2021 Annual Groundwater Monitoring Report for Fly Ash Reservoir (FAR) II Cardinal Operating Company – Cardinal Plant 306 County Road 7E Brilliant, Ohio

January 27, 2022

Submitted to:

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Cox-Colvin & ASSOCIATES, INC. ENVIRONMENTAL SERVICES

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Executive Summary

Cox-Colvin & Associates, Inc. (Cox-Colvin) has prepared this 2021 Annual Groundwater Monitoring Report (Report) for the Fly Ash Reservoir II (FAR II), an existing coal combustion residual (CCR) unit at the Cardinal Plant in Brilliant, Ohio. This report has been prepared in accordance with §257.90(e) of the Federal Coal Combustion Residuals Rules ("CCR Rules", 40 CFR Subpart D), which requires owners and/or operators of existing CCR landfills and surface impoundments to prepare a groundwater monitoring and corrective action report no later than January 31, annually. This report summarizes groundwater monitoring activities conducted pursuant to the CCR Rules from January 1, 2021, through December 31, 2021.

During 2021 groundwater monitoring, statistically significant increases (SSIs) above background concentrations were observed for the following constituents and wells:

- Boron: FA-8, M-10, M-1004, M-11, M-21, M-22, M-23, M-GS-3
- Calcium: FA-8, M-1004, M-13, M-16, M-GS-1
- Chloride: M-1003, M-1004, M-16, M-8, M-GS-3
- Fluoride: FA-8, M-10, M-11, M-13, M-21
- pH: FA-8
- Sulfate: M-1003, M-13, M-8
- Total Dissolved Solids (TDS): M-1003, M-13, M-16, M-GS-1, M-GS-2

Additionally, statistically significant decreases (SSDs) of pH below background levels were observed at M-11, M-13, and M-1309 during 2021 groundwater monitoring.

In accordance with §257.95 of the CCR Rules, assessment monitoring at FAR II was initiated in May 2018 after an SSI over groundwater background levels was first detected. FAR II remained in an assessment monitoring program from May 2018 through January 2019. In February 2019, it transitioned to a corrective action program following detection of statistically significant levels (SSLs) of groundwater contamination above groundwater protection standards (GWPSs). In accordance with §257.98(a)(1)(i) of the CCR Rules, assessment monitoring continues to be conducted as part of the corrective actions being performed. FAR II was operating under an assessment monitoring program (§257.95 of the CCR Rules) at the start of the 2021 annual reporting period and remained in the assessment monitoring program throughout the 2021 annual reporting period.

Statistical evaluations of two assessment monitoring events were completed during this annual reporting period – the second semiannual event of 2020 (October 2020)[1] and the

[1] Although samples were collected in October 2020, evaluation of the laboratory results was performed in 2021 and discussion of the evaluation is, therefore, included in this annual report. The October 2020 sampling results were included in the 2020 Annual Groundwater Monitoring Report.

first semiannual event of 2021 (April 2021). Consistent with previous evaluations, SSLs above GWPSs were identified for the following constituents and wells:

- Lithium: FA-8, M-11
- Molybdenum: FA-8, M-11

Statistical analysis of the October semi-annual sampling event of 2021 will be completed in 2022 and presented in next year's Annual Groundwater Monitoring Report.

Assessment of corrective measures for the lithium and molybdenum SSLs was initiated on February 7, 2019, and completed on July 9, 2019, with 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 initiated in 2021 and are ongoing pursuant to §257.98 of the CCR Rules.

1.0 Introduction

Cox-Colvin & Associates, Inc. (Cox-Colvin) has prepared this 2021 Annual Groundwater Monitoring Report for the Fly Ash Reservoir II (FAR II) at the Cardinal Plant in Brilliant, Ohio (Figure 1-1, Site). This report has been prepared in accordance with §257.90(e) of the Federal Coal Combustion Residuals Rule ("CCR Rules", 40 CFR Subpart D), which requires owners and/or operators of existing CCR landfills and surface impoundments to prepare a groundwater monitoring and corrective action report no later than January 31, annually. This report summarizes groundwater monitoring activities conducted pursuant to the CCR Rules from January 1, 2021, through December 31, 2021.

1.1 Site Summary

The Site is located one mile west and south of Brilliant, Ohio in Jefferson County and is operated by Cardinal Operating Company (Cardinal). Located along the Ohio River, the generating plant consists of three coal-powered units with an 1,800-megawatt (MW) capacity. Units 1 and 2 began operation in 1967 and Unit 3 began operation in 1977. Each generating unit is equipped with an electrostatic precipitator (ESP) for removal of fly ash particulate matter, a selective catalytic reduction (SCR) system for removal of nitrogen oxide, and flue gas desulfurization (FGD) systems for removal of sulfur dioxide (Geosyntec 2017).

1.2 CCR Unit Description

FAR II is an existing wet fly ash disposal reservoir that is located approximately one mile north of the 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 received 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).

As of July 2021, FAR II no longer receives waste streams and is presently undergoing closure. The CCR Unit and associated monitoring wells are shown in Figure 1-2.

I.3 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 FAR II lies the Monongahela Group, which consists 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 (Geosyntec 2017).

Based on monitoring well data in the vicinity of the FAR II, the uppermost aquifer is the Morgantown Sandstone unit. FAR II is partially incised through the Morgantown Sandstone. Hydraulic conductivity values of the Morgantown Sandstone are in the range of 1×10^{-1} to 1×10^{-6} cm/sec and tend to be driven by interconnected fracture flow. The Morgantown Sandstone has a gradient to the east, southeast, and southwest, generally flowing away from FAR II (Geosyntec 2017).

2.0 Groundwater Monitoring System

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 Evaluation (Geosyntec 2017).

The FAR II groundwater monitoring network consists of 24 monitoring wells, as shown in Figure 1-2. 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. Additionally, monitoring well M-2000 was installed in 2019 as a delineation well to facilitate characterization of the nature and extent of a previously identified release. Although it has been sampled semi-annually as part of the corrective measures program, it is not part of the groundwater monitoring system used for assessment monitoring.

No CCR monitoring wells were installed or decommissioned during 2021.

3.0 Groundwater Monitoring Program

In accordance with §257.95 of the CCR Rules, assessment monitoring at FAR II was initiated in May 2018 after a statistically significant increase (SSI) over groundwater background levels was detected for boron. As discussed in Section 4.3.1 concentrations of constituents in groundwater remain above background levels.

FAR II remained in an assessment monitoring program from May 2018 through January 2019. In February 2019, it transitioned to a corrective action program following detection of statistically significant levels (SSLs) of lithium and molybdenum in groundwater above their respective groundwater protection standards (GWPSs). In accordance with §257.98(a)(1)(i) of the CCR Rules, assessment monitoring continues to be conducted as part of the corrective action program. Concentrations of lithium and molybdenum in groundwater remain above their respective GWPSs, and FAR II remained in the corrective action program through 2021.

3.1 Statistical Analysis Plan

Evaluation of analytical data is performed in accordance with the Statistical Analysis Plan (Geosyntec 2020b), which describes a logic process regarding the statistical analysis of groundwater data collected in compliance with the Federal CCR Rules. No revisions were made to the Statistical Analysis Plan during 2021.

3.2 Monitoring Frequency

In accordance with §257.95(d)(1) of the CCR Rules, monitoring wells are sampled semi-annually for constituents listed in Appendix III of the CCR Rules. Additionally, annual sampling of all Appendix IV constituents is performed, along with semiannual sampling of those constituents in Appendix IV that were detected during the annual sampling of all Appendix IV constituents.

In September 2021, a demonstration was made that an alternative monitoring frequency may be appropriate (Cox-Colvin 2021a). A copy is provided in Appendix A. The purpose of the alternative monitoring frequency, which is optional, is to permit semiannual monitoring of all Appendix IV parameters, rather than only those that were previously detected during annual monitoring. The alternative monitoring frequency results in more, rather than less, analysis of groundwater quality. All Appendix IV parameters were analyzed during both 2021 sampling events.

There was no suspension of groundwater monitoring requirements at FAR II under §257.90(g) of the CCR Rules.

4.0 Key Actions Completed

The sections below summarize key actions completed in 2021 with respect to CCR Rules groundwater monitoring and corrective actions at FAR II.

4.1 Groundwater Elevation and Flow

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 2021 sampling events are presented in Figures 4-1 and 4-2, respectively. The potentiometric maps show that groundwater near FAR II flows southeast towards the Ohio River. Groundwater flow rate calculations relative to FAR II are summarized in Tables 4-1 and 4-2.

4.2 Groundwater Sampling

Table 4-3 contains a summary of groundwater samples collected for analysis in association with CCR activities at FAR II. The first (Spring) semi-annual monitoring event of 2021 was completed in April 2021 and the second (Fall) semi-annual monitoring event of 2021 was completed in October and November 2021. Additionally, monitoring well M-2000 was sampled in April and October 2021 as part of corrective action activities. A total of 53 samples were collected. Analytical results are summarized in Table 4-4.

4.3 Data Evaluation

Data evaluations performed in 2021 consisted of the following:

- Comparison of Fall 2020 monitoring data to GWPSs for Appendix IV constituents[2]
- Comparison of Spring 2021 monitoring data to background levels for Appendix III constituents
- Comparison of Spring 2021 monitoring data to GWPSs for Appendix IV constituents
- Comparison of Fall 2021 monitoring data to background levels for Appendix III constituents

Comparison of Fall 2021 monitoring data to GWPSs for Appendix IV constituents is ongoing and will be included in the 2022 annual report.

[2] Although samples were collected in October 2020, evaluation of the laboratory results was performed in 2021 and discussion of the evaluation is, therefore, included in this annual report. The October 2020 sampling results were included in the 2020 Annual Groundwater Monitoring Report.

