2023 Annual Groundwater Monitoring Report for Bottom Ash Pond (BAP) Cardinal Operating Company – Cardinal Plant 306 County Road 7E Brilliant, Ohio

January 30, 2024

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 2023 Annual Groundwater Monitoring Report (Report) for the Bottom Ash Pond (BAP), 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, 2023, through December 31, 2023.

During 2023 groundwater monitoring, statistically significant increases (SSIs) above background levels were identified[1] for the constituents and well pairings listed below:

- Boron: MW-BAP-1, MW-BAP-2, MW-BAP-3
- Chloride: MW-BAP-1, MW-BAP-2, MW-BAP-3
- Fluoride: MW-BAP-1, MW-BAP-2
- pH2: MW-BAP-1, MW-BAP-2

In accordance with §257.95 of the CCR Rules, assessment monitoring at the BAP was initiated in May 2018 after an SSI over groundwater background levels was first detected. The BAP was operating under the assessment monitoring program (§257.95 of the CCR Rules) at the start of the 2022 annual reporting period and remained in the assessment monitoring program throughout the 2023 annual reporting period.

Statistical evaluations of two assessment monitoring events were completed during this annual reporting period – the second semiannual event of 2022 (October 2022)[3] (Appendix IV parameters) and the first semiannual event of 2023 (April 2023) for both Appendix III & IV. These evaluations identified no statistically significant levels (SSLs) above groundwater protection standards (GWPSs). As such, no corrective actions are necessary.

[1] 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 upper prediction limit (UPL) without resampling or additional testing.
[2] Unlike other monitored constituents that are compared to only a UPL, pH is compared to both a UPL and an LPL when evaluating potential SSIs. In this context, a statistically significant decrease (SSD) of pH values below the LPL is included as a potential "SSI" for consistency with the language and requirements of the CCR Rule.
[3] Although samples were collected in October 2022, evaluation of the laboratory results was performed in 2023 and discussion of the evaluation is, therefore, included in this annual report. The October 2022 sampling results were included in the 2022 Annual Groundwater Monitoring Report.

1.0 Introduction

Cox-Colvin & Associates, Inc. (Cox-Colvin) has prepared this 2023 Annual Groundwater Monitoring Report for the Bottom Ash Pond (BAP) 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 Rule from January 1, 2023, through December 31, 2023.

1.1 Site Summary

The Site is located one mile south of Brilliant, Ohio in Jefferson County 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. 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 2016).

1.2 CCR Unit Description

The BAP is currently in the closure process. The unit is situated along the Ohio River south of Cardinal Plant Unit 3. The BAP perimeter dikes enclosing the facility are approximately 6,500 feet (ft) in length with a 20-foot average height. The dikes were originally constructed in the 1960s, with major reconstruction in 1974 as part of the Unit 3 addition. The BAP received bottom ash, pyrite, and other wastes from the coal burning process in addition to stormwater drainage and wastewater flows from the property (Geosyntec 2016). The Northern Portion of the Bottom Ash Pond is currently being excavated and retrofitted with an NPDES-compliant liner to receive non-CCR waste streams. Retrofit of the southern portion of the BAP was completed in March of 2022, and the Retrofit BAP is now a separate CCR unit from the rest of the Bottom Ash Pond.

The BAP and associated monitoring wells are shown in Figure 1-2.

1.3 Regional Physiographic Setting

The BAP is located immediately west of the Ohio River. Regional geology is dominated by sedimentary bedrock units overlain by unconsolidated deposits (typically sand and gravel) associated with the Ohio River Valley in an area of Ohio which was unglaciated

during the most recent ice age. Bedrock consists of interbedded shale, sandstone, coal, and limestone of the Pennsylvanian Age Conemaugh Formation.

The uppermost aquifer at the BAP consists of fine to coarse sand and gravel below a silty clay, interbedded organic clay, and silt. Groundwater in the uppermost aquifer generally flows southeast towards the Ohio River (to which it is hydraulically connected) with hydraulic conductivity ranging from 1×10^{-1} to 1×10^{-4} centimeters per second (cm/s) (Geosyntec 2016).

