]	2.0	4.3	14.1	3.7	16.6
	M-6 ^[1]	1.0	11.0	2.8	12.1	2.5
	M-8 ^[2]	2.0	14.9	4.1	29.2	2.1
	M-GS-1 ^[2]	2.0	12.5	4.9	17.3	3.5
	M-GS-2 ^[2]	2.0	90.2	0.7	90.4	0.7
M-GS-3 ^[2]	2.0	19.5	3.1	17.2	3.5	
M-GS-4 ^[2]	2.0	34.9	1.7	19.5	3.1	
M-GS-5 ^[1]	2.0	6.5	9.4	5.4	11.2	

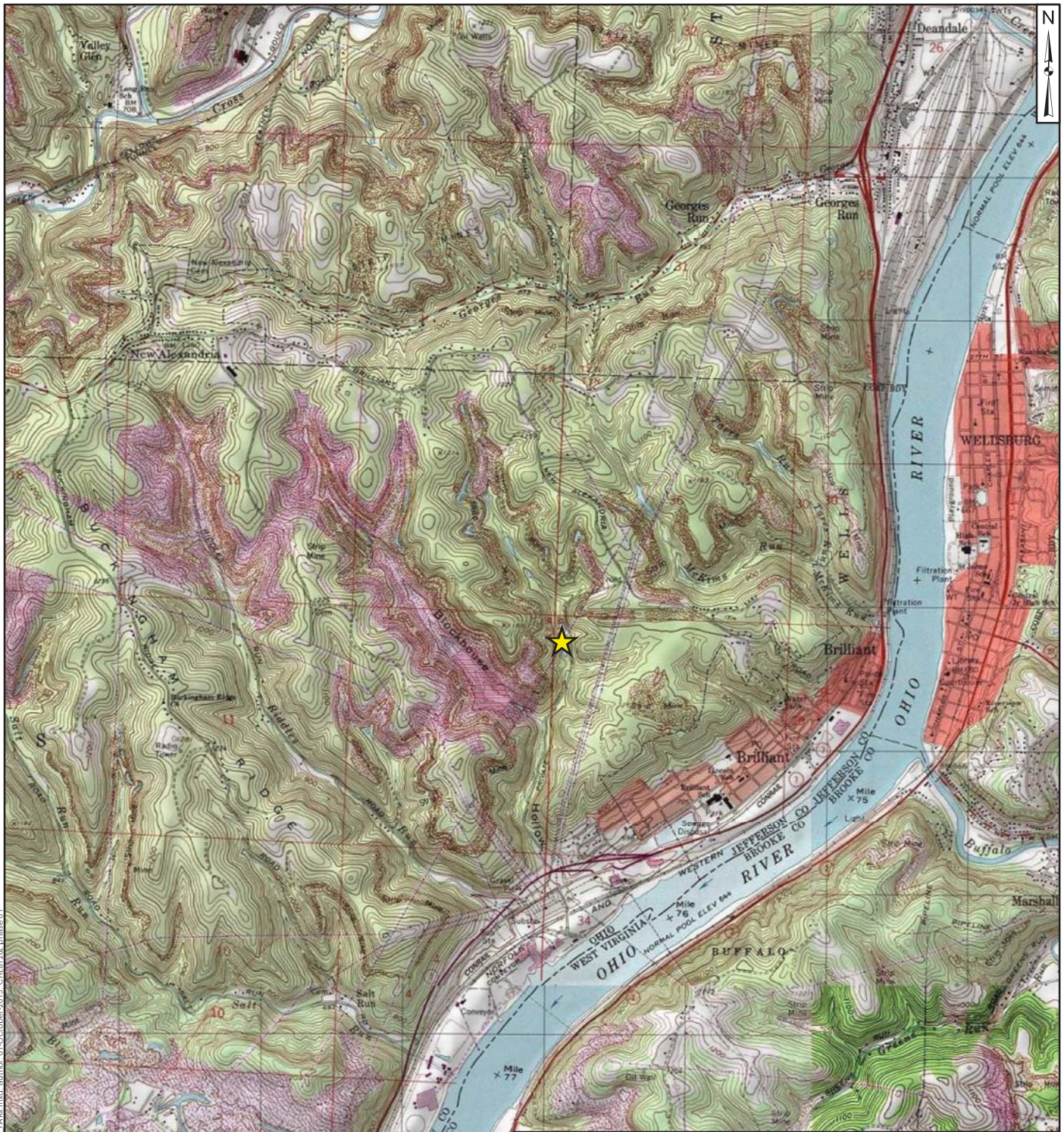
Notes:

[1] - Background Well

[2] - Downgradient Well

NC - Groundwater residence time could not be calculated

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

Figure

1

Ann Arbor, Michigan

01-October-2015



Monitoring Well Network

- ◆ Compliance Sampling Location
- ◆ Background Sampling Location
- ◆ Corrective Measures Delineation Well
- ▲ 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 - Fly Ash Reservoir II (Geosyntec, 2017) provided by Buckeye Power.