4.3.1 Background Levels

Background levels in FAR II groundwater were previously updated for boron in August 2020 and for all other Appendix III constituents[3] in January 2020. In February 2021, boron background levels were updated using data collected between June 2016 and April 2020. Background levels were set to the calculated upper prediction limits (UPLs). Both UPLs and lower prediction limits (LPLs) were calculated for pH.

During 2021 groundwater monitoring, SSIs above background concentrations were identified for the constituents and wells listed below. While the prediction limits were calculated for a one-of-two retesting procedure, an SSI was conservatively assumed if a result was above its respective UPL. No resampling was performed to verify SSIs.

- Boron: FA-8, M-10, M-1004, M-11, M-21, M-22, M-23, M-GS-3
- Calcium: FA-8, M-1004, M-13, M-16, M-GS-1
- Chloride: M-1003, M-1004, M-16, M-8, M-GS-3
- Fluoride: FA-8, M-10, M-11, M-13, M-21
- pH: FA-8
- Sulfate: M-1003, M-13, M-8
- Total Dissolved Solids (TDS): M-1003, M-13, M-16, M-GS-1, M-GS-2

Additionally, statistically significant decreases (SSDs) of pH below background levels were observed at M-11, M-13, and M-1309.

Background concentrations of Appendix IV constituents in FAR II groundwater were established in February 2020 and updated in February 2021. Appendix IV background concentrations are used while determining GWPS values. Because the Appendix IV background levels are based upon upper threshold limits (UTLs), as opposed to UPLs, direct comparison of individual laboratory results to Appendix IV background levels is not appropriate. Instead, statistical evaluation is performed (using confidence bands) to determine whether GWPSs are exceeded, as discussed below.

4.3.2 Groundwater Protection Standards

A GWPS was established for each Appendix IV parameter in accordance with the United States Environmental Protection Agency's Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance (EPA 2009) and the Site's Statistical Analysis Plan (Geosyntec 2020b). The established GWPSs were determined to be the greater value of the background concentration and the maximum contaminant level (MCL) for each Appendix IV parameter. If an MCL was not available, values were obtained from §257.95(h)(2) of the CCR Rules. The current GWPSs are presented in Table 4-5.

[3] "Appendix III" and "Appendix IV" constituents refer to those constituents listed in the respective appendices of the CCR Rules.

A statistical evaluation of the October 2020 assessment monitoring data was completed in February 2021 (Geosyntec 2021) and included an evaluation of SSLs for Appendix IV parameters. SSLs were observed for the following constituents and wells.

- Lithium: FA-8, M-11
- Molybdenum: FA-8, M-11

A statistical evaluation of the April 2021 assessment monitoring data was completed in August 2021 (Cox-Colvin 2021b) and included an evaluation of SSLs for Appendix IV parameters. SSLs were observed for the following constituents and wells.

- Lithium: FA-8, M-11
- Molybdenum: FA-8, M-11

An alternate source was not identified for the SSLs, and corrective measures have been initiated, as discussed in Section 4.4.

Statistical evaluation of the October 2021 assessment monitoring data is ongoing and will be discussed in the 2022 annual groundwater monitoring report.

4.4 Corrective Actions

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 2019b). 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 2019a). 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 of potential corrective measures outlined in the ACM Report were reviewed and discussed.

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 2020a).

On July 13, 2021, Cardinal issued a notice of intent to close the FAR II CCR Unit (Buckeye Power 2021). The notice stated that the unit had ceased receiving waste streams and was initiating closure in place, in accordance with the Closure Plan and the Permit to Install issued by the Ohio EPA. The closure activities will include dewatering the FAR II, grading

the CCR, and installation of a final cover system. The final cover system is designed to meet the requirements of §257.102(d)(3) of the CCR Rules.

Closure is currently underway in accordance with §257.100 through §257.102 of the CCR Rules. The groundwater monitoring system will continue to be maintained during the post-closure care period defined in §257.104(c) of the CCR Rules.

5.0 Problems Encountered and Resolutions

On October 19, 2021, monitoring well M-10 was purged dry after initial collection of field parameters (including pH), but before samples for laboratory analysis could be collected. Samples for laboratory analysis were collected following recovery of groundwater in the well on October 20, 2021. To ensure sufficient sample volume for laboratory analyses, no field parameters were collected on October 20, 2021.

Due to a laboratory error, analysis of mercury in samples collected on October 18, 2021, from M-8 and M-23, and on October 20, 2021, from M-10 was not performed at the same time as other laboratory analyses. The oversight was identified in January 2022, and the laboratory was able to perform mercury analysis on the initial samples that had not yet been discarded. Although the samples from M-8 and M-23 were completed one day outside of method hold times, results are consistent with previous observations and the data is considered to be representative of groundwater conditions during the second semi-annual sampling event.

No monitoring wells were added or abandoned within the well network during 2021.

No alternative source demonstrations under either §257.94(e)(2) or §257.95(g)(3)(ii) of the CCR Rules were performed during 2021.

6.0 Projected Key Activities

It is anticipated that the FAR II will remain in the corrective measures program in 2022. The following activities are projected for FAR II:

- The 2021 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 2021 assessment monitoring event will be completed.
- Two semi-annual groundwater assessment monitoring program events will be conducted.
- A statistical evaluation of the first semiannual assessment monitoring event of 2022 will be completed.
- Implementation of the selected remedy will continue.
- The 2022 Annual Groundwater Monitoring Report will be prepared for submittal in January 2023.

7.0 References

Buckeye Power. 2021. *Notice of Intent to Close a CCR Unit, Cardinal Fly Ash Reservoir II (July 13, 2021).* Columbus, OH: Buckeye Power, Inc.

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Figures

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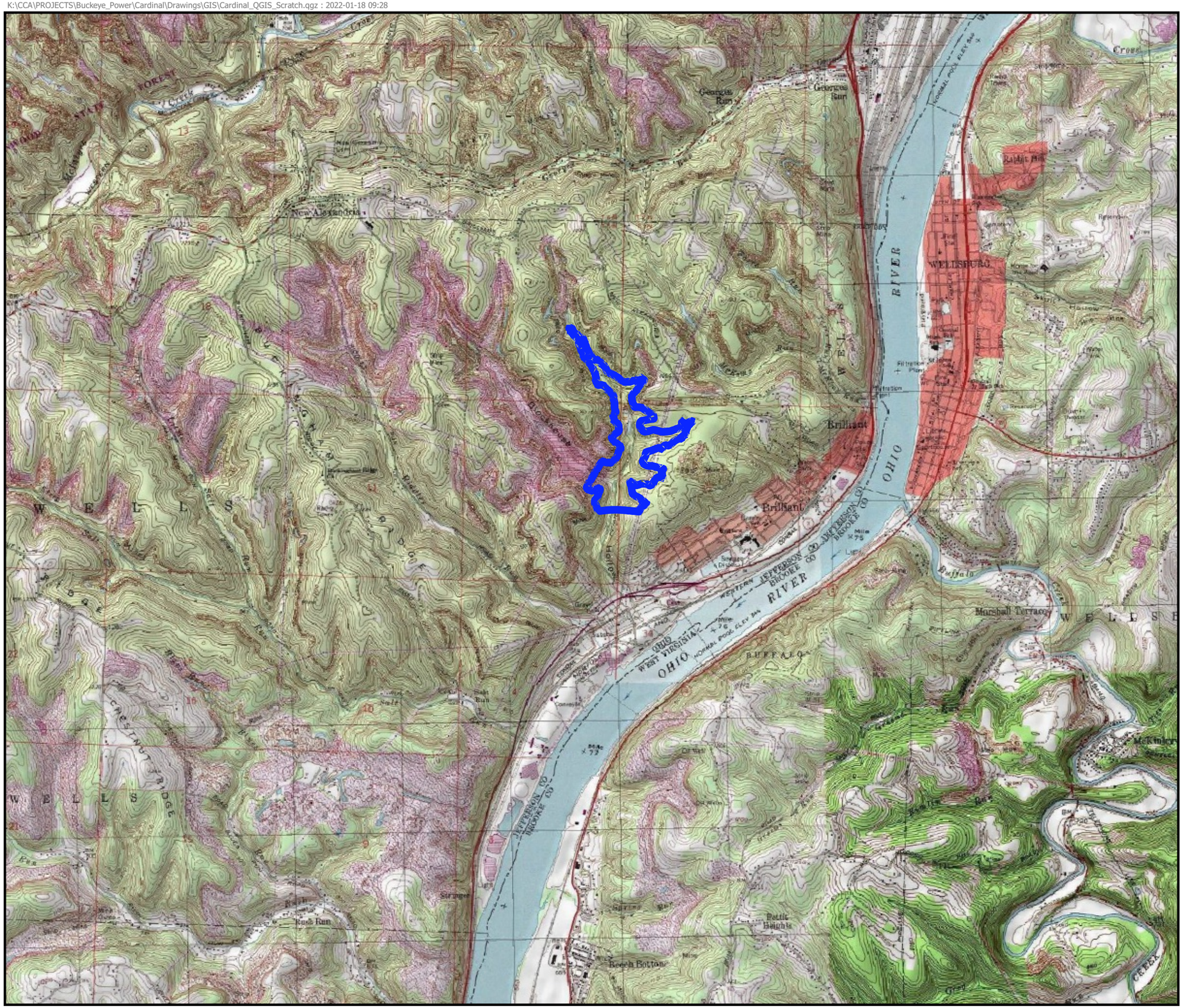