2.0 Groundwater Monitoring System

The BAP's groundwater monitoring network was designed to comply with §257.91 of the CCR Rules. 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 BAP.

The BAP groundwater monitoring well network consists of five monitoring wells, as shown in Figure 1-2. Two upgradient monitoring wells (MW-BAP-4 and MW-BAP-5) are used to measure background conditions and three downgradient monitoring wells (MW-BAP-1, MW-BAP-2, and MW-BAP-3) are used as compliance wells. Monitoring well construction and soil boring logs were provided in the Groundwater Monitoring Network Evaluation (Geosyntec 2016).

No monitoring wells were installed or decommissioned during 2023 as part of the current BAP monitoring network.

A retrofit has been completed on the southern portion of the BAP. Additional wells for CCR monitoring have been installed in the proximity of the southern portion of the BAP, to conform to the CCR groundwater monitoring system requirements. Logs of these wells are included in the Retrofit Bottom Ash Pond CCR Unit's Groundwater Monitoring System Report. However, those wells are not necessary for, and have not been added to, the current monitoring network.

3.0 Groundwater Monitoring Program

In accordance with §257.95 of the CCR Rules, assessment monitoring at the BAP was initiated in May 2018 after a statistically significant increase (SSI) over groundwater background levels was detected for boron, chloride, and fluoride. The BAP remained in assessment monitoring throughout 2023.

Concentrations of CCR constituents in groundwater continue to be above background levels (Section 4.3.1), but no statistically significant levels (SSLs) above groundwater protection standards (GWPSs) have been identified at the BAP (Section 4.3.2). As such, the BAP is not eligible to return to detection monitoring, but not required to enter corrective action monitoring. In accordance with §257.95(f) of the CCR Rules, the BAP remains in assessment monitoring.

3.1 Statistical Analysis Plan

Evaluation of analytical data is performed in accordance with the Statistical Analysis Plan (Geosyntec 2020), which describes a logic process regarding the statistical analysis of groundwater data collected in compliance with the Federal CCR Rule. No revisions were made to the Statistical Analysis Plan during 2023.

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). 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 2023 sampling events.

There has been no suspension of groundwater monitoring requirements at the BAP under §257.90(g) of the CCR Rule.

4.0 Key Actions Completed

The sections below summarize key actions completed in 2023 with respect to CCR Rule groundwater monitoring and corrective actions at the BAP.

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 2023 sampling events are presented in Figures 4-1 and 4-2, respectively. Because the BAP is adjacent to the Ohio River, the potentiometric surface is generally flat. Groundwater flow rate calculations relative to the BAP 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 for the BAP monitoring program. The first semi-annual monitoring event of 2023 was completed in April 2023 and the second semi-annual monitoring event of 2023 was completed in October 2023. A total of 12 samples were collected. Analytical results are summarized in Table 4-4.

4.3 Data Evaluation

Data evaluations performed in 2023 consisted of the following:

- Comparison of Fall 2022 monitoring data to GWPSs for Appendix IV constituents[4]
- Comparison of Spring 2023 monitoring data to background levels for Appendix III constituents
- Comparison of Spring 2023 monitoring data to GWPSs for Appendix IV constituents

Comparison of Fall 2023 monitoring data to background levels for Appendix III constituents and GWPSs for Appendix IV constituents is ongoing and will be included in the 2024 annual report.

[4] Although samples were collected in October 2022, evaluation of the laboratory results was performed in 2023 and discussion of the evaluation is, therefore, included in this annual report. The October 2022 sampling results were included in the 2022 Annual Groundwater Monitoring Report.

4.3.1 Background Levels

Background concentrations in BAP groundwater were previously updated for Appendix III constituents[5] in 2019. In February 2021, background concentrations were recalculated for the boron, calcium, chloride, fluoride, and pH. These background levels were based upon interwell upper prediction limits (UPLs). In 2023, background concentrations for the following constituents were recalculated: boron, chloride, fluoride, pH, sulfate, and total dissolved solids (TDS).