**Site Layout
Fly Ash Reservoir II**

AEP Cardinal Generating Plant
Brilliant, Ohio

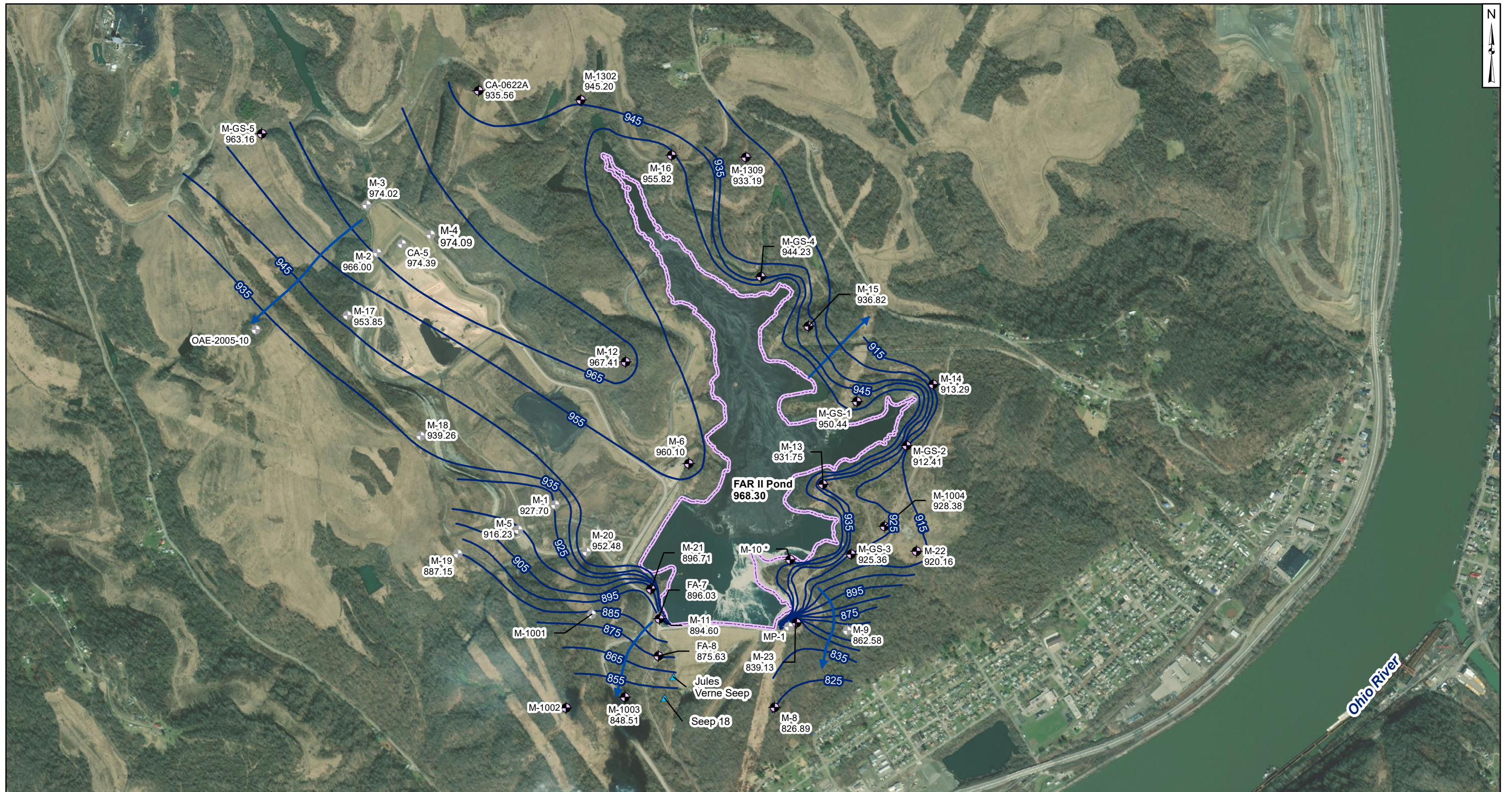
Geosyntec
consultants

Columbus, Ohio

2020/01/14

Figure

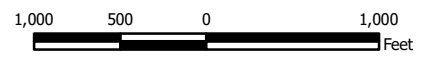
2



- Legend**
- ◆ FAR II Network Monitoring Well
 - ⊕ State/Other Program Monitoring Well
 - ▲ Seep
 - Groundwater Elevation Contour
 - Approximate Groundwater Flow Direction
 - ▭ Fly Ash Reservoir (FAR II)

Notes

- Monitoring well coordinates and water level data (collected on April 6 - 7, 2020) 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 AEP.
- Groundwater elevation units are feet above mean sea level (ft amsl).
- MW-10 was excluded during contouring, due to an anomalous value (890.88 ft amsl).
- Groundwater discharge observed from Jules Verne Seep location.
- OAE-2005-10, M-1001, and M-1002 were not gauged in April 2020.