Legend

Fly Ash Reservoir (FAR) II

USGS Topographical Map

N

0 0.5 1 1.5 2 mi

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Figure

1-1

Site Location Map
Fly Ash Reservoir (FAR) II
Cardinal Plant
Brilliant, Ohio

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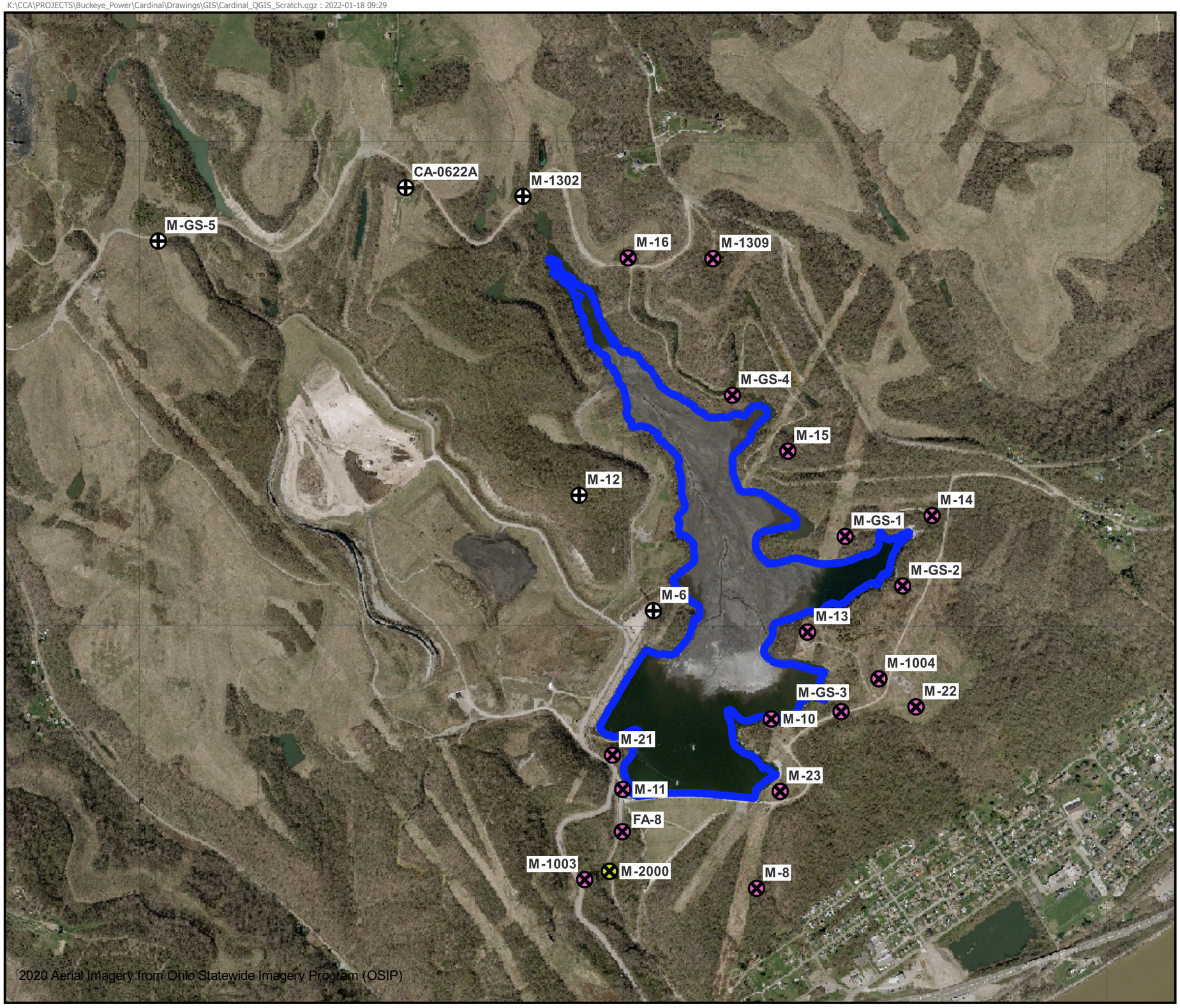

Legend

- Fly Ash Reservoir (FAR) II

Monitoring Wells

- Background
- Downgradient
- Delineation Well

N

0 1,000 2,000 3,000 ft

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Figure

1-2

CCR Unit and Monitoring Wells
Fly Ash Reservoir (FAR) II
Cardinal Plant
Brilliant, Ohio

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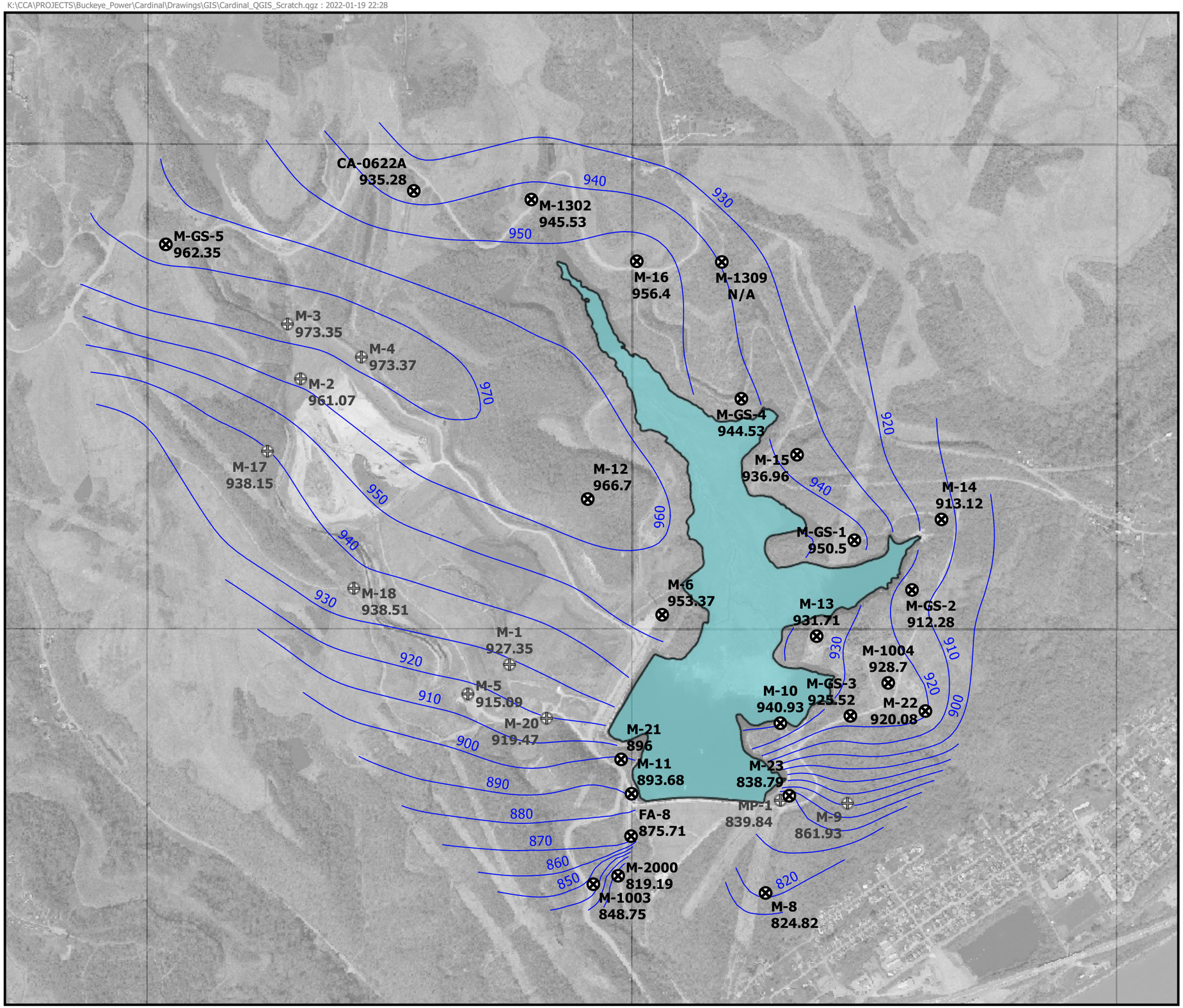

Legend

- FAR II Monitoring Well and Groundwater Elevation
- State/Other Program Monitoring Well
- Groundwater Elevation Contour
- Fly Ash Reservoir (FAR) II

N

0 1,000 2,000 3,000 ft

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Figure

4-1

Potentiometric Surface Map - Morgantown Sandstone
Fly Ash Reservoir II - April 5, 2021
Cardinal Plant
Brilliant, Ohio