During 2023 groundwater monitoring, SSIs above background levels were identified[6] for the constituents and well pairings listed below:

- Boron: MW-BAP-1, MW-BAP-2, MW-BAP-3
- Chloride: MW-BAP-1, MW-BAP-2, MW-BAP-3
- Fluoride: MW-BAP-1, MW-BAP-2
- pH[7]: MW-BSP-1, MW-BAP-2

Background concentrations of Appendix IV constituents in BAP groundwater were most recently updated in February 2021 (Geosyntec 2021b). 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 2020). 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.

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

[6] 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 upper prediction limit (UPL) without resampling or additional testing.

[7] Unlike other monitored constituents that are compared to only a UPL, pH is compared to both a UPL and an LPL when evaluating potential SSIs. In this context, a statistically significant decrease (SSD) of pH values below the LPL is included as a potential "SSI" for consistency with the language and requirements of the CCR Rule.

Statistical analyses of October 2022 (Cox-Colvin 2022a) and April 2023 (Cox-Colvin 2022b) monitoring data identified no SSLs at the BAP.

Statistical evaluation of the October 2023 assessment monitoring data is ongoing and will be discussed in the 2024 annual groundwater monitoring report.

4.4 Corrective Actions

There is no evidence that a release from the BAP has resulted in groundwater concentrations above GWPS values. As such, no corrective actions or remedies are necessary.

4.5 Closure Activities

Although not a corrective action under §257.96 to §257.98 of the CCR Rules, the BAP is currently being retrofitted and will be "clean" closed by removing all CCR materials at the time of closure and decontaminating all areas affected by releases (if any). These activities commenced in 2021 in accordance with the Unit's closure/retrofit plans. Retrofit of the southern portion of the pond was completed in March 2022; work on the remaining northern portion of the pond is still being conducted. The removal and decontamination activities will eliminate the potential that contaminants from the BAP could result in a future exceedance of GWPS established pursuant to §257.95(h) of the CCR Rules (Sargent & Lundy 2020a, Sargent & Lundy 2020b).

5.0 Problems Encountered and Resolutions

No monitoring wells were gauged dry, abandoned, or added to the well network during 2023. All analytical data received were deemed to be of acceptable quality and no resampling was performed.

No alternative source demonstrations under either §257.94(e)(2) or §257.95(g)(3)(ii) of the CCR Rules were performed during 2023.

6.0 Projected Key Activities

The bottom ash pond is currently being retrofitted and will be "clean" closed by removing all CCR materials at the time of closure and decontaminating all areas affected by releases (if any). These activities commenced in 2021 in accordance with closure requirements in §257.102 of the CCR Rule. The removal and decontamination activities will eliminate the potential that contaminants from the BAP could result in a future exceedance of GWPS established pursuant to §257.95(h) of the CCR Rules (Sargent & Lundy 2020a, Sargent & Lundy 2020b).

As specified in §257.102(c) of the CCR Rules, closure activities at the BAP will be complete when all CCR has been removed and groundwater monitoring concentrations do not exceed GWPS. Furthermore, §257.104(a)(2) excludes the BAP from post-closure care criteria following removal of all CCR. Presuming that groundwater concentrations remain lower than GWPSs, the BAP groundwater monitoring system will no longer need to be maintained following completion of closure activities.

The following groundwater assessment monitoring activities are projected for the BAP:

- The 2023 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 2023 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 2024 will be completed.
- The 2024 Annual Groundwater Monitoring Report will be prepared for submittal in January 2025.

7.0 References

Cox-Colvin. 2021a. *Alternative Monitoring Frequency for the BAP CCR Program; Cardinal Operating Company; Brilliant, Ohio.* Plain City, Ohio: Cox-Colvin & Associates, Inc.

Cox-Colvin. 2022a. *Cardinal Plant Bottom Ash Pond (BAP) Statistical Analysis Summary – 2021 Second Semiannual Event. Technical Memorandum from Nate Wanner (CPG) to Nicholas Kasper of Ohio Electric Cooperative dated September 9, 2022.* Plain City, OH: Cox-Colvin & Associates, Inc.