**Potentiometric Surface Map - Morgantown Aquifer
Fly Ash Reservoir II
April 2020**

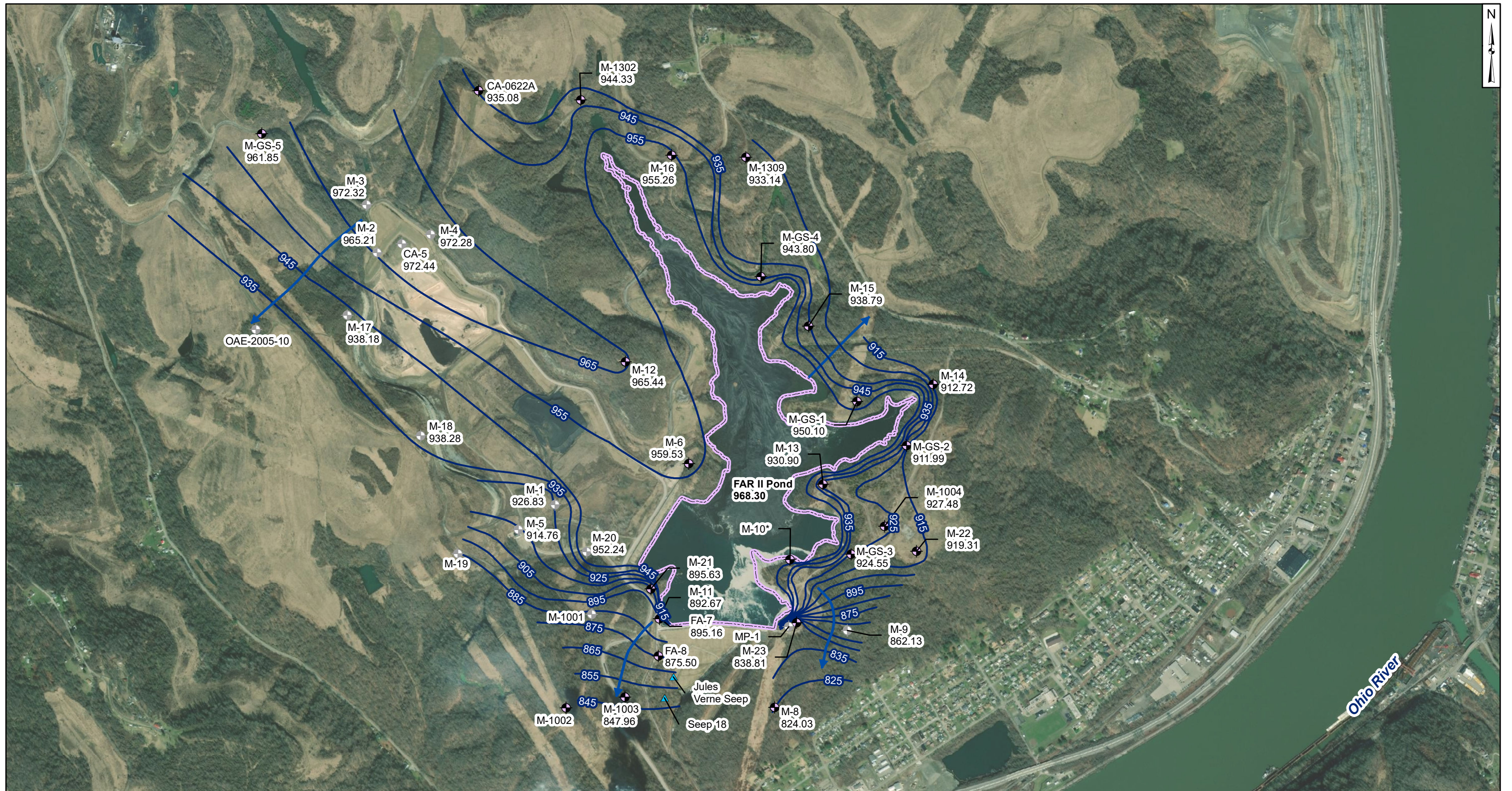
Buckeye Power Cardinal Generating Plant
Brilliant, Ohio



Columbus, Ohio

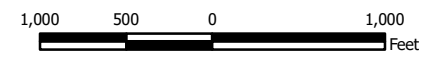
2021/01/08

Figure
3



- Legend**
- ◆ FAR II Network Monitoring Well
 - ⊕ State/Other Program Monitoring Well
 - ▲ Seep
 - Groundwater Elevation Contour
 - ➔ Approximate Groundwater Flow Direction
 - ⬡ Fly Ash Reservoir (FAR II)

- Notes**
- Monitoring well coordinates and water level data (collected on October 1, 2020) provided by Buckeye Power.
 - Site features based on information available in Groundwater Monitoring Network Evaluation - Cardinal Site - Fly Ash Reservoir II (Geosyntec, 2017).
 - Groundwater elevation units are feet above mean sea level (ft amsl).
 - MW-10 was excluded during contouring, due to an anomalous value (890.14 ft amsl).
 - Groundwater discharge observed from Jules Verne Seep location.
 - OAE-2005-10, M-19, M-1001, and M-1002 were not gauged in October 2020.



**Potentiometric Surface Map - Morgantown Aquifer
Fly Ash Reservoir II
October 2020**

Buckeye Power Cardinal Generating Plant
Brilliant, Ohio

Geosyntec
consultants

Figure

4

Columbus, Ohio

2021/01/07