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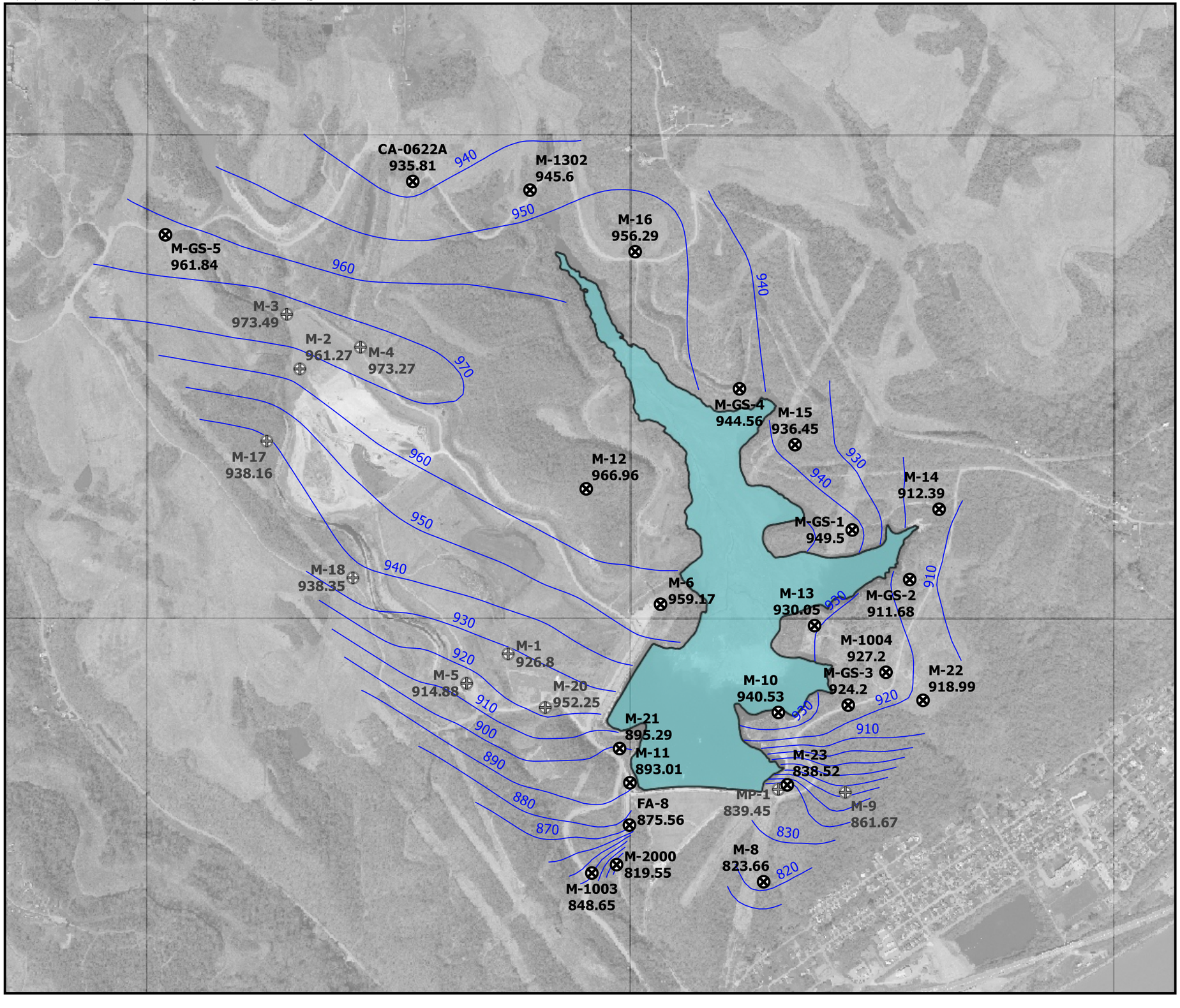

Legend

- FAR II Monitoring Well and Groundwater Elevation
- State/Other Program Monitoring Well
- Groundwater Elevation Contour
- Fly Ash Reservoir (FAR) II

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0 1,000 2,000 3,000 ft

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Figure

4-2

Potentiometric Surface Map - Morgantown Sandstone
Fly Ash Reservoir II - October 11, 2021
Cardinal Plant
Brilliant, Ohio

Tables

Table 4-1. Groundwater Flow Calculations, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio, April 2021

Program	Groundwater Zone	Well	Hydraulic Location[1]	Depth to Water (ft)	Potentiometric Elevation[3] (ft)	Hydraulic Gradient[2] (ft/ft)	Hydraulic Conductivity[4] (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter[5] (in.)	Residence Time[6] (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
FAR II CCR	Morgantown Sandstone	CA-0622A	Upgradient	227	935.28	0.01887	1.E-06	1.E-04	1.E-01	0.32	0.00017	**0.01671**	16.71252	6	0.030	**30**	2992
FAR II CCR	Morgantown Sandstone	FA-8	Downgradient	45.32	875.71	0.12993	1.E-06	1.E-04	1.E-01	0.32	0.00115	**0.11509**	115.09206	6	0.004	**4**	434
FAR II CCR	Morgantown Sandstone	M-6	Upgradient	57.2	953.37	0.00929	1.E-06	1.E-04	1.E-01	0.32	0.00008	**0.00823**	8.22692	3	0.030	**30**	3039
FAR II CCR	Morgantown Sandstone	M-8	Downgradient	68.38	824.82	0.02407	1.E-06	1.E-04	1.E-01	0.32	0.00021	**0.02132**	21.32406	6	0.023	**23**	2345
FAR II CCR	Morgantown Sandstone	M-10	Downgradient	92.49	940.93	0.02209	1.E-06	1.E-04	1.E-01	0.32	0.00020	**0.01957**	19.56516	4.87	0.021	**21**	2074
FAR II CCR	Morgantown Sandstone	M-11	Downgradient	86.53	893.68	0.03478	1.E-06	1.E-04	1.E-01	0.32	0.00031	**0.03081**	30.80561	3	0.008	**8**	812
FAR II CCR	Morgantown Sandstone	M-12	Upgradient	223.96	966.7	0.00463	1.E-06	1.E-04	1.E-01	0.32	0.00004	**0.00410**	4.10082	6	0.122	**122**	12193
FAR II CCR	Morgantown Sandstone	M-13	Downgradient	59.43	931.71	0.01278	1.E-06	1.E-04	1.E-01	0.32	0.00011	**0.01132**	11.32185	6	0.044	**44**	4416
FAR II CCR	Morgantown Sandstone	M-14	Downgradient	75.09	913.12	0.01883	1.E-06	1.E-04	1.E-01	0.32	0.00017	**0.01668**	16.68120	6	0.030	**30**	2997
FAR II CCR	Morgantown Sandstone	M-15	Downgradient	137.32	936.96	0.01385	1.E-06	1.E-04	1.E-01	0.32	0.00012	**0.01227**	12.26909	6	0.041	**41**	4075
FAR II CCR	Morgantown Sandstone	M-16	Downgradient	112.15	956.4	0.00778	1.E-06	1.E-04	1.E-01	0.32	0.00007	**0.00689**	6.89000	6	0.073	**73**	7257
FAR II CCR	Morgantown Sandstone	M-21	Downgradient	122.61	896	0.04285	1.E-06	1.E-04	1.E-01	0.32	0.00038	**0.03796**	37.95585	6	0.013	**13**	1317
FAR II CCR	Morgantown Sandstone	M-22	Downgradient	87.96	920.08	0.02769	1.E-06	1.E-04	1.E-01	0.32	0.00025	**0.02453**	24.52757	6	0.020	**20**	2039
FAR II CCR	Morgantown Sandstone	M-23	Downgradient	147.11	838.79	0.07007	1.E-06	1.E-04	1.E-01	0.32	0.00062	**0.06207**	62.07115	6	0.008	**8**	806
FAR II CCR	Morgantown Sandstone	M-1003	Downgradient	87.13	848.75	0.10312	1.E-06	1.E-04	1.E-01	0.32	0.00091	**0.09134**	91.34479	6	0.005	**5**	547
FAR II CCR	Morgantown Sandstone	M-1004	Downgradient	79.59	928.7	0.00901	1.E-06	1.E-04	1.E-01	0.32	0.00008	**0.00798**	7.98108	6	0.063	**63**	6265
FAR II CCR	Morgantown Sandstone	M-1302	Upgradient	85.19	945.53	0.01552	1.E-06	1.E-04	1.E-01	0.32	0.00014	**0.01375**	13.74956	6	0.036	**36**	3636
FAR II CCR	Morgantown Sandstone	M-1309	Downgradient	-	-	0.02068	1.E-06	1.E-04	1.E-01	0.32	0.00018	**0.01832**	18.31983	6	0.027	**27**	2729
FAR II CCR	Morgantown Sandstone	M-GS-1	Downgradient	41.37	950.5	0.02142	1.E-06	1.E-04	1.E-01	0.32	0.00019	**0.01897**	18.97190	6	0.026	**26**	2635
FAR II CCR	Morgantown Sandstone	M-GS-2	Downgradient	78.53	912.28	0.02384	1.E-06	1.E-04	1.E-01	0.32	0.00021	**0.02111**	21.11428	6	0.024	**24**	2368
FAR II CCR	Morgantown Sandstone	M-GS-3	Downgradient	74.81	925.52	0.02234	1.E-06	1.E-04	1.E-01	0.32	0.00020	**0.01979**	19.78530	6	0.025	**25**	2527
FAR II CCR	Morgantown Sandstone	M-GS-4	Downgradient	84.2	944.53	0.01411	1.E-06	1.E-04	1.E-01	0.32	0.00013	**0.01250**	12.50199	6	0.040	**40**	3999
FAR II CCR	Morgantown Sandstone	M-GS-5	Upgradient	77.19	962.35	0.01752	1.E-06	1.E-04	1.E-01	0.32	0.00016	**0.01552**	15.52058	6	0.032	**32**	3222

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Measurements and calculations represent conditions on April 5, 2021. No depth to water readings were collected at M-1309.

[1] *Groundwater Monitoring Network Evaluation; Cardinal Site – Fly Ash Reservoir II, Brilliant, Ohio* prepared by Geosyntec Consultants in September 2016 (Revised February 2017).

[2] Hydraulic gradient was calculated from a potentiometric surface using GDAL software tools (https://gdal.org/programs/gdaldem.html).

[3] Elevations datum is National Geodetic Vertical Datum of 1929 (NGVD29).

[4] Low and high conductivity values are from the 2017 Groundwater Monitoring Network Evaluation, with a representative value chosen within this range that is consistent with previous velocity calculations.

[5] Well diameter represents the diameter of the borehole (sandpack).