Cox-Colvin. 2022b. *Cardinal Plant Bottom Ash Pond (BAP) Statistical Analysis Summary - 2022 First Semiannual Event. Technical Memorandum from Nate Wanner, CPG and Henry Stahl of Cox-Colvin to Nicholas Kasper of Ohio Electric Cooperative dated March 8, 2022.* Plain City, OH: Cox-Colvin & Associates, Inc.

EPA. 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance, March 2009 (EPA 530/R-09-007).* Environmental Protection Agency, Office of Resource Conservation and Recovery.

Geosyntec. 2021b. *Cardinal Plant Bottom Ash Pond Statistical Analysis Summary - 2020 Second Semiannual Event. Memorandum from Allison Kreinberg and Bryan VanDuinen, P.E. (MI) of Geosyntec Consultants to Nicholas Kasper of Ohio Electric Cooperative dated February 2, 2021*. Columbus, Ohio: Geosyntec Consultants.

Geosyntec. 2016. *Groundwater Monitoring Network Evaluation; Cardinal Site - Bottom Ash Pond; Brilliant, Ohio (Geosyntec Project No. CHE8126L).* Brilliant, Ohio: Geosyntec Consultants.

Geosyntec. 2020. *Statistical Analysis Plan; Cardinal Power Plant; Brilliant, Ohio (Revision 1).* Columbus, Ohio: Geosyntec Consultants.

Sargent & Lundy. 2020a. "Cardinal Power Plant Bottom Ash Pond Complex; Amendment of Existing Closure Plan; Revision 0, October 19, 2020 (Project No. 13770-005)."

Sargent & Lundy. 2020b. "Cardinal Power Plant Permit to Install Application Bottom Ash South Pond CCR Retrofit."

Figures

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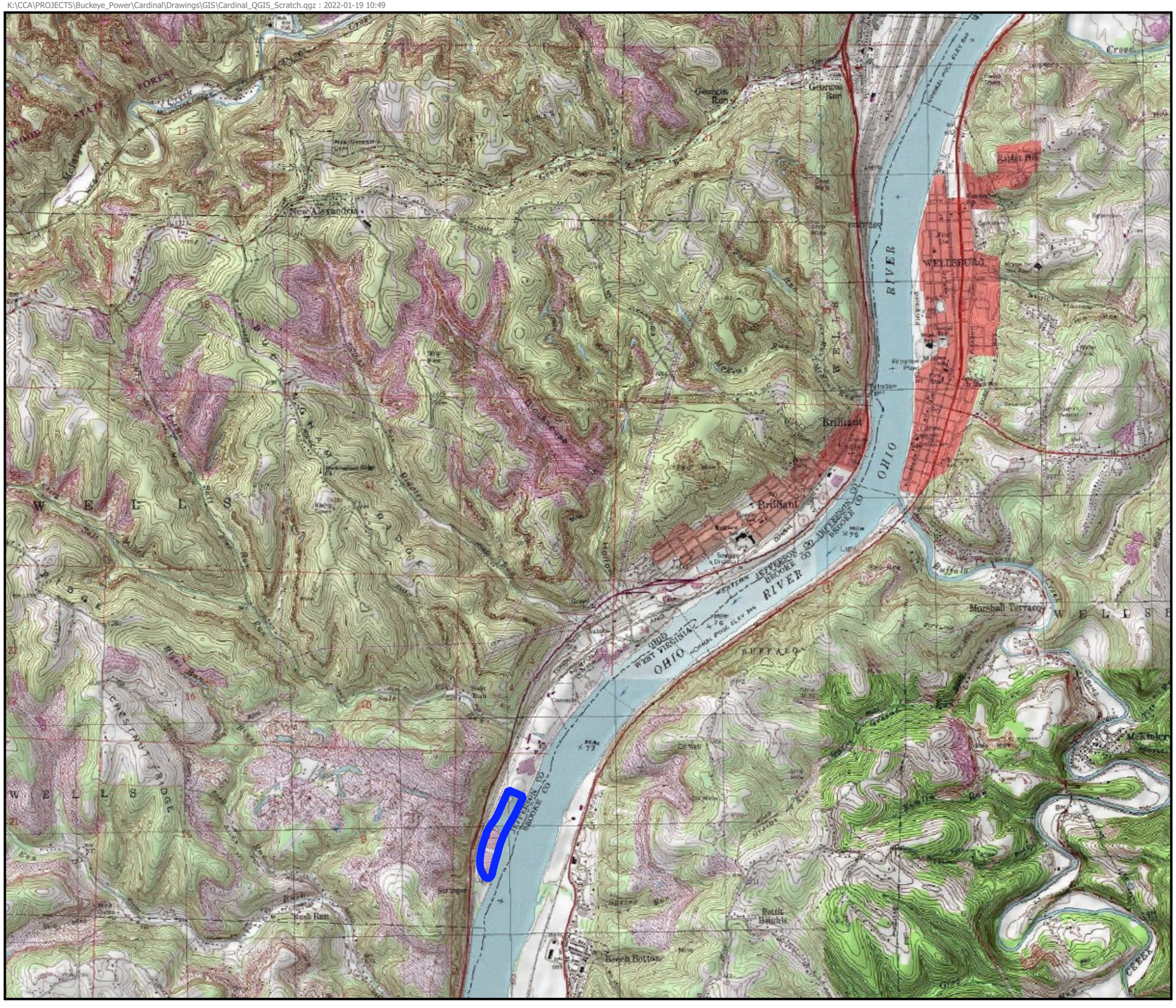