[6] Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

Table 4-2. Groundwater Flow Calculations, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio, October 2021

Program	Groundwater Zone	Well	Hydraulic Location[1]	Depth to Water (ft)	Potentiometric Elevation[3] (ft)	Hydraulic Gradient[2] (ft/ft)	Hydraulic Conductivity[4] (cm/sec)			Effective Porosity	Groundwater Velocity (ft/day)			Well Diameter[5] (in.)	Residence Time[6] (days)		
							Low	Representative	High		Low	Representative	High		Low	Representative	High
FAR II	Morgantown Sandstone	CA-0622A	Upgradient	226.47	935.81	0.01537	1.E-06	1.E-04	1.E-01	0.32	0.00014	**0.01361**	13.61205	6	0.037	**37**	3673
FAR II	Morgantown Sandstone	FA-8	Downgradient	45.47	875.56	0.18835	1.E-06	1.E-04	1.E-01	0.32	0.00167	**0.16685**	166.84529	6	0.003	**3**	300
FAR II	Morgantown Sandstone	M-6	Upgradient	51.4	959.17	0.01128	1.E-06	1.E-04	1.E-01	0.32	0.00010	**0.00999**	9.99458	3	0.025	**25**	2501
FAR II	Morgantown Sandstone	M-8	Downgradient	69.54	823.66	0.01890	1.E-06	1.E-04	1.E-01	0.32	0.00017	**0.01674**	16.73999	6	0.030	**30**	2987
FAR II	Morgantown Sandstone	M-10	Downgradient	92.89	940.53	0.01885	1.E-06	1.E-04	1.E-01	0.32	0.00017	**0.01670**	16.69837	4.87	0.024	**24**	2430
FAR II	Morgantown Sandstone	M-11	Downgradient	87.2	893.01	0.11458	1.E-06	1.E-04	1.E-01	0.32	0.00102	**0.10150**	101.50241	3	0.002	**2**	246
FAR II	Morgantown Sandstone	M-12	Upgradient	223.7	966.96	0.00232	1.E-06	1.E-04	1.E-01	0.32	0.00002	**0.00205**	2.05375	6	0.243	**243**	24346
FAR II	Morgantown Sandstone	M-13	Downgradient	61.09	930.05	0.01458	1.E-06	1.E-04	1.E-01	0.32	0.00013	**0.01292**	12.91510	6	0.039	**39**	3871
FAR II	Morgantown Sandstone	M-14	Downgradient	75.82	912.39	0.01183	1.E-06	1.E-04	1.E-01	0.32	0.00010	**0.01048**	10.47904	6	0.048	**48**	4771
FAR II	Morgantown Sandstone	M-15	Downgradient	137.83	936.45	0.01318	1.E-06	1.E-04	1.E-01	0.32	0.00012	**0.01167**	11.67264	6	0.043	**43**	4284
FAR II	Morgantown Sandstone	M-16	Downgradient	112.26	956.29	0.00532	1.E-06	1.E-04	1.E-01	0.32	0.00005	**0.00471**	4.71333	6	0.106	**106**	10608
FAR II	Morgantown Sandstone	M-21	Downgradient	123.32	895.29	0.04210	1.E-06	1.E-04	1.E-01	0.32	0.00037	**0.03730**	37.29600	6	0.013	**13**	1341
FAR II	Morgantown Sandstone	M-22	Downgradient	89.05	918.99	0.01108	1.E-06	1.E-04	1.E-01	0.32	0.00010	**0.00982**	9.81824	6	0.051	**51**	5093
FAR II	Morgantown Sandstone	M-23	Downgradient	147.38	838.52	0.09679	1.E-06	1.E-04	1.E-01	0.32	0.00086	**0.08574**	85.73550	6	0.006	**6**	583
FAR II	Morgantown Sandstone	M-1003	Downgradient	87.23	848.65	0.07602	1.E-06	1.E-04	1.E-01	0.32	0.00067	**0.06734**	67.34241	6	0.007	**7**	742
FAR II	Morgantown Sandstone	M-1004	Downgradient	81.09	927.2	0.01199	1.E-06	1.E-04	1.E-01	0.32	0.00011	**0.01062**	10.62123	6	0.047	**47**	4708
FAR II	Morgantown Sandstone	M-1302	Upgradient	85.12	945.6	0.01158	1.E-06	1.E-04	1.E-01	0.32	0.00010	**0.01026**	10.26049	6	0.049	**49**	4873
FAR II	Morgantown Sandstone	M-1309	Downgradient	-	-	0.01332	1.E-06	1.E-04	1.E-01	0.32	0.00012	**0.01180**	11.79616	6	0.042	**42**	4239
FAR II	Morgantown Sandstone	M-GS-1	Downgradient	42.37	949.5	0.03025	1.E-06	1.E-04	1.E-01	0.32	0.00027	**0.02680**	26.79661	6	0.019	**19**	1866
FAR II	Morgantown Sandstone	M-GS-2	Downgradient	79.13	911.68	0.02396	1.E-06	1.E-04	1.E-01	0.32	0.00021	**0.02123**	21.22802	6	0.024	**24**	2355
FAR II	Morgantown Sandstone	M-GS-3	Downgradient	76.13	924.2	0.01295	1.E-06	1.E-04	1.E-01	0.32	0.00011	**0.01148**	11.47514	6	0.044	**44**	4357
FAR II	Morgantown Sandstone	M-GS-4	Downgradient	84.17	944.56	0.01134	1.E-06	1.E-04	1.E-01	0.32	0.00010	**0.01004**	10.04280	6	0.050	**50**	4979
FAR II	Morgantown Sandstone	M-GS-5	Upgradient	77.7	961.84	0.00918	1.E-06	1.E-04	1.E-01	0.32	0.00008	**0.00813**	8.13206	6	0.061	**61**	6149

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Measurements and calculations represent conditions on October 11, 2021. No depth to water readings were collected at M-1309.

[1] *Groundwater Monitoring Network Evaluation; Cardinal Site – Fly Ash Reservoir II, Brilliant, Ohio* prepared by Geosyntec Consultants in September 2016 (Revised February 2017).

[2] Hydraulic gradient was calculated from a potentiometric surface using GDAL software tools (https://gdal.org/programs/gdaldem.html).

[3] Elevations datum is National Geodetic Vertical Datum of 1929 (NGVD29).

[4] Low and high conductivity values are from the 2017 Groundwater Monitoring Network Evaluation, with a representative value chosen within this range that is consistent with previous velocity calculations.

[5] Well diameter represents the diameter of the borehole (sandpack).

[6] Residence time is an estimation of how long it would take groundwater to travel a distance equivalent to the well diameter at the calculated velocity.

Table 4-3. Summary of CCR Groundwater Samples, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name	Type of Well	Sample Date	Constituents Analyzed	Purpose
CA-0622A	Upgradient	4/19/2021	Appendix III and IV	Assessment monitoring program
CA-0622A	Upgradient	10/27/2021	Appendix III and IV	Assessment monitoring program
FA-8	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
FA-8	Downgradient	10/13/2021	Appendix III and IV	Assessment monitoring program
M-10	Downgradient	4/8/2021	Appendix III and IV	Assessment monitoring program
M-10	Downgradient	10/20/2021	Appendix III and IV	Assessment monitoring program
M-1003	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-1003	Downgradient	10/14/2021	Appendix III and IV	Assessment monitoring program
M-1004	Downgradient	4/12/2021	Appendix III and IV	Assessment monitoring program
M-1004	Downgradient	4/12/2021	Appendix III and IV	Assessment monitoring program (duplicate)
M-1004	Downgradient	10/25/2021	Appendix III and IV	Assessment monitoring program
M-11	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-11	Downgradient	10/15/2021	Appendix III and IV	Assessment monitoring program
M-12	Upgradient	4/15/2021	Appendix III and IV	Assessment monitoring program
M-12	Upgradient	11/1/2021	Appendix III and IV	Assessment monitoring program
M-13	Downgradient	4/9/2021	Appendix III and IV	Assessment monitoring program
M-13	Downgradient	4/9/2021	Appendix III and IV	Assessment monitoring program (duplicate)
M-13	Downgradient	10/22/2021	Appendix III and IV	Assessment monitoring program
M-13	Downgradient	10/22/2021	Appendix III and IV	Assessment monitoring program (duplicate)
M-1302	Upgradient	4/6/2021	Appendix III and IV	Assessment monitoring program
M-1302	Upgradient	10/27/2021	Appendix III and IV	Assessment monitoring program
M-1309	Downgradient	4/14/2021	Appendix III and IV	Assessment monitoring program
M-1309	Downgradient	11/2/2021	Appendix III and IV	Assessment monitoring program
M-14	Downgradient	4/15/2021	Appendix III and IV	Assessment monitoring program
M-14	Downgradient	10/25/2021	Appendix III and IV	Assessment monitoring program
M-15	Downgradient	4/6/2021	Appendix III and IV	Assessment monitoring program
M-15	Downgradient	10/26/2021	Appendix III and IV	Assessment monitoring program
M-16	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-16	Downgradient	11/1/2021	Appendix III and IV	Assessment monitoring program
M-2000	Downgradient	4/6/2021	Appendix III and IV	Corrective action program
M-2000	Downgradient	10/13/2021	Appendix III and IV	Corrective action program
M-2000	Downgradient	10/13/2021	Appendix III and IV	Corrective action program (duplicate)
M-21	Downgradient	4/20/2021	Appendix III and IV	Assessment monitoring program
M-21	Downgradient	10/21/2021	Appendix III and IV	Assessment monitoring program
M-22	Downgradient	4/16/2021	Appendix III and IV	Assessment monitoring program
M-22	Downgradient	10/20/2021	Appendix III and IV	Assessment monitoring program
M-23	Downgradient	4/13/2021	Appendix III and IV	Assessment monitoring program
M-23	Downgradient	10/18/2021	Appendix III and IV	Assessment monitoring program
M-6	Upgradient	4/8/2021	Appendix III and IV	Assessment monitoring program
M-6	Upgradient	10/26/2021	Appendix III and IV	Assessment monitoring program
M-8	Downgradient	4/12/2021	Appendix III and IV	Assessment monitoring program
M-8	Downgradient	10/18/2021	Appendix III and IV	Assessment monitoring program
M-GS-1	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-GS-1	Downgradient	10/25/2021	Appendix III and IV	Assessment monitoring program
M-GS-2	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-GS-2	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program (duplicate)
M-GS-2	Downgradient	10/25/2021	Appendix III and IV	Assessment monitoring program
M-GS-3	Downgradient	4/7/2021	Appendix III and IV	Assessment monitoring program
M-GS-3	Downgradient	10/27/2021	Appendix III and IV	Assessment monitoring program
M-GS-4	Downgradient	4/8/2021	Appendix III and IV	Assessment monitoring program
M-GS-4	Downgradient	11/1/2021	Appendix III and IV	Assessment monitoring program
M-GS-5	Upgradient	4/8/2021	Appendix III and IV	Assessment monitoring program
M-GS-5	Upgradient	10/14/2021	Appendix III and IV	Assessment monitoring program

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Table 4-4. Sampling Data, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name		CA-0622A	CA-0622A	FA-8	FA-8	M-6	M-6	M-8	M-8	M-10	M-10	M-11
Sample Name		CA-0622A	CA-0622A	FA-8	FA-8	M-6	M-6	M-8	M-8	M-10	M-10	M-11
Sample Date		4/19/2021	10/27/2021	4/7/2021	10/13/2021	4/8/2021	10/26/2021	4/12/2021	10/18/2021	4/8/2021	10/20/2021	4/7/2021
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50285378001	50301592002	50284345005	50300369002	50284608003	50301330007	50284750006	50300742002	50284608002	50300742003	50284345006
APPENDIX III CONSTITUENTS												
Boron	MG/L	**0.299**	**0.329**	**4.6**	**4.72**	**0.248**	**0.242**	**0.0271**	**0.029**	**0.534**	**0.515**	**4.64**
Calcium	MG/L	**74.9**	**74**	**233**	**204**	**19.8**	**16.8**	**106**	**103**	**11.5**	**11.4**	**227**
Chloride	MG/L	**4280**	**3980**	**57.5**	**43.8**	**38.1**	**44.4**	**6.3**	**7**	**13.7**	**13.7**	**58.6**
Fluoride	MG/L	< 0.05	< 0.05	**0.61**	**0.7**	**1.2**	**1.2**	**0.097**	**0.12**	**0.78**	**0.84**	**0.61**
Sulfate	MG/L	**19.5**	**7.7**	**756**	**716**	**12.7**	**35.5**	**102**	**103**	**142**	**137**	**769**
Total Dissolved Solids	MG/L	**6760**	**6630**	**1270**	**1210**	**756**	**720**	**420**	**414**	**674**	**710**	**1200**
pH	SU	**7.41**	**7.54**	**7.63**	**8.11**	**8.18**	**8.04**	**7.05**	**7.16**	**7.88**	**7.98**	**7.94**
APPENDIX IV CONSTITUENTS												
Antimony	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.0047**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.00054**
Arsenic	MG/L	**0.0203**	**0.0174**	**0.0092**	**0.0107**	**0.0076**	**0.0165**	**0.0011**	**0.0011**	< 0.0005	< 0.0005	**0.0048**
Barium	MG/L	**1.32**	**1.41**	**0.0219**	**0.0236**	**0.523**	**0.546**	**0.109**	**0.108**	**0.0795**	**0.08**	**0.0212**
Beryllium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	**0.0025**	**0.0021**	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cadmium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	**0.00038**	**0.00032**	< 0.0001	< 0.0001	< 0.0001	**0.00023**	< 0.0001
Chromium	MG/L	**0.0011**	< 0.001	< 0.001	< 0.001	**0.0197**	**0.0174**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	MG/L	< 0.0005	< 0.0005	**0.00074**	**0.0017**	**0.0085**	**0.0135**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.00096**
Fluoride	MG/L	< 0.05	< 0.05	**0.61**	**0.7**	**1.2**	**1.2**	**0.097**	**0.12**	**0.78**	**0.84**	**0.61**
Lead	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.037**	**0.0463**	< 0.0005	< 0.0005	**0.00094**	**0.0012**	**0.00052**
Lithium	MG/L	**0.0875**	**0.083**	**0.186**	**0.19**	**0.0267**	**0.0256**	< 0.01	< 0.01	**0.0205**	**0.0204**	**0.185**
Mercury	MG/L	**0.00000052**	**0.00000118**	**0.00000088**	**0.00000056**	**0.0000074**	**0.0000263**	< 0.0000005	**0.00000127**	**0.00000072**	**0.00000068**	**0.00000051**
Molybdenum	MG/L	**0.0019**	**0.0015**	**0.281**	**0.284**	**0.0014**	**0.0106**	< 0.0005	< 0.0005	**0.0021**	**0.0023**	**0.293**
Potassium	UG/L	**11000**	**9440**	**11100**	**11100**	**3540**	**4220**	**2030**	**2050**	**1910**	**1920**	**11100**
Selenium	MG/L	**0.00059**	**0.00076**	**0.004**	< 0.0005	**0.0137**	**0.0027**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.0057**
Thallium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Combined Radium	pCi/L	**8.47**	**8.62**	**1.8**	**1.04**	**9.33**	**8.4**	**0.399**	**1.29**	**1.56**	**1.05**	**0.443**

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NA = Not Analyzed
< = Not detected at reporting limit
Bold = Detected

Table 4-4. Sampling Data, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name		M-11	M-12	M-12	M-13	M-13	M-13	M-13	M-14	M-14	M-15	M-15
Sample Name		M-11	M-12	M-12	M-13	M-13 Dup	M-13	M-13 Dup	M-14	M-14	M-15	M-15
Sample Date		10/15/2021	4/15/2021	11/1/2021	4/9/2021	4/9/2021	10/22/2021	10/22/2021	4/15/2021	10/25/2021	4/6/2021	10/26/2021
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50300369007	50285183001	50301859003	50284608004	50284608005	50301003003	50301003004	50285183002	50301330004	50284345001	50301330006
APPENDIX III CONSTITUENTS												
Boron	MG/L	**4.42**	**0.291**	**0.32**	**0.283**	**0.276**	**0.27**	**0.233**	**0.228**	**0.206**	**0.229**	**0.245**
Calcium	MG/L	**205**	**127**	**352**	**14.2**	**15.3**	**12.3**	**9.08**	**0.522**	< 0.5	**1.69**	**1.47**
Chloride	MG/L	**42.4**	**390**	**175**	**2.2**	**3.2**	**3**	**3.2**	**1.2**	**1.8**	**25.3**	**24.4**
Fluoride	MG/L	**0.72**	**2.2**	**0.55**	**2.2**	**1.5**	**1.6**	**1.4**	**0.8**	**0.82**	**1.3**	**1.4**
Sulfate	MG/L	**693**	**641**	**1510**	**34**	**17.3**	**22.5**	**15.9**	**1.1**	**0.88**	**2.8**	**1.2**
Total Dissolved Solids	MG/L	**1230**	**912**	**2620**	**521**	**543**	**485**	**425**	**367**	**353**	**545**	**563**
pH	SU	**6.72**	**6.54**	**6.47**	**7.79**	NA	**8.26**	NA	**8.9**	**9.19**	**8.57**	**9.11**
APPENDIX IV CONSTITUENTS												
Antimony	MG/L	**0.00057**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Arsenic	MG/L	**0.0048**	**0.0016**	**0.002**	**0.0012**	**0.0017**	**0.00063**	**0.00052**	< 0.0005	< 0.0005	**0.0019**	**0.0016**
Barium	MG/L	**0.0195**	**0.0233**	**0.0191**	**0.171**	**0.216**	**0.145**	**0.107**	**0.0143**	**0.0137**	**0.0413**	**0.043**
Beryllium	MG/L	< 0.0001	< 0.0001	< 0.0001	**0.00021**	**0.00075**	**0.0001**	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cadmium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chromium	MG/L	< 0.001	< 0.001	< 0.001	**0.0013**	**0.0038**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	MG/L	**0.00092**	**0.004**	**0.0153**	< 0.0005	**0.0013**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Fluoride	MG/L	**0.72**	**2.2**	**0.55**	**2.2**	**1.5**	**1.6**	**1.4**	**0.8**	**0.82**	**1.3**	**1.4**
Lead	MG/L	< 0.0005	< 0.0005	< 0.0005	**0.0014**	**0.0037**	**0.00051**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Lithium	MG/L	**0.187**	**0.0676**	**0.15**	**0.0113**	**0.0157**	**0.0129**	< 0.01	< 0.01	< 0.01	**0.0126**	< 0.01
Mercury	MG/L	< 0.0000005	< 0.0000005	**0.00000169**	**0.00000138**	**0.00000267**	**0.00000058**	**0.00000068**	**0.00000054**	**0.00000103**	< 0.0000005	**0.00000052**
Molybdenum	MG/L	**0.286**	< 0.0005	< 0.0005	**0.0008**	**0.00082**	**0.00057**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Potassium	UG/L	**10800**	**4180**	**6210**	**1650**	**2140**	**1490**	**1190**	**527**	< 500	**877**	**875**
Selenium	MG/L	**0.0033**	< 0.0005	< 0.0005	**0.00057**	**0.0012**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Thallium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Combined Radium	pCi/L	**0.632**	**0.356**	**2.12**	**3**	**4.61**	**0.953**	**1.19**	**0**	**0.291**	**0.584**	**0.346**