Legend

Bottom Ash Pond (BAP)

USGS Topographical Map

N

0 0.5 1 1.5 2 mi

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Figure

1-1

Site Location Map
Bottom Ash Pond (BAP)
Cardinal Plant
Brilliant, Ohio

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Legend

Bottom Ash Pond (BAP)

Monitoring Wells

- Downgradient
- Upgradient

N

0 400 800 1,200 ft

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Figure

1-2

CCR Unit and Monitoring Wells
Bottom Ash Pond (BAP)
Cardinal Plant
Brilliant, Ohio

DWG NAME: Water Levels 2023 DATE PRINTED: 1/19/2024 K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings

644.23
MW-BAP-4
644.25
644.20
644.15
644.10
644.04
MW-BAP-1
644.05
644.10
MW-BAP-5
MW-BAP-2
644.15
MW-BAP-1001
644.33
MW-BAP-1002
644.11
644.12
MW-BAP-3
644.30
644.25
644.20
644.15
644.10
644.09
MW-BAP-1003

Legend

- BAP Monitor Well
- Non-BAP Monitor Well
- 644.05 Approximate Groundwater Elevation Contour
- 644.04 Groundwater Elevation on April 10, 2023
- Bottom Ash Pond (BAP)

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.

N

Scale
0' 150' 300' 600'

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Figure
4-1

Potentiometric Surface Map - Uppermost Aquifer - April 10, 2023,
Bottom Ash Pond (BAP),
Cardinal Plant,
Brilliant, Ohio

DWG NAME: Water Levels 2023 DATE PRINTED: 1/19/2024 K:\CCA\PROJECTS\Buckeye_Power\Cardinal\Drawings

644.70
MW-BAP-4

644.75
MW-BAP-1

644.70
MW-BAP-5

MW-BAP-2
644.77

644.82
MW-BAP-1001

MW-BAP-1002
644.69

MW-BAP-3
644.58

MW-BAP-1003
644.64

644.70
644.72
644.74
644.76
644.80
644.76
644.72
644.68
644.64
644.60

Legend

- BAP Monitor Well
- Non-BAP Monitor Well
- 644.76 Approximate Groundwater Elevation Contour
- 644.75 Groundwater Elevation on April 10, 2023
- Bottom Ash Pond (BAP)

Source of Aerial Photograph: Ohio Statewide Imagery Program, 2020.

N

Scale
0' 150' 300' 600'

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Figure
4-2

Potentiometric Surface Map - Uppermost Aquifer - October 9, 2023,
Bottom Ash Pond (BAP),
Cardinal Plant,
Brilliant, Ohio

Tables

Table 4-1. Groundwater Flow Calculations April 2023, Bottom Ash Pond (BAP), Cardinal Plant, Brilliant, Ohio

Program	Groundwater Zone	Well	Hyrdaulic Location[1]	Depth to Water (ft)	Potentiometric Elevation (ft)[2]	Gradient[3] (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
BAP	BAP	MW-BAP-1	Downgradient	28.52	644.04	0.0003	0.0001	0.05	0.1	0.36	0.0002	**0.11**	0.22	8	3.05	**6.10**	3048
BAP	BAP	MW-BAP-2	Downgradient	29.32	644.15	0.0004	0.0001	0.05	0.1	0.36	0.0003	**0.17**	0.35	8	1.93	**3.86**	1930
BAP	BAP	MW-BAP-3	Downgradient	28.93	644.12	0.0007	0.0001	0.05	0.1	0.36	0.0005	**0.27**	0.54	8	1.23	**2.46**	1228
BAP	BAP	MW-BAP-4	Upgradient	19.61	644.23	0.0003	0.0001	0.05	0.1	0.36	0.0002	**0.12**	0.24	8	2.84	**5.67**	2836
BAP	BAP	MW-BAP-5	Upgradient	28.04	644.10	0.0004	0.0001	0.05	0.1	0.36	0.0003	**0.17**	0.33	8	2.02	**4.03**	2015

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Measurements and calculations represent conditions on April 21, 2023.

[1] *Groundwater Monitoring Network Evaluation; Cardinal Site – Bottom Ash Pond, Brilliant, Ohio* prepared by Geosyntec Consultants in July 2016.

[2] Based on the National Geodetic Vertical Datum of 1929 (NGVD29) and top of casing elevations surveyed in October 2021.

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

[4] Low and high conductivity values are from the 2016 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 October 2023, Bottom Ash Pond (BAP), Cardinal Plant, Brilliant, Ohio

Program	Groundwater Zone	Well	Hyrdaulic Location[1]	Depth to Water (ft)	Potentiometric Elevation (ft)[2]	Gradient[3] (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
BAP	BAP	MW-BAP-1	Downgradient	27.81	644.75	0.0431	0.0001	0.05	0.1	0.36	0.0340	**16.98**	33.96	8	0.02	**0.04**	20
BAP	BAP	MW-BAP-2	Downgradient	28.70	644.77	0.0445	0.0001	0.05	0.1	0.36	0.0350	**17.52**	35.05	8	0.02	**0.04**	19
BAP	BAP	MW-BAP-3	Downgradient	28.47	644.58	0.0442	0.0001	0.05	0.1	0.36	0.0348	**17.39**	34.78	8	0.02	**0.04**	19
BAP	BAP	MW-BAP-4	Upgradient	19.14	644.70	0.0297	0.0001	0.05	0.1	0.36	0.0234	**11.69**	23.38	8	0.03	**0.06**	29
BAP	BAP	MW-BAP-5	Upgradient	27.44	644.70	0.0426	0.0001	0.05	0.1	0.36	0.0335	**16.76**	33.51	8	0.02	**0.04**	20

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Measurements and calculations represent conditions on October 9, 2023.

[1] *Groundwater Monitoring Network Evaluation; Cardinal Site – Bottom Ash Pond, Brilliant, Ohio* prepared by Geosyntec Consultants in July 2016.

[2] Based on the National Geodetic Vertical Datum of 1929 (NGVD29) and top of casing elevations surveyed in October 2021.