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NA = Not Analyzed
< = Not detected at reporting limit
Bold = Detected

Table 4-4. Sampling Data, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name		M-16	M-16	M-21	M-21	M-22	M-22	M-23	M-23	M-1003	M-1003	M-1004
Sample Name		M-16	M-16	M-21	M-21	M-22	M-22	M-23	M-23	M-1003	M-1003	M-1004
Sample Date		4/7/2021	11/1/2021	4/20/2021	10/21/2021	4/16/2021	10/20/2021	4/13/2021	10/18/2021	4/7/2021	10/14/2021	4/12/2021
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50284345003	50301859002	50285378002	50301003002	50285183003	50301003001	50284750005	50300742001	50284608001	50300369005	50284750003
APPENDIX III CONSTITUENTS												
Boron	MG/L	**0.181**	**0.181**	**3.31**	**3.53**	**4.16**	**3.81**	**0.686**	**0.7**	**0.124**	**0.13**	**2.42**
Calcium	MG/L	**2.59**	**2.37**	**187**	**208**	**175**	**173**	**110**	**100**	**72.3**	77.5	**113**
Chloride	MG/L	**10.3**	**11.1**	**51**	**46**	**51.7**	**46.9**	**13.1**	**14.5**	**7.9**	**7.5**	**37.2**
Fluoride	MG/L	**0.33**	**0.31**	**0.087**	**0.11**	**0.42**	**0.51**	**0.19**	**0.64**	**0.18**	**0.21**	**1.3**
Sulfate	MG/L	**276**	**233**	**960**	**928**	**396**	**390**	**1660**	**1690**	**130**	**165**	**296**
Total Dissolved Solids	MG/L	**811**	**734**	**1600**	**1580**	**880**	**960**	**3210**	**3080**	**507**	**532**	**810**
pH	SU	**8.32**	**8.96**	**6.66**	**6.95**	**6.79**	**6.98**	**6.83**	**6.96**	**7.91**	**7.47**	**7.01**
APPENDIX IV CONSTITUENTS												
Antimony	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Arsenic	MG/L	< 0.0005	< 0.0005	**0.0012**	**0.003**	< 0.0005	< 0.0005	**0.00089**	**0.00081**	< 0.0005	**0.00058**	**0.0018**
Barium	MG/L	**0.0337**	**0.0336**	**0.0122**	**0.0126**	**0.0235**	**0.023**	**0.0078**	**0.0076**	**0.0733**	**0.0793**	**0.043**
Beryllium	MG/L	< 0.0001	< 0.0001	**0.00018**	**0.00062**	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cadmium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chromium	MG/L	< 0.001	< 0.001	< 0.001	< 0.001	**0.0019**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	MG/L	< 0.0005	< 0.0005	**0.0016**	**0.0018**	**0.0017**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Fluoride	MG/L	**0.33**	**0.31**	**0.087**	**0.11**	**0.42**	**0.51**	**0.19**	**0.64**	**0.18**	**0.21**	**1.3**
Lead	MG/L	< 0.0005	< 0.0005	< 0.0005	**0.0016**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Lithium	MG/L	**0.0146**	**0.0164**	**0.0685**	**0.0838**	**0.0532**	**0.0606**	**0.0502**	**0.0594**	**0.0118**	**0.0122**	**0.018**
Mercury	MG/L	< 0.0000005	< 0.0000005	**0.00000082**	**0.00000062**	< 0.0000005	< 0.0000005	< 0.0000005	0.0000005	< 0.0000005	< 0.0000005	**0.0000011**
Molybdenum	MG/L	< 0.0005	< 0.0005	**0.0188**	**0.023**	**0.0715**	**0.0576**	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.0098**
Potassium	UG/L	**1240**	**1130**	**5520**	**5220**	**3350**	**2760**	**5080**	**5970**	**3110**	**3430**	**2210**
Selenium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Thallium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Combined Radium	pCi/L	**0.805**	**0.921**	**1.07**	**0.248**	**1.47**	**1.28**	**2.12**	**0.362**	**5.14**	**2.73**	**0.5**

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NA = Not Analyzed
< = Not detected at reporting limit
Bold = Detected

Table 4-4. Sampling Data, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name		M-1004	M-1004	M-1302	M-1302	M-1309	M-1309	M-2000	M-2000	M-2000	M-GS-1	M-GS-1
Sample Name		M-1004	M-1004 Dup	M-1302	M-1302	M-1309	M-1309	M-2000	M-2000	M-2000 Dup	M-GS-1	M-GS-1
Sample Date		10/25/2021	4/12/2021	4/6/2021	10/27/2021	4/14/2021	11/2/2021	4/6/2021	10/13/2021	10/13/2021	4/7/2021	10/25/2021
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50301330001	50284750004	50284345002	50301592001	50284866001	50301859004	50284345004	50300369001	50300369003	50284602001	50301330003
APPENDIX III CONSTITUENTS												
Boron	MG/L	**2.39**	**2.54**	**0.264**	**0.282**	**0.272**	**0.277**	**4.24**	**4.76**	**4.73**	**0.262**	**0.27**
Calcium	MG/L	**104**	**115**	**3.39**	**3.07**	**3.6**	**3.13**	**229**	**200**	**198**	**18.1**	**17.4**
Chloride	MG/L	**36.7**	**36.3**	**29.2**	**30.9**	**41.9**	**43**	**56.1**	**53.3**	**49.8**	**35.3**	**36.2**
Fluoride	MG/L	**1.3**	**1.4**	**2**	**1.7**	**1.2**	**0.98**	**0.37**	**0.5**	**0.45**	**0.68**	**0.5**
Sulfate	MG/L	**292**	**271**	**46.9**	**51.7**	**76.5**	**73.7**	**763**	**741**	**775**	**79.4**	**83**
Total Dissolved Solids	MG/L	**856**	**798**	**695**	**618**	**706**	**683**	**1340**	**1320**	**1290**	**648**	**620**
pH	SU	**7.23**	NA	**8.33**	**8.54**	**7.11**	**8.64**	**7.5**	**7.93**	NA	**7.46**	**7.61**
APPENDIX IV CONSTITUENTS												
Antimony	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Arsenic	MG/L	**0.0011**	**0.0015**	< 0.0005	< 0.0005	**0.0018**	**0.0016**	**0.0011**	**0.0013**	**0.0013**	< 0.0005	< 0.0005
Barium	MG/L	**0.0388**	**0.043**	**0.107**	**0.112**	**0.0316**	**0.0291**	**0.0241**	**0.0237**	**0.0237**	**0.0826**	**0.0851**
Beryllium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cadmium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chromium	MG/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.0011**	**0.001**	**0.001**	< 0.0005	< 0.0005
Fluoride	MG/L	**1.3**	**1.4**	**2**	**1.7**	**1.2**	**0.98**	**0.37**	**0.5**	**0.45**	**0.68**	**0.5**
Lead	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Lithium	MG/L	**0.0238**	**0.02**	**0.0158**	**0.0104**	**0.0189**	**0.0176**	**0.194**	**0.194**	**0.195**	**0.0202**	**0.0192**
Mercury	MG/L	**0.00000092**	< 0.0000005	< 0.00000051	< 0.00000051	**0.00000122**	**0.00000134**	< 0.0000005	< 0.0000005	< 0.0000005	< 0.0000005	**0.00000094**
Molybdenum	MG/L	**0.0104**	**0.0103**	< 0.0005	< 0.0005	**0.001**	**0.001**	**0.209**	**0.207**	**0.204**	< 0.0005	< 0.0005
Potassium	UG/L	**2020**	**2200**	**1410**	**1400**	**1260**	**1120**	**10100**	**9860**	**9850**	**2000**	**1700**
Selenium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Thallium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Combined Radium	pCi/L	**1.29**	**0.106**	**0.532**	**0.353**	**1.31**	**1.58**	**2.97**	**2.17**	**2.45**	**0.618**	**0.539**

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NA = Not Analyzed
< = Not detected at reporting limit
Bold = Detected