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

[4] Low and high conductivity values are from the 2016 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, Bottom Ash Pond (BAP), Cardinal Plant, Brilliant, Ohio

Well Name	Type of Well	Sample Date	Constituents Analyzed	Purpose
MW-BAP-1	Downgradient	4/21/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-1	Downgradient	10/18/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-2	Downgradient	4/26/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-2	Downgradient	10/18/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-3	Downgradient	4/20/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-3	Downgradient	10/18/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-3	Downgradient	10/18/2023	Appendix III and IV	Assessment monitoring program (Duplicate)
MW-BAP-4	Upgradient	4/25/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-4	Upgradient	4/25/2023	Appendix III and IV	Assessment monitoring program (Duplicate)
MW-BAP-4	Upgradient	10/18/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-5	Upgradient	4/20/2023	Appendix III and IV	Assessment monitoring program
MW-BAP-5	Upgradient	10/18/2023	Appendix III and IV	Assessment monitoring program

K:\CCA\PROJECTS\Buckeye_Power\Cardinal\BAP\Annual Groundwater and Corrective Measures Reports\2023\Tables\[Table 4-3 - Sample Summary BAP.xlsx]Yearly_Sampling_Summary

Table 4-4 Sampling Data, Bottom Ash Pond (BAP), Cardinal Plant, Brilliant, Ohio

Well Name		MW-BAP-1	MW-BAP-1	MW-BAP-2	MW-BAP-2	MW-BAP-3	MW-BAP-3	MW-BAP-3	MW-BAP-4	MW-BAP-4	MW-BAP-4	MW-BAP-5	MW-BAP-5
Sample Name		MW-BAP-1	MW-BAP-1	MW-BAP-2	MW-BAP-2	MW-BAP-3	MW-BAP-3	MW-BAP-3 DUP	MW-BAP-4	MW-BAP-4 DUP	MW-BAP-4	MW-BAP-5	MW-BAP-5
Sample Date		4/21/2023	10/18/2023	4/26/2023	10/18/2023	4/20/2023	10/18/2023	10/18/2023	4/25/2023	4/25/2023	10/18/2023	4/20/2023	10/18/2023
Laboratory	Concentration	Pace Analytical	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	50342942001	50357061001	50343493001	50357061002	50342942004	50356927003	50356927004	50343331001	50343331002	50356927005	50342942002	50357061003
APPENDIX III CONSTITUENTS													
Boron	MG/L	**2.23**	**2.44**	**1.99**	**2.04**	**2.03**	**2.12**	**2.12**	**0.0445**	**0.0421**	**0.02**	**0.126**	**0.11**
Calcium	MG/L	**144**	**145**	**79.1**	**78.4**	**80.6**	**82.8**	**81.9**	**196**	**184**	**190**	**191**	**172**
Chloride	MG/L	**57.1**	**60.5**	**63.1**	**59.9**	**65**	**63.4**	**63.6**	**29.9**	**29.8**	**25.4**	**18.2**	**13.7**
Fluoride	MG/L	**0.36**	**0.33**	**0.76**	**0.54**	**0.097**	**0.09**	**0.09**	NA	NA	**0.08**	**0.074**	< 0.05 U
Sulfate	MG/L	**344**	**349**	**167**	**157**	**180**	**170**	**168**	**587**	**556**	**486**	**383**	**313**
Total Dissolved Solids	MG/L	**818**	**766**	**483**	**463**	**488**	**492**	**489**	**1050**	**1040**	**1110**	**900**	**801**
pH	SU	**7.28**	**7.2**	**7.04**	**6.46**	**6.9**	**6.57**	NA	**6.34**	NA	**6.33**	**6.75**	**6.67**
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	< 0.0005
Arsenic	MG/L	**0.0015**	< 0.0005 U	**0.0211**	**0.02**	< 0.0005	< 0.0005 U	< 0.0005 U	**0.0458**	**0.0465**	**0.06**	**0.0068**	**0.01**
Barium	MG/L	**0.0731**	**0.05**	**0.155**	**0.15**	**0.0467**	**0.05**	**0.05**	**0.0738**	**0.0744**	**0.04**	**0.0779**	**0.07**
Beryllium	MG/L	< 0.0001	< 0.0001 U	< 0.0001	< 0.0001 U	< 0.0001	< 0.0001 U	< 0.0001 U	**0.00042**	**0.00044**	< 0.0001 U	< 0.0001	< 0.0001 U
Cadmium	MG/L	**0.00019**	**0.00024**	< 0.0001	< 0.0001 U	< 0.0001	**0.0001**	**0.0001**	**0.00023**	**0.00026**	< 0.0001 U	< 0.0001	< 0.0001 U
Chromium	MG/L	**0.0029**	**0.001**	< 0.001	< 0.001 U	< 0.001	**0.0016**	**0.0012**	**0.0083**	**0.0083**	**0.0015**	< 0.001	< 0.001 U
Cobalt	MG/L	**0.0012**	**0.0006**	**0.0011**	**0.0014**	< 0.0005	**0.00059**	**0.00054**	**0.0204**	**0.0207**	**0.02**	**0.00063**	< 0.0005 U
Fluoride	MG/L	**0.36**	**0.33**	**0.76**	**0.54**	**0.097**	**0.09**	**0.09**	NA	NA	**0.08**	**0.074**	< 0.05 U
Lead	MG/L	**0.0017**	< 0.0005 U	< 0.0005	< 0.0005 U	< 0.0005	< 0.0005 U	< 0.0005 U	**0.0071**	**0.0074**	**0.0012**	**0.0005**	< 0.0005 U
Lithium	MG/L	**0.0244**	**0.02**	< 0.01	< 0.01 U	< 0.01	< 0.01 U	< 0.01 U	**0.016**	**0.0159**	< 0.01 U	< 0.01	< 0.01 U
Mercury	MG/L	**0.00000985**	**0.00000131**	**0.00000081**	< 5E-7 U	< 5E-7	**0.00000091**	**0.00000101**	**0.0000177**	**0.0000184**	**0.00000213**	**0.000000847**	< 5.1E-7 U
Molybdenum	MG/L	**0.0269**	**0.03**	**0.0331**	**0.03**	**0.0013**	**0.0015**	**0.0015**	**0.0016**	**0.0016**	**0.0014**	< 0.0005	< 0.0005 U
Potassium	UG/L	**10700**	**10.4**	**5580**	**5.51**	**4050**	**4.2**	**4.11**	**3000**	**3150**	**1**	**860**	**0.76**
Selenium	MG/L	< 0.0005	< 0.0005 U	< 0.0005	< 0.0005 U	< 0.0005	< 0.0005 U	< 0.0005 U	**0.0012**	**0.0011**	< 0.0005 U	< 0.0005	< 0.0005 U
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	< 0.0005
Combined Radium	pCi/L	**1.23**	NA	**0.92**	NA	**0.558**	NA	NA	**0.967**	**1.23**	NA	**0.841**	NA