Table 4-4. Sampling Data, Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

Well Name		M-GS-2	M-GS-2	M-GS-2	M-GS-3	M-GS-3	M-GS-4	M-GS-4	M-GS-5	M-GS-5
Sample Name		M-GS-2	M-GS-2 Dup	M-GS-2	M-GS-3	M-GS-3	M-GS-4	M-GS-4	M-GS-5	M-GS-5
Sample Date		4/7/2021	4/7/2021	10/25/2021	4/7/2021	10/27/2021	4/8/2021	11/1/2021	4/8/2021	10/14/2021
Laboratory	Concentration	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical	Pace Analytical
Lab ID	Units	50284602002	50284602006	50301330002	50284602003	50301330008	50284602004	50301859001	50284602005	50300369004
APPENDIX III CONSTITUENTS										
Boron	MG/L	**0.233**	**0.264**	**0.207**	**1.33**	**1.25**	**0.188**	**0.183**	**0.302**	**0.293**
Calcium	MG/L	**7.04**	**7.08**	**10.2**	**78.5**	**72.9**	**3.04**	**3.18**	**3.03**	**4.76**
Chloride	MG/L	**27**	**26.1**	**24.5**	**34.5**	**34.1**	**11.5**	**11.8**	**121**	**108**
Fluoride	MG/L	**0.44**	**0.43**	**0.34**	**0.19**	**0.12**	**0.6**	**0.53**	**5.7**	**5.5**
Sulfate	MG/L	**111**	**109**	**165**	**1340**	**1290**	**23.8**	**29.4**	**262**	**347**
Total Dissolved Solids	MG/L	**646**	**621**	**656**	**2410**	**2300**	**549**	**474**	**1280**	**1280**
pH	SU	**7.44**	NA	**7.71**	**6.34**	**6.2**	**8.59**	**8.7**	**8.36**	**8.31**
APPENDIX IV CONSTITUENTS										
Antimony	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Arsenic	MG/L	**0.0049**	**0.0049**	**0.0066**	**0.086**	**0.0955**	**0.0029**	**0.0026**	**0.0083**	**0.0076**
Barium	MG/L	**0.0253**	**0.0251**	**0.0269**	**0.0074**	**0.0118**	**0.0145**	**0.0147**	**0.136**	**0.133**
Beryllium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Cadmium	MG/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chromium	MG/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cobalt	MG/L	< 0.0005	< 0.0005	< 0.0005	**0.00085**	**0.001**	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Fluoride	MG/L	**0.44**	**0.43**	**0.34**	**0.19**	**0.12**	**0.6**	**0.53**	**5.7**	**5.5**
Lead	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.00082**	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Lithium	MG/L	**0.0166**	**0.0197**	**0.0147**	**0.0598**	**0.0585**	< 0.01	**0.0106**	**0.0189**	**0.0157**
Mercury	MG/L	< 0.0000005	< 0.0000005	**0.00000075**	< 0.0000005	**0.0000013**	< 0.0000005	< 0.0000005	< 0.0000005	< 0.0000005
Molybdenum	MG/L	**0.0033**	**0.0034**	**0.0074**	**0.0012**	**0.0017**	**0.0019**	**0.0027**	**0.0016**	**0.0015**
Potassium	UG/L	**1560**	**1430**	**1580**	**4200**	**3980**	**1100**	**994**	**1960**	**2330**
Selenium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Thallium	MG/L	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Combined Radium	pCi/L	**2.16**	**0.31**	**0.117**	**0.959**	**1.67**	**1.27**	**1.13**	**2**	**1.61**

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NA = Not Analyzed
< = Not detected at reporting limit
Bold = Detected

Table 4-5. Groundwater Protection Standards (GWPS), Fly Ash Reservoir (FAR) II, Cardinal Plant, Brilliant, Ohio

	Concentration Units	MCL	CCR Rules § 257.95(h)(2)	Backgorund Limit	FAR II GWPS
APPENDIX IV CONSTITUENTS					
Antimony	MG/L	0.006	-	0.0029	0.006
Arsenic	MG/L	0.01	-	0.037	0.037
Barium	MG/L	2	-	1.24	2
Beryllium	MG/L	0.004	-	0.002	0.004
Cadmium	MG/L	0.005	-	0.0002	0.005
Chromium	MG/L	0.1	-	0.015	0.1
Cobalt	MG/L	-	0.006	0.032	0.032
Fluoride	MG/L	4	-	6.6	6.6
Lead	MG/L	-	0.015	0.055	0.055
Lithium	MG/L	-	0.04	0.149	0.149
Mercury	MG/L	0.002	-	0.000017	0.002
Molybdenum	MG/L	-	0.1	0.068	0.1
Radium, Combined	pCi/L	5	-	15.2	15.2
Selenium	MG/L	0.05	-	0.016	0.05
Thallium	MG/L	0.002	-	0.001	0.002

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MCL = Maximum Contaminant Level
GWPS is the higher value of either the background limit or the MCL. If an MCL is not available, values from the CCR Rules are used.
Background values are based upon statistical upper threshold limit (UTL) calculations.
UTLs are intended for comparison to confidence bands, not individual observations.

Appendix A

Alternative Monitoring Frequency

Alternative Monitoring Frequency for the FAR II CCR Program Cardinal Operating Company Brilliant, Ohio

September 21, 2021

Submitted to:

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio 43913

Submitted by:

Cox-Colvin & Associates, Inc.
7750 Corporate Blvd.
Plain City, Ohio 43064
(614) 526-2040

Cox-Colvin
& ASSOCIATES, INC.
ENVIRONMENTAL SERVICES

Table of Contents

1.0 Introduction

Cox-Colvin & Associates, Inc. (Cox-Colvin) is pleased to provide this demonstration summarizing an alternative monitoring frequency for the Fly Ash Reservoir (FAR) II Coal Combustion Residuals (CCR) unit at the Cardinal Operating Company (Cardinal) power plant in Brilliant, Ohio. The purpose of this alternative monitoring frequency is to permit semiannual monitoring of all Appendix IV parameters, rather than only those that were previously detected during annual monitoring.

2.0 Analyses Required for Assessment Monitoring

In accordance with the United States Environmental Protection Agency's (USEPA's) regulations regarding the disposal of CCR in landfills and surface impoundments (40 CFR 257.90-257.98, "CCR Rule"), groundwater monitoring at the FAR II is performed semi-annually. In accordance with CCR Rule 257.95(a), the FAR II entered an assessment monitoring program following a statistically significant increase (SSI) over background levels for one or more of the constituents listed in CCR Rule Appendix III (Appendix III Constituents). The FAR II subsequently entered a corrective action monitoring program following identification of a statistically significant level (SSL). In compliance with CCR Rule 257.98(a)(1)(i), the corrective action monitoring program meets the requirements of assessment monitoring program under CCR Rule Section 257.95.

Once a CCR unit is subject to assessment (or corrective action) monitoring, CCR Rule Section 257.95(b) requires initial and annual sampling and analysis of groundwater for all constituents listed in CCR Rule Appendix IV (Appendix IV Constituents). CCR Rule Section 257.95 requires semiannual sampling and statistical analysis of all Appendix III Constituents and also those Appendix IV Constituents previously detected during the initial or annual sampling. The CCR Rule does not require semiannual analysis of Appendix IV Constituents that were not previously detected. The above CCR Rule requirements for assessment monitoring are summarized in the following table:

Timeframe	Appendix III Constituents	Appendix IV Constituents
Start of Assessment Monitoring	All	All
Annually	All	All
Semiannually	All	Detected Only

Table 1: CCR Rule Monitoring Frequency

3.0 Alternative Monitoring Frequency

The alternative monitoring frequency in Table 2 is being implemented for the FAR II program.

Timeframe	Appendix III Constituents	Appendix IV Constituents
Start of Assessment Monitoring	All	All
Semiannually	All	***All***

Table 2: Alternative Monitoring Frequency

The only change to the CCR Rule monitoring frequency is that all Appendix IV Constituents are sampled and analyzed semiannually, as opposed to only those that were previously detected. By analyzing **all** constituents on a semi-annual basis, the annual sampling event (to analyze detectable concentrations) is no longer needed. The alternative monitoring frequency is being implemented as an option (not a requirement) for sampling and analysis in order to:

- Simplify sampling and analysis with a consistent suite of analyses during each sampling event.
- Alleviate the need to track the particular Appendix IV Constituents that have been detected and whether a sample event meets requirements for annual or semiannual analyses.
- Reduce the likelihood that individual analyses are inadvertently omitted during a semiannual sampling.
- Provide flexibility to implement a conservative approach where the CCR Rule lacks details or clarity. For example, the CCR Rule does not specify whether "detected" in Section 257.95(d)(1) includes concentrations that the laboratory estimated below reporting limits ("J"-qualified), or whether results from all dates should be reviewed for "detected" constituents versus only results from the most recent annual sampling.

The alternative monitoring frequency in Table 2 is acceptable for the FAR II corrective action monitoring program. However, as noted above, its implementation is optional, not a requirement. If the alternative monitoring frequency is not used, then all requirements summarized in Table 1 above must be met (i.e., all Appendix IV Constituents are analyzed annually, and previously detected Appendix IV Constituents are analyzed semiannually).

4.0 Supporting Information and Demonstration

CCR Rule Section 257.95(c) allows operators to demonstrate the need for an alternative monitoring frequency for repeated sampling and analysis for Appendix IV Constituents. The need to vary monitoring frequency must be evaluated on a site-specific basis, and the demonstration supported by, at a minimum, the information specified in paragraphs (c)(1) and (2) of the regulation.

A demonstration that this alternative monitoring frequency is acceptable is provided below. CCR Rule paragraph text is provided in ***bold, italic*** font followed by supporting information in standard font.

(1) Information documenting that [sic] the need for less frequent sampling. The alternative frequency must be based on consideration of the following factors:

(i) Lithology of the aquifer and unsaturated zone;
(ii) Hydraulic conductivity of the aquifer and unsaturated zone; and
(iii) Groundwater flow rates.

The alternative monitoring frequency was not developed as a result of hydrogeological conditions of the aquifer (e.g., very slow flow velocities, poor well yields, etc.). The alternative monitoring frequency results in more frequent sampling of those Appendix IV Constituents that were not previously detected. Because sampling will not be performed less frequently, the requirements of this paragraph are not applicable.

(2) Information documenting that the alternative frequency will be no less effective in ensuring that any leakage from the CCR unit will be discovered within a timeframe that will not materially delay the initiation of any necessary remediation measures.

All requirements of CCR Rule assessment monitoring will be met. Additionally, Appendix IV Constituents that were not previously detected will be sampled and analyzed twice as frequently as required by the CCR Rule. As such, the alternative frequency could result in earlier detection of any leakage from the CCR unit containing the constituents. Initiation of any necessary remediation measures will not be delayed by the alternative monitoring frequency and could potentially be accelerated.

5.0 Certification of Qualified Professional Engineer

In accordance with CCR Rule Section 257.95(c)(3), this alternative groundwater sampling and analysis frequency is certified by Nick M. Petruzzi, PE, a qualified professional engineer licensed by the State of Ohio (PE #E-73052).

Nick M. Petruzzi, P.E.

9/21/21
Date

Stamp

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