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< = Not detected at reporting limit

Bold = Detected

NA = Not Analyzed

Table 4-5. Groundwater Protection Standards (GWPS),
Bottom Ash Pond (BAP), Cardinal Plant, Brilliant, Ohio

	Concentration Units	MCL	CCR Rules § 257.95(h)(2)	Background Limit	BAP GWPS
APPENDIX IV CONSTITUENTS					
Antimony	MG/L	0.006	-	0.0005	0.006
Arsenic	MG/L	0.01	-	0.065	0.065
Barium	MG/L	2	-	0.12	2
Beryllium	MG/L	0.004	-	0.0002	0.004
Cadmium	MG/L	0.005	-	0.00018	0.005
Chromium	MG/L	0.1	-	0.005	0.1
Cobalt	MG/L	-	0.006	0.02	0.02
Fluoride	MG/L	4	-	0.17	4
Lead	MG/L	-	0.015	0.0056	0.015
Lithium	MG/L	-	0.04	0.0018	0.04
Mercury	MG/L	0.002	-	0.000005	0.002
Molybdenum	MG/L	-	0.1	0.0034	0.1
Radium, Combined	pCi/L	5	-	1.6	5
Selenium	MG/L	0.05	-	0.0007	0.05
Thallium	MG/L	0.002	-	0.0005	